

ORIGINAL RESEARCH

Mineralization of the lower second molar and cervical vertebral maturation as indicators of the pubertal growth spurt in pediatric patients

Mineralización del segundo molar inferior y maduración vertebral cervical como indicadores del pico de crecimiento puberal en pacientes pediátricos

Jeremy Alexander Laz Medina ¹. William Ubilla Mazzini ². Tanya Moreira Campuzano ³

¹ Graduate, School of Dentistry. Universidad de Guayaquil. <https://orcid.org/0009-0003-2634-9016>

² Master's Degree in Education. Specialist in Orthodontics. Professor, Universidad de Guayaquil. <https://orcid.org/0000-0001-5940-1456>

³ Specialist in Orthodontics. Professor, Orthodontics Specialization Program, Universidad de Guayaquil. <https://orcid.org/0000-0002-1158-0245>

Correspondence to: william.ubillam@ug.edu.ec

Received: 25/04/2026 Accepted: 27/06/2026

ABSTRACT

In the orthodontics practice and orthopedics, one of the most important factors is determining biological maturity. Biological maturity, unlike chronological age—which only takes the time elapsed since birth, indicates an individual's rate of development. This makes it possible to identify the appropriate time to apply orthopedic forces and thus make the most of the patient's growth potential. Objective: To determine the relationship between the stages of mineralization of the lower second molar and cervical vertebral maturation to identify the peak identification of pubertal growth in radiographic records of patients treated at the Comprehensive Pediatric Dentistry Clinic of the University of Guayaquil during the year 2026. Methodology: Quantitative approach, descriptive and correlational in nature, with a non-experimental design. The study included a population of 60 radiographic pairs (panoramic and cephalometric) and a final sample of 40 pairs from patients aged 6 to 12 years. Results: Conclusion: Indicators of cervical vertebral maturation and dental mineralization of the lower second molar exhibit a positive and statistically significant relationship. Consequently, both processes tend to progress in parallel during growth.

Keywords: Orthodontics. Lower second molar. Cervical vertebral maturity. Pubertal growth.

RESUMEN

En la práctica de la Ortodoncia y la Ortopedia, uno de los factores más importantes es el establecimiento de la maduración biológica. La madurez biológica, a diferencia de la edad cronológica que solo tiene en cuenta el tiempo transcurrido desde el nacimiento, señala la velocidad de desarrollo del individuo. Esto permite identificar cuándo es el momento apropiado para aplicar fuerzas ortopédicas y así sacar el mayor provecho posible del potencial de crecimiento del paciente. Objetivo: Determinar la relación entre los estadios de mineralización del segundo molar inferior y la maduración vertebral cervical para la identificación del pico de crecimiento puberal en registros radiográficos de pacientes atendidos en la clínica Integral de Odontopediatría de la Universidad de Guayaquil durante el año 2026. Metodología: enfoque cuantitativo, tipo descriptivo y correlacional, diseño no experimental. Con una población de 60 pares radiográficos (Panorámico-Cefalométrico) y una muestra final de 40 pares, de pacientes de entre 6 a 12 años de edad. Resultados: Conclusión: indicadores de maduración vertebral cervical y mineralización dentaria del segundo molar inferior exhiben una relación positiva y estadísticamente significativa. En consecuencia, ambos procesos tienden a progresar de forma paralela durante el crecimiento.

Palabras clave: Ortodoncia. Segundo molar inferior. Madurez vertebral cervical. Crecimiento puberal.

INTRODUCTION

The determination of biological maturation is a key aspect of orthodontic and orthopedic practice. Unlike chronological age, which only considers the time elapsed since birth, biological maturity indicates the individual's rate of development, allowing the appropriate timing for the application of orthopedic forces to be identified and thus maximizing the patient's growth potential ⁽¹⁾.

The reference method for assessing maturation has traditionally been used in carpal radiographs. What had become a standard practice has currently been replaced by the so-called cervical vertebral maturation (CVM) analysis proposed by Baccetti. This method has gained importance because it allows pubertal growth to be assessed through a lateral skull radiograph and is considered a common diagnostic procedure in orthodontics ⁽²⁾. Despite this, the search for simpler approaches has led to the investigation of dental maturation as an alternative indicator.

The Demirjian approach, which examines the levels of dental mineralization using panoramic radiographs, represents a promising option due to its high consistency and low cost. However, the international literature reports certain discrepancies regarding the reliability of dental age in predicting the peak of skeletal growth, indicating that ethnic and geographical factors may have a significant impact on this relationship ⁽³⁾.

In Guayaquil, there is a clinical need to determine whether identifying a specific dental stage is sufficient to establish whether a child has entered the peak growth period. Therefore, this study aims to determine the statistical relationship between cervical vertebral maturation according to Baccetti mineralization second molar according to Demirjian.

Malocclusions are among the most common oral health conditions in children and adolescents ⁽³⁾. They affect facial aesthetics, masticatory function, and the quality of life of affected individuals. Their high prevalence represents one of the main reasons for consultation in orthodontics and orthopedics. Therefore, diagnosis and treatment planning are required to assess therapeutic outcomes.

In this regard, it is necessary to identify factors associated with treatment effectiveness that facilitate the diagnosis of the patient's biological maturity. During the pubertal growth period, significant skeletal changes occur, particularly in the mandibular level. These changes increase mandibular growth and facilitate correction of maxillomandibular discrepancies and various malocclusions. Coordination between therapeutic intervention and the peak of growth allows clinical outcomes to be maximized; conversely, an intervention performed outside this period considerably reduces its effectiveness ⁽⁴⁾.

Due to this limitation, other methods have been developed to determine skeletal maturity. Currently, cervical vertebral maturation (CVM), assessed through cephalometric radiographs, is considered one of the most reliable indicators for identifying skeletal growth stages. Nevertheless, obtaining this information requires radiographic exposure and an additional cost when the examination is not part of the initial diagnostic protocol.

In recent years, the development of more accessible and less invasive diagnostic methods has been aligned with radiation protection and the ALARA principle (As Low as Reasonably Achievable), whose purpose is to minimize exposure to ionizing radiation without compromising diagnostic quality.

Dental mineralization of the mandibular second molar has attracted increasing scientific interest, as it is considered a potentially useful biological indicator of skeletal maturity. Its development and growth occur through different stages that coincide with pubertal growth and can be determined using panoramic radiographs, which are commonly included in diagnostic protocols. International studies have reported statistically significant correlations between cervical vertebral and dental mineralization stages.

Biological maturity is a fundamental pillar of diagnosis and therapeutic planning because it enables identification of the period when a patient has the greatest growth potential. In recent decades, the relationship between dental and skeletal maturation has been investigated by numerous researchers using different diagnostic methods, among which the Baccetti method for determining cervical vertebral maturation and the Demirjian method for evaluating dental mineralization stand out ⁽⁶⁾.

BACKGROUND

Martínez and Ardón, in San Salvador, El Salvador, in 2021, conducted a literature review to evaluate whether there was a difference between the Baccetti cervical vertebral maturation method and the Fishman carpal method for determining the peak of maximum growth. Through a search in PubMed and SciELO, they selected 8 of 248 studies published between 2000 and 2020. Six studies showed a high correlation between both methods, while two demonstrated a moderately positive correlation. The authors concluded that the Baccetti method is

statistically reliable, valid, and clinically useful for assessing skeletal maturity, in addition to reducing the need for additional carpal radiographs and radiographic exposure of patients ⁽⁷⁾.

Lucchese A. et al., in Milan, Italy, in 2022, conducted a systematic review to evaluate the effectiveness of the cervical vertebral maturation (CVM) method for predicting the pubertal growth peak. Of 1,284 articles, 43 were included. The results showed a statistically significant, moderate-to-high correlation between the cervical vertebral maturation method and other methods, such as carpal radiography, chronological age, dental age, and height. They concluded that the Baccetti method is effective for assessing skeletal maturity, although they recommended complementing it with other biological indicators ⁽⁸⁾.

Magalhães M. et al., in 2022, conducted a systematic review and meta-analysis to estimate the chronological age corresponding to each cervical vertebral maturation stage proposed by Baccetti and to analyze differences according to sex and continent. Forty-one studies including a total of 9,867 participants were included. The results showed that females reached the cervical stages at younger ages than males and that variations existed among populations. They concluded that the age ranges of the Baccetti method should be interpreted according to the characteristics of each region ⁽⁹⁾.

Ferrillo M. et al., in Catanzaro, Italy, in 2024, conducted a systematic review to evaluate the reliability of dental maturation according to the Demirjian method as an indicator of skeletal maturity. Of 136 articles, 19 were selected, of which 17 demonstrated adequate reliability for estimating skeletal maturation. The results showed that the mandibular second molar had the greatest predictive capacity, with the pubertal growth peak occurring between stage F in females and stage G in males. They concluded that the Demirjian method is a reliable tool for assessing biological maturation, although further research is required ⁽¹⁰⁾.

Ercan and Yüksel, in Nevşehir, Turkey, in 2023, conducted a cross-sectional observational study to determine skeletal, dental, and sexual maturation stages during the pubertal growth peak. The study included 98 patients, comprising 49 females and 49 males. Overall, 81.6% of patients of both sexes were classified as being in cervical vertebral maturation stage CS3, while 81.6% of females and 89.8% of males showed stage G of mandibular second molar mineralization. A significant correlation was found between both methods and sex ($p < 0.05$). The authors concluded that stages CS3 and G correspond to the pubertal growth peak and that the mandibular second molar is a useful indicator of biological maturation ⁽¹⁰⁾.

Vásquez Pacheco et al., in Villahermosa, Tabasco, Mexico, in 2025, conducted an analytical, cross-sectional observational study to determine the correlation between the Baccetti skeletal maturation method and the dental calcification stages of the Demirjian method. A total of 202 radiographs were analyzed, including 101 panoramic radiographs and 101 lateral skull radiographs from patients aged 9 to 18 years. They found a strong positive correlation between the Demirjian and Baccetti stages ($r = 0.729$; $p < 0.001$), as well as between these methods and chronological age. The authors concluded that both methods are reliable tools for estimating biological maturity and guiding orthodontic treatment planning ⁽¹¹⁾.

Kamran et al., in Swat, Pakistan, in 2023, conducted a descriptive cross-sectional study to determine the correlation between skeletal maturation and the mineralization stages of the mandibular second molar. One hundred patients aged between 8 and 16 years were examined. Spearman's results demonstrated a very high and statistically significant correlation between dental mineralization stages and vertebral maturation stages ($r = 0.97$; $p < 0.001$). They concluded that mandibular second molar mineralization is a reliable indicator of skeletal maturation and the pubertal growth peak ⁽¹¹⁾.

Fajardo Morales et al., in Cuenca, Ecuador, conducted a study to estimate the correlation between chronological and dental age and cervical vertebral maturation stages. The research used a quantitative, observational, and correlational approach through the analysis of 400 panoramic and lateral cephalometric radiographs; 205 were from females and 195 from males, aged between 4 and 17 years. They found correspondence between Demirjian stage D and Baccetti CVM I, as well as between stage E and CVM II. In addition, they identified a moderate relationship between both methods in the mandibular second molar. They concluded that there is a significant relationship between dental maturation, vertebral maturation, and chronological age, without important differences according to sex ⁽¹³⁾.

MATERIALS AND METHODS

Research Approach

The present research was conducted using a quantitative approach, since the study variables were recorded in structured categories and subsequently converted into data for statistical analysis. Dental mineralization and cervical maturation stages were represented on ordinal scales, while sex and chronological age were used as complementary variables to characterize the sample. This approach made it possible

to quantify the frequency and distribution of the Demirjian and Baccetti stages, as well as to analyze the statistical relationship between both indicators. Consequently, the findings were presented using percentages, tables, and graphical representations of association.

Types of Research

According to its scope, the study was both descriptive and correlational. It was descriptive because it characterized the distribution of dental and cervical maturation stages according to sex and chronological age. It was also correlational because it established the monotonic relationship between both stages without the need to establish a causal relationship between them. The study had an observational, non-experimental design, since there was no manipulation of variables and no interventions were performed. Data was collected through observation and classification of existing radiological studies. It was also cross-sectional because a single radiographic pair from everyone was analyzed at a specific point in time. Likewise, it was retrospective because previously obtained imaging studies, originally acquired for dental care purposes during 2026, were used.

The population consisted of 60 radiographic pairs from pediatric patients treated at the Comprehensive Pediatric Dentistry and Orthopedics Clinic during 2026. The studies consisted of a panoramic radiograph and a lateral cephalometric skull radiograph belonging to the same individual. Non-probability convenience sampling was performed, using the available radiographic pairs that met the inclusion and exclusion criteria. Forty pairs of panoramic and cephalometric radiographs were ultimately selected, corresponding to patients between 6 and 12 years of age, of whom 24 were male and 16 were female.

Unit of Analysis

The unit of analysis was represented by radiographic pairs belonging to the same individual. On the cephalometric or lateral skull radiograph, cervical vertebrae C2, C3, and C4 were analyzed using the Baccetti method. On orthopantomograms or panoramic radiographs, the left mandibular second molar, corresponding to tooth 3.7, was evaluated using the Demirjian method.

Inclusion Criteria: Radiographs from male and female patients aged between 6 and 12 years, with adequate radiographic clarity of both the left mandibular second molar, tooth 3.7, on the panoramic radiograph and cervical vertebrae C2, C3, and C4 on the cephalometric radiograph.

Exclusion Criteria: Radiographs outside the established age range, with distortions that prevented visualization of the structures of interest, and dental anomalies involving the left mandibular second molar, including agenesis, ectopic eruption, or impaction.

Data Collection Techniques and Instruments

Data were collected using an indirect, structured, non-participant radiographic observation technique, since these variables were identified through the analysis of previously obtained imaging studies without intervention or direct contact with the patients. The instrument used was a structured data collection table developed specifically for the research. The table included specific fields such as study code, sex, age, Demirjian stage, and Baccetti stage. To maintain patient confidentiality, the names associated with each record were replaced with alphanumeric codes ranging from P01 to P40.

Data Collection Procedure

The data collection process was conducted consecutively, considering the following aspects:

- The radiographic records were provided by students who were conducting clinical cases related to Pediatric Dentistry and Orthopedics at the faculty during 2026. Initially, 60 radiographic pairs were collected. Each pair consisted of a panoramic radiograph and a lateral cephalometric radiograph from the same patient.
- Each radiographic set was checked to ensure that it included information regarding the patient's age and sex, as well as adequate diagnostic quality for the left mandibular second molar and cervical vertebrae C2, C3, and C4. Considering the established inclusion and exclusion criteria, 40 radiographic pairs were selected to constitute the final study sample.
- The selected studies were anonymized by assigning alphanumeric codes from P01 to P40 to safeguard patient identity and confidentiality. During the research process, a formal request was prepared and submitted to the Dean of the Faculty of Dentistry at the University of Guayaquil to obtain the institutional authorization required for the academic and scientific use of the imaging studies included in the research.
- First, vertebrae C2, C3, and C4 were examined on the lateral cephalometric radiographs, considering the concavities of their lower borders and the shape of the vertebral bodies, to assign the corresponding stage from CS1 to CS6 using the Baccetti method.
- Next, the orthopantomograms were evaluated, examining the left mandibular second molar corresponding to tooth 3.7. The Demirjian method was applied, and the mineralization stage from A to H was determined according to crown formation, bifurcation, and apical closure.

- Age, sex, and maturation stages were recorded in a structured data collection table developed in Microsoft Excel. Subsequently, the information was examined to identify missing records, duplicates, or possible coding errors.
- The weighted Kappa coefficient was then applied to measure interobserver agreement, and statistical analysis was performed using Spearman's rho coefficient on the collected data. The results were presented using frequency tables, percentages, and graphical representations.

Statistical Processing and Analysis

The data collected from the radiographs were stored, classified, coded, and cleaned in a structured data collection table in Microsoft Excel. The table contained the code assigned to each case, age, sex, Demirjian stage, and Baccetti stage. Before analysis, the consistency of the classifications was verified, and the weighted Kappa coefficient was calculated by comparing the results determined by the researcher with those provided by the second specialist evaluator. Based on descriptive statistics, absolute frequencies and percentages were determined to understand the distribution of both stages. The results were organized overall and according to the chronological age and sex of the individuals. Cross-tabulations and bar charts were also prepared for data interpretation.

To relate the indicators analyzed to the pubertal growth peak, the Baccetti stages were grouped according to the degree of skeletal maturation: CS1 and CS2 corresponded to the prepubertal stage, CS3 and CS4 to the circumpubertal phase, and CS5 and CS6 to the post pubertal stage. For studies classified as CS3 and CS4, the frequencies and percentages of the Demirjian stages were calculated in order to identify the mineralization stages of the mandibular second molar that occurred most frequently around the pubertal growth peak.

Spearman's rho coefficient was applied because the Demirjian and Baccetti stages are ordinal variables. This analysis allowed the strength and direction of the monotonic relationship between the two variables to be determined. A two-tailed test was applied, and a statistical significance level of 0.05 was established. Findings with a **p-value lower than 0.05** were considered statistically significant.

For statistical analysis, the Demirjian stages were coded as follows: A = 1, B = 2, C = 3, D = 4, E = 5, F = 6, G = 7, and H = 8. The Baccetti stages were coded as follows: CS1 = 1, CS2 = 2, CS3 = 3, CS4 = 4, CS5 = 5, and CS6 = 6.

Ethical Considerations

During the research process, a request was submitted to the Dean of the Faculty of Dentistry of the University of Guayaquil to formalize the institutional authorization required for the academic use of the radiological studies included in the research. Since the research was considered observational and retrospective, no new radiological examinations or clinical interventions were performed on the patients. The confidentiality of the information was ensured through anonymization of the radiographic records. Identifying information, such as patient names, was replaced in the data collection table with codes ranging from P01 to P40. The imaging records were kept under the custody of the researcher and were not shared with individuals outside the research team. Likewise, the analysis performed by the second evaluator was conducted using coded radiographs without access to information that could identify the patients.

RESULTS

An analysis was conducted of the 40 radiographic pairs corresponding to pediatric patients aged between 6 and 12 years. The weighted Kappa agreement index was calculated, with the following results:

Table 1. Distribution of the sample according to chronological age

Age (years)	Frequency	Percentage
6	7	17.5%
7	9	22.5%
8	13	32.5%
9	4	10.0%
10	3	7.5%
11	2	5.0%
12	2	5.0%
Total	40	100.0%

Source: prepared by the authors based on the research database.

Interpretation: The sample consisted of 40 radiographic pairs from patients aged between 6 and 12 years. The most frequent age was 8 years, with 13 individuals, corresponding to 32.5% of the sample, followed by 7 years, with 9 cases (22.5%), and 6 years, with 7 cases (17.5%). Lower frequencies were observed among patients aged 9 to 12 years: 9-year-olds accounted for 4 cases (10.0%), while 10-year-olds accounted for only 3 records (7.5%). The lowest figures were observed among 11- and 12-year-olds, with 2 study pairs and 5.0% in each group.

Table 2. Distribution of the sample according to sex

Sex	Frequency	Percentage
Male	24	60.0%
Female	16	40.0%
Total	40	100.0%

Source: prepared by the authors based on the research database.

Interpretation: Of the 40 imaging pairs included in the study, 24 were from male patients (60.0%), whereas 16 were from female patients (40.0%). Thus, there was a predominance of male participants in the analyzed sample.

CERVICAL VERTEBRAL MATURATION ACCORDING TO BACCETTI

Table 3. Distribution of Baccetti stages according to sex

Stage	Male n	Male %	Female n	Female %	Total n	Total %
CS1	0	0.0%	0	0.0%	0	0.0%
CS2	3	12.5%	1	6.3%	4	10.0%
CS3	17	70.8%	9	56.3%	26	65.0%
CS4	4	16.7%	6	37.5%	10	25.0%
CS5	0	0.0%	0	0.0%	0	0.0%
CS6	0	0.0%	0	0.0%	0	0.0%
Total	24	100.0%	16	100.0%	40	100.0%

Source: prepared by the authors based on the research database.

Interpretation: Stage CS3 was the most frequent in both sexes. In the male group, it was detected in 17 records, representing 70.8%, while in the female group, 9 cases were identified, corresponding to 56.3%. On the other hand, stage CS4 showed a higher incidence among females, with 6 records (37.5%), compared with 4 cases (16.7%) among males. Stage CS2 accounted for 12.5% of the male frequency and 6.3% of the female frequency. No cases were found in CS1, CS5, or CS6.

Table 4. Distribution of Baccetti stages according to chronological age

Age (years)	Total by age	CS2 n	CS2 %	CS3 n	CS3 %	CS4 n	CS4 %
6	7	2	28.6%	5	71.4%	0	0.0%
7	9	2	22.2%	7	77.8%	0	0.0%
8	13	0	0.0%	11	84.6%	2	15.4%
9	4	0	0.0%	1	25.0%	3	75.0%
10	3	0	0.0%	1	33.3%	2	66.7%
11	2	0	0.0%	1	50.0%	1	50.0%
12	2	0	0.0%	0	0.0%	2	100.0%
Total	40	4	10.0%	26	65.0%	10	25.0%

Source: prepared by the authors based on the research database.

Interpretation: Among 6-year-olds, stage CS3 predominated at 71.4%, while CS2 was present in 28.6%. At 7 years, CS3 also remained the most common stage, reaching 77.8%. In the 8-year-old group, 84.6% were classified as CS3 and 15.4% as CS4. From the age of 9 years onward, an increase in the proportion of CS4 was observed, representing 75.0% at 9 years, 66.7% at 10 years, 50.0% at 11 years, and 100% at 12 years, based on two study cases. Descriptively, a trend toward more advanced vertebral stages was observed as chronological age increased.

DENTAL MINERALIZATION OF THE MANDIBULAR SECOND MOLAR 3.7 ACCORDING TO DEMIRJIAN

Table 5. Distribution of Demirjian stages according to sex

Stage	Male n	Male %	Female n	Female %	Total n	Total %
A	0	0.0%	0	0.0%	0	0.0%
B	0	0.0%	0	0.0%	0	0.0%
C	7	29.2%	4	25.0%	11	27.5%
D	11	45.8%	5	31.3%	16	40.0%
E	4	16.7%	4	25.0%	8	20.0%
F	2	8.3%	2	12.5%	4	10.0%
G	0	0.0%	1	6.3%	1	2.5%
H	0	0.0%	0	0.0%	0	0.0%
Total	24	100.0%	16	100.0%	40	100.0%

Source: prepared by the authors based on the research database.

Interpretation: Stage D was the most common in both sexes. The male group recorded 11 studies, equivalent to 45.8%, whereas the female group had 5 cases, representing 31.3%. In stage C, males predominated with 29.2%, compared with 25.0% among females. On the other hand, stages E and F showed higher proportions among females, with 25.0% and 12.5%, respectively, compared with 16.7% and 8.3% among males. There was a single radiographic case classified as stage G, accounting for 6.3% of the female group. No studies were identified in stages A, B, or H.

Table 6. Distribution of Demirjian stages according to chronological age

Age (years)	Total by age	C n	C %	D n	D %	E n	E %	F n	F %	G n	G %
6	7	7	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
7	9	3	33.3%	6	66.7%	0	0.0%	0	0.0%	0	0.0%
8	13	1	7.7%	8	61.5%	3	23.1%	1	7.7%	0	0.0%
9	4	0	0.0%	2	50.0%	1	25.0%	1	25.0%	0	0.0%
10	3	0	0.0%	0	0.0%	3	100.0%	0	0.0%	0	0.0%
11	2	0	0.0%	0	0.0%	0	0.0%	2	100.0%	0	0.0%
12	2	0	0.0%	0	0.0%	1	50.0%	0	0.0%	1	50.0%
Total	40	11	27.5%	16	40.0%	8	20.0%	4	10.0%	1	2.5%

Source: prepared by the authors based on the research database.

Interpretation: At 6 years of age, all cases were classified as Demirjian stage C. At 7 years, stage D was the most common, accounting for 66.7%, followed by stage C, which accounted for the remaining 33.3%. In the 8-year-old group, stage D predominated at 61.5%.

At 9 years, stage D accounted for 50.0%. At 10 years, all studies were categorized as stage E, while those at 11 years were classified as stage F. Finally, cases at 12 years were found in stages E and G, each accounting for 50.0%. The results indicated progressive advancement in dental mineralization as age increased.

RELATIONSHIP BETWEEN THE DEMIRJIAN AND BACCETTI METHODS

Table 7. Cross-tabulation of Demirjian and Baccetti stages

Demirjian	CS2 n	CS2 %	CS3 n	CS3 %	CS4 n	CS4 %	Total n	Total %
A	0	0.0%	0	0.0%	0	0.0%	0	0.0%
B	0	0.0%	0	0.0%	0	0.0%	0	0.0%
C	2	18.2%	9	81.8%	0	0.0%	11	27.5%
D	2	12.5%	13	81.3%	1	6.3%	16	40.0%
E	0	0.0%	3	37.5%	5	62.5%	8	20.0%
F	0	0.0%	1	25.0%	3	75.0%	4	10.0%
G	0	0.0%	0	0.0%	1	100.0%	1	2.5%
H	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	4	10.0%	26	65.0%	10	25.0%	40	100.0%

Source: prepared by the authors based on the research database.

Interpretation: According to Demirjian, stages C and D were predominantly concentrated in Baccetti stage CS3, with 81.8% and 81.3%, respectively, and lower percentages in stages CS2 and CS4. Stages E, F, and G showed greater concentration in CS4, with 62.5%, 75.0%, and 100%, respectively. Stages E and F showed lower concentrations in CS3, with 37.5% and 25.0%, respectively. These findings demonstrate a concomitant progression between dental mineralization stages and cervical vertebral maturation stages.

Table 8. Correlation between Demirjian and Baccetti stages

Variables	n	Spearman's rho	p-value	Direction	Interpretation
Demirjian–Baccetti	40	0.633	< 0.001	Positive	Strong and statistically significant

Source: prepared by the authors based on the research database.

Spearman's rho coefficient showed a value of 0.633, with a statistical significance of less than 0.001. This result demonstrated a positive, strong, and statistically significant association between the Demirjian and Baccetti stages. Consequently, as the mineralization stage of the mandibular second molar progressed, a tendency toward advancement in the cervical vertebral maturation stage was also observed. Because the p-value was lower than the predefined significance level of 0.05, the null hypothesis, which stated that there was no relationship between the two variables, was rejected.

DISCUSSION

The assessment of biological maturation is crucial for determining the appropriate timing of treatments that require the patient's maximum growth potential. In this regard, the present study evaluated the relationship between mineralization of the left mandibular second molar using Demirjian and cervical vertebral maturation using the Baccetti method in radiographic studies corresponding to patients aged 6 to 12 years. The main finding was a strong, positive, and statistically significant association between both parameters, with a Spearman's rho of 0.633 and a p-value < 0.001. This indicates that as dental mineralization stages advanced, cervical maturation stages also tended to advance.

Interobserver agreement confirmed the reproducibility of the assessments. The linear weighted Kappa coefficient was reported as 0,735 for Demirjian and 0,759 for Baccetti, indicating substantial agreement. These results demonstrated adequate consistency between the stages assessed by the researcher and those assessed by the evaluator.

Regarding cervical vertebral maturation, Baccetti stage CS3 was the most frequent, accounting for 65.0%, followed by CS4 at 25.0% and CS2 at 10.0%. The frequency of cases classified as CS3 and CS4 indicates that a large proportion of the sample was in intermediate or circumpubertal maturation phases associated with maximum growth acceleration. This finding is consistent with Ercan and Yüksel⁽¹⁰⁾, who reported a predominance of CS3 during the pubertal growth peak in 81.6% of their participants.

Stage CS3 predominated in both males and females, with relatively similar percentages; however, CS4 was observed in 37.5% of females and 17.7% of males. This trend may be related to earlier skeletal maturation in females, according to Magalhães et al., who found that females may reach more advanced stages earlier than males⁽¹⁴⁾. However, these differences are descriptive only and cannot be interpreted

as statistically significant. Regarding age, CS3 predominated between 6 and 8 years, whereas CS4 increased from 9 years onward. This progression is consistent with the developmental sequence described by Magalhães et al. ⁽¹⁴⁾. Nevertheless, the presence of different cervical stages among individuals of similar chronological age demonstrates that chronological age alone is not a reliable indicator of biological maturation. Furthermore, the groups aged 10 years and older contained few records; therefore, their percentage-based interpretation should be approached with caution.

Regarding dental mineralization of the mandibular second molar, Demirjian stage D was the most predominant, accounting for 40.0%, followed by C at 27.5% and E at 20.0%; F and G were the stages with lower percentages, at 10% and 2.5%, respectively. Distribution according to sex showed a higher representation among females in the more advanced stages, consistent with the trend observed using Baccetti.

Age demonstrated an orderly progression, with 6-year-olds classified as stage C, 7- and 8-year-olds predominantly in stage D, and 10- and 11-year-olds identified in stages E and F, respectively. These observations demonstrate that mandibular second molar development increases as age advances. However, individual variability was observed, reinforcing the need to use maturation indicators with greater validity.

The cross-tabulation showed that 81.8% of records classified as stage C and 81.3% of those classified as stage D coincided with Baccetti stage CS3. In contrast, the more advanced dental stages showed correspondence with CS4 in 62.5% of stage E, 75.0% of stage F, and the single stage G case. Thus, the progression of dental development was accompanied by advancement in cervical vertebral maturation.

This relationship was validated through Spearman's rho, which demonstrated a value of 0.633, indicating a strong positive association. This result is consistent with that reported by Martínez and Ardón et al. ⁽¹⁵⁾, who observed a high relationship between the indicators in most of the studies analyzed. Similarly, Vásquez Pacheco et al. ⁽¹⁶⁾ found a strong positive correlation of 0,729.

CONCLUSIONS

It was determined that cervical vertebral maturation and dental mineralization of the mandibular second molar exhibit a positive and statistically significant relationship. Consequently, both processes tend to progress in parallel during growth.

Cervical vertebral assessment revealed that most records were in circumpubertal stages of maturation, with a predominance of CS3 and a greater presence of CS4 between older age groups. Likewise, the female group showed higher concentrations in more advanced cervical stages. Mineralization of the mandibular second molar demonstrated a consistent progression with chronological age. Early and intermediate stages were more frequent among younger individuals, whereas more advanced dental stages corresponded to older age groups, with slight descriptive differences according to sex.

The correspondence observed between Demirjian stages C and D and Baccetti stage CS3, as well as between stages E, F, and G and CS4, supports the use of the mandibular second molar as an additional indicator for estimating the pubertal growth period. Nevertheless, its assessment should be complemented by subsequent skeletal and clinical analysis, since a precise equivalence between all stages cannot be established.

REFERENCES

1. Adil, S., Islam, Z. U., Kareem, K., Raza, H. A., Tauheed, S., & Hassan, S. Correlation of Dental and Skeletal Maturity Using Demirjian and Cervical Vertebral Maturation Indices in Orthodontic Patients. *Journal of Gandhara Medical and Dental Science*, 2022:9(4).
2. Batista-González, N. M., Díaz-Collera, R., Corría-Santana, Y., Rodríguez-González, L., & García-González, V. El método de baccetti como herramienta estratégica para la Ortodoncia en cuba: Una revisión bibliográfica. *Evento Internacional Estomatología*, 2025:8.
3. Bint-e-Nasir, Z., Jan, A., Khalid, Z., Tariq, Q. u., Zia, R., & Arshad, N. Skeletal Maturity Assessment using Mandibular Canine Calcification Stages. *Pakistan Armed Forces Medical Journal*, 2023:73(2), 464-467.
4. Briones-Reyes, J. L., Meléndez-Wong, C. A., Favela-Flores, S., Martínez-Martínez, M. A., Valdés-Abularach, L. P., & Hachity-Ortega, J. A. Análisis comparativo entre edad cronológica, edad ósea y edad dental en los niños de Torreón, Coahuila. *Revista de la Academia Mexicana de Odontología Pediátrica*, 2022:34(1), 10-14.
5. Buenaventura, C., Lago, R., Fernández, A., Álvarez-Vaz, R., & Picapedra, A. Estimación de la edad por medio del grado de mineralización dental: método de Demirjian. *Odontoestomatología*, 2022:24(40).
6. Campoverde, L. G., Ochoa, B. R., Campoverde, D. G., Cantero, L. S., & Soto, A. R. Relación del crecimiento sagital de los maxilares y el índice de maduración cervical. *Investigación Clínica*, 2023:63(2), 115-125.

7. Castillo-Páez, J. A., Villasmil-Suárez, L. G., & Guada-Melet, N. V. Skull-facial anthropometric traits of forensic odontologic interest for estimating sex, race, and age. Review of the literature. *Revista Científica Odontológica*, 2021;9(1), 1-10.
8. Dadgar, S., Hadian, M., Farhad, S., & Rakhshan, V. Correlations among chronological age, cervical vertebral maturation index, and Demirjian developmental stage of the maxillary and mandibular canines and second molars. *Surgical and Radiologic Anatomy*, 2020;43, 131-143.
9. De Melo, K. C., Gimenez, C. M., Gomes, V. F., Bertoz, A. M., Bertoz, F. A., & Moreira, A. G. Revisão sistemática dos métodos de correlação entre a idade dentária e cronológica em função das análises de Demirjian. *Revista Brasileira de Criminalística*, 2020;9(2), 123-133.
10. Ercan, D. E., & Yüksel, S. Skeletal, dental, and sexual maturation as an indicator of pubertal growth spurt. *American Journal of Human Biology*, 2023;35(12), e23957.
11. Fajardo Morales, J. S., Portilla Guamán, A. F., Verdugo Tinitana, V. I., & Reinoso Quezada, S. Correlación entre la edad cronológica y dental con los estadios de maduración vertebral. *Revista ADM*, 2024;81(3), 138-146.
12. Ferrillo, M., Curci, C., Roccuzzo, A., Migliario, M., Invernizi, M., & de Sire, A. Reliability of cervical vertebral maturation compared to hand-wrist for skeletal maturation assessment in growing subjects: A systematic review. *Journal of Back and Musculoskeletal Rehabilitation*, 2021;34(6), 925-936.
13. Ferrillo, M., Pascale, R., Cingolani, M., Mazzoni, A., Gaudio, R. M., Di Vella, G., y otros. Skeletal maturation evaluation: which is the reliability of dental maturation indexes? A systematic review. *Acta Odontologica Scandinavica*, 2024;82(5), 1-14.
14. Magalhaes, M. I., Machado, V., Mascarenhas, P., Botelho, J., Mendes, J. J., & Delgado, A. S. Chronological age range estimation of cervical vertebral maturation using Baccetti method: a systematic review and meta-analysis. *European Journal of Orthodontics*, 2022;44(5), 1460-2210.
15. Martínez Roque, K. M., & Ardón, E. Madurez esquelética: el descubrimiento de la edad biológica a través de los métodos de evaluación de vértebras cervicales Baccetti y carpal de Fishman. *Revista Minerva*, 2021;4(1), 51-62.
16. Vasquez Pacheco, Z., Cadena Carrera, A., Limonchi Palacio, L. V., Lehmann Mendoza, J. M., & López Alvarado, M. Á. Correlación del método de maduración esquelética de Baccetti con los estadios de calcificación dental del método de Demirjian en pacientes de la UJAT. *Ciencia Latina Revista Científica Multidisciplinaria*, 2025;9(6), 1-14.

DECLARATION OF CONTRIBUTIONS

"Conceptualization and design: Jeremy Laz, William Ubilla, Tanya Moreira; Literature review: Jeremy Laz, William Ubilla; Methodology and validation: Jeremy Laz, William Ubilla; Formal analysis: Jeremy Laz, William Ubilla, Tanya Moreira; Investigation and data collection: Jeremy Laz; Resources: Tanya Moreira; Data analysis and interpretation: Jeremy Laz, William Ubilla; Writing – original draft preparation: Jeremy Laz; Writing – review and editing: Jeremy Laz, William Ubilla, Tanya Moreira; Supervision: William Ubilla, Tanya Moreira; Project administration: Jeremy Laz, William Ubilla; Funding acquisition: Not applicable."

CONFLICTS OF INTEREST

The authors declare that there were no conflicts of interest during the conduct of the research. The manuscript was submitted exclusively to the Scientific Journal "Especialidades Odontológicas UG" for review and publication.

FUNDING

The authors declare that the research was conducted using their own funds.

COPYRIGHT



This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives (CC BY-NC-ND) License. Its use, distribution, or reproduction in other media is permitted, provided that appropriate credit is given to the original author(s) and copyright holder, and that the original publication in this journal is cited in accordance with accepted academic practices. Any use, distribution, or reproduction that does not comply with these terms is prohibited.

HOW TO CITE:

Laz Medina JA. Ubilla Mazzini W. Moreira Campuzano T. Mineralization of the mandibular second molar and cervical vertebral maturation as indicators of the pubertal growth spurt in pediatric patients. *Revista Científica Especialidades Odontológicas UG*. 2026;9(2):15-24.