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ARTICLE

RELATIONSHIP BETWEEN DENTAL CALCIFICATION STAGES AND CERVICAL VERTEBRAL MATURATION IN MEXICAN INDIVIDUALS. A CROSS-SECTIONAL STUDY

Relación entre las etapas de calcificación dental y la maduración vertebral cervical en individuos mexicanos. Un estudio transversal

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ABSTRACT

Introduction: This study used panoramic and lateral cephalometric radiographs to evaluate the relationship between dental calcification stages and cervical vertebral maturation in Mexican individuals.

Material and Methods: In this study, 201 patients aged 6 to 17 from Queretaro, Mexico, underwent lateral cephalometric radiographs and panoramic radiographs. Two trained and calibrated orthodontists and oral radiologists used Baccetti's method to assess cervical maturation stages and Demirjian's method to evaluate dental calcification stages. The correlation between the stages was assessed using Spearman's correlation coefficient. Additionally, the chi-square test was used to evaluate the association between the stages of both methods, using the teeth with the highest correlation values ($p<0.05$).

Results: The strongest correlation values were observed for the second molar (r=0.706), second premolar (r=0.661), and lower canine (r=0.653) ($p<0.001$). Among these teeth, the lower canine displayed the strongest association. There was a significant relationship between the CS3 vertebra stage and the G stage (42.9%), as well as between the CS4 stage and the H stage (48.2%) ($p<0.001$).

Conclusions: Based on the sample results, the stage of bone development can be identified by examining dental calcification using the lower canine on panoramic radiographs as a reference. This knowledge can help determine the stage of cervical calcification, which can help create an effective treatment plan.

Keywords: *Cephalometry; Cervical vertebrae; Radiography, panoramic; Tooth calcification; Cross-sectional studies; Bone development*

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RESUMEN

Introducción: Este estudio utilizó radiografías cefalométricas panorámicas y laterales para evaluar la relación entre las etapas de calcificación dental y la maduración vertebral cervical en individuos mexicanos.

Materiales y Métodos: En este estudio, 201 pacientes de 6 a 17 años de Querétaro, México, se sometieron a radiografías laterales de cabeza y panorámicas. Dos ortodoncistas y radiólogos orales entrenados y calibrados utilizaron el método de Baccetti para evaluar las etapas de maduración cervical y el método de Demirjian para evaluar las etapas de calcificación dental. La correlación entre las etapas se evaluó mediante el coeficiente de correlación de Spearman. Adicionalmente, se utilizó la prueba de chi-cuadrado para evaluar la asociación entre las etapas de ambos métodos, utilizando los dientes con los valores de correlación más altos (p< 0,05).

Resultados: Los valores de correlación más fuertes se observaron para el segundo molar (r = 0,706), segundo premolar (r = 0,661) y canino inferior (r = 0,653) (p< 0,001). Entre estos dientes, el canino inferior mostró la asociación más fuerte. Hubo una relación significativa entre el estadio de la vértebra CS3 y el estadio G (42,9%), así como entre el estadio CS4 y el estadio H (48,2%) (p<0,001).

Conclusión: Con base en los resultados de la muestra, se puede identificar el estadio de desarrollo óseo examinando la calcificación dental utilizando el canino inferior en radiografías panorámicas como referencia. Este conocimiento puede ayudar a determinar el estadio de calcificación cervical, lo que puede ayudar a crear un plan de tratamiento eficaz.

Palabras clave: *Cefalometría; Vértebras cervicales; Radiografía panorámica; Calcificación de dientes; Estudios transversales; Desarrollo óseo*

INTRODUCTION

Every individual has a unique rate of bone growth. Dentists evaluate physiological parameters, including chronological, dental, and bone ages, to determine the estimated biological age and develop tailored treatment plans.[1-3] This evaluation can be influenced by genetic, racial, and environmental factors,[4,5] though it can be efficiently assessed radiologically. The chronological age represented by the date of birth is not reliable for identifying the bone growth of a person; for this reason, it is essential to evaluate dental maturation using its calcification that allows inferring by correlation its moment of bone growth, being the Demirjiam's method the most used,[6-8] and considering a simple and practical method, which is obtained from panoramic radiographs, also known as orthopantomography (OPG).[5,9-11]

Dental age or dental development is a good indicator because teeth are strong and highly resistant. Therefore, they are the least affected by endocrine and environmental factors or dietary modifications compa-red to other structures.[6,12,13] Furthermore, it is necessary to evaluate the bone age of an individual, which

will determine the possibility of carrying out treatments that include stimulation or control of mandibular or maxillary growth.[14] Therefore, it helps in the diagnosis and treatment and in knowing the patient's response,[5,15] which will influence an early correction of some skeletal and dental discrepancies in children.[15-20]

Knowledge of the patient's age is of interest to several areas of dentistry, including orthodontics, pediatric dentistry, and even forensic dentistry for treatment, legal and forensic factors, which age estimation methods can solve.[6,21,22] The importance of dispensing with a radiographic examination due to the accumulation of radiation over time led to the search for alternative methods to carpal radiography and then to lateral skull radiography, techniques that can have a good approximation and that, in some instances avoid taking of an additional radiograph.[23-25]

In Latin America, a few studies have evaluated this correlation, and Mexico is no exception; some variation in the correlation results could exist due to racial and environmental aspects. Therefore, more methodologically well-designed research is required to corroborate the few results.

For this reason, this research aimed to determine the correlation between the stages of dental calcification using panoramic radiography and cervical vertebral maturation using lateral cephalometric radiographs in Mexican individuals from 6 to 17 years of age.

MATERIALS AND METHODS

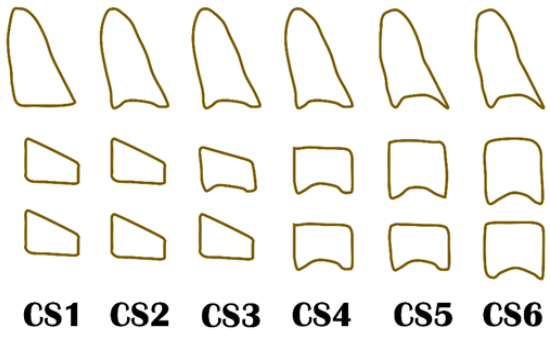
This cross-sectional and correlation study was approved by the technical report of the reviewers of the Dentistry Faculty of the Universidad Científica del Sur with code No. POS-117-2024-00237. This study assessed 201 consecutive sets of panoramic and lateral cephalometric radiographs of individuals aged 6 to 17. It was conducted at a private radiology center in Queretaro, Mexico, between January 2022 and June 2023.

The selected radiographs needed to meet specific criteria, including high image quality and proper positioning. Panoramic radiographs were required to capture all the teeth up to the second molars, whether during mixed or permanent dentition. For lateral radiographs, patients had to be in occlusion, and the image had to include at least the fourth cervical vertebra. Radiographs of patients with syndromes or skeletal alterations and those with anatomical distortions or metallic artifacts were excluded from the study.

The radiographs were taken using a Vatel model I-Pax from 2020, with the serial number HDG-07B10T2. The equipment has a focal area of 0.5 x 0.5 mm and a maximum output of 90 kV/10 mA. Specifically, for panoramic radiographs, the settings were 67 kVp at 8.0 mA with an exposure time of 10.1 seconds.

Figura 1

Scheme of Baccetti's method of bone maturation of the cervical vertebrae



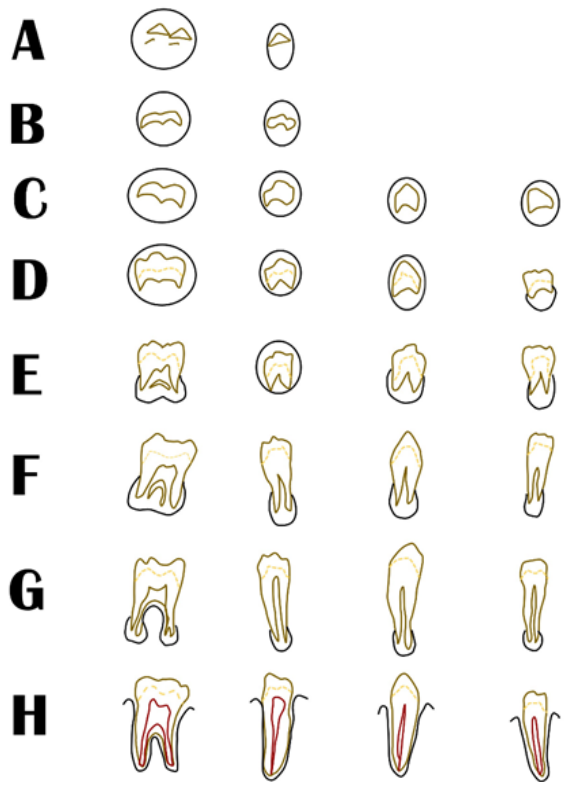
Meanwhile, for lateral cephalometric radiographs, the settings were 80 kVp at 100 mA with an exposure time of 0.9 seconds.

The EzDent-I software was used to analyze panoramic and lateral skull images. Two researchers and oral radiologists received training and calibration overseen by a specialist in oral and maxillofacial radiology with ten years of experience and an orthodontics specialist of the same level of expertise. Additionally, a pilot study was conducted, followed by two rounds of intra-rater calibration. The second calibration took place two weeks later and involved checking 10% of the total sample until an intra-rater agreement of at least 0.85 was achieved using the Kappa Test.

Finally, both evaluators utilized Baccetti's method[26] to assess cervical maturation stages on lateral X-rays and Demirjian's method27 to evaluate dental calcification stages on panoramic X-rays (Figure 1 and Figure 2).

Figura 1

Scheme of Demirjian's method for age estimation



Statistical analysis

All the samples were measured, and the data collected were organized in an Excel spreadsheet and imported into the IBM Statistical Package for the Social Sciences (SPSS) software, version 29 (IBM Corp., NY, USA). Spearman's correlation coefficient was used between Baccetti's and Demirjian's method stages for the whole sample and then for both genders. Based on the strongest correlation the level of association was tested using the Chi-square test; $p<0.05$ was used.

RESULTS

Table 1 shows the initial characteristics of the sample. Table 2 evaluates the correlation between the skeletal maturation stages of the cervical vertebrae according to Baccetti's method and the calcification of the dental roots of all the lower teeth on the left side from the central incisor to the second molar according to Demirjian's method, finding the highest correlation values for the second molar (r=0.706), the second premolar (r=0.661) and the canine (r=0.653) ($p<0.001$). A very similar behavior was found

Table 1

Description of the samples evaluated

Sex	n	Age Mean (SD)
Female	107	12.32 (4.38)
Male	94	12.44 (1.48)

$p=0.075$ T-test.

Table 2

Spearman's correlation between Baccetti's method values and root calcification according to Demirjian's method in lower left teeth

Indicators		Central incisor	Lateral incisor	Canine	First premolar	Second premolar
Baccetti's method	R^2	0.334**	0.373**	0.653**	0.627**	0.661**
	p	<0.001	<0.001	<0.001	<0.001	<0.001
	n	201	201	201	201	201

**: Correlation is significant at the 0.01 level (bilateral). Spearman's rho.

Table 3

Spearman's correlation between Baccetti's method values and root calcification according to Demirjian's method in lower left teeth, in both genders

Gender	Indicators		Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar
Female	Baccetti's method	R^2	0.371**	0.400**	**0.566****	**0.527****	0.512**	0.409**	**0.588****
		p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		n	107	107	107	107	107	107	107
Male	Baccetti's method	R^2	0.290**	0.341**	**0.731****	0.718**	**0.802****	0.485**	**0.812****
		p	0.005	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		n	94	94	94	94	94	94	94

**: Correlation is significant at the 0.01 level (bilateral). Spearman's rho.

Table 4

Association between Baccetti's method stages and Demirjian's stages of root calcification in the second molar, second premolar and left canine

Baccetti's stage		Stage of root calcification of second molars A	B	C	D	E	F	G	H	Total	*p*-value
CS 1	n	0	2	6	12	10	3	1	0	34	<0.001
	%	0	5.9	17.6	**35.3**	29.4	8.8	2.9	0	100	
CS 2	n	0	0	1	7	7	7	7	0	29	
	%	0	0	3.4	**24.1**	24.1	24.1	24.1	0	100	
CS 3	n	0	0	0	1	3	9	12	3	28	
	%	0	0	0	3.6	10.7	32.1	**42.9**	10.7	100	
CS 4	n	0	0	0	2	0	8	26	20	56	
	%	0	0	0	3.6	0	14.3	**46.4**	35.7	100	
CS 5	n	0	0	1	0	0	1	19	17	38	
	%	0	0	2.6	0	0	2.6	**50**	44.7	100	
CS 6	n	0	0	0	0	0	2	5	9	16	
	%	0	0	0	0	0	12.5	31.1	**56.3**	100	
Total	n	0	2	8	22	20	30	70	49	201	
	%	0	1	4	10.9	10	14.9	34.8	24.4	100	

The Table 4 continues on the next page →

→ Table 4. Association between Baccetti's method stages and Demirjian's stages of root calcification in the second molar, second premolar and left canine

Baccetti's stage		Stage of root calcification of the left second premolar A	B	C	D	E	F	G	H	Total	*p*-value
CS 1	n	0	1	7	12	8	5	1	0	34	<0.001
	%	0	2.9	20.6	**35.3**	23.5	14.7	2.9	0	100	
CS 2	n	0	0	1	4	9	7	5	3	29	
	%	0	0	3.4	13.8	31	**24.1**	17.2	10.3	100	
CS 3	n	0	0	0	0	6	4	6	12	28	
	%	0	0	0	0	21.4	14.3	21.4	**42.9**	100	
CS 4	n	0	0	0	0	2	5	18	31	56	
	%	0	0	0	0	3.6	8.9	32.1	**55.4**	100	
CS 5	n	0	0	1	0	0	3	10	24	38	
	%	0	0	2.6	0	0	7.9	26.3	**63.2**	100	
CS 6	n	0	0	0	0	0	2	2	12	16	
	%	0	0	0	0	0	12.5	12.5	**75**	100	
Total	n	0	1	9	16	25	26	42	82	201	
	%	0	0.5	4.5	8	12.4	12.9	20.9	40.8	100	

Baccetti's stage		Root calcification stage of the left canine A	B	C	D	E	F	G	H	Total	*p*-value
CS 1	n	0	0	0	5	14	9	4	2	34	<0.001
	%	0	0	0	14.7	**41.2**	26.5	11.80	5.9	100	
CS 2	n	0	0	0	1	4	11	10	3	29	
	%	0	0	0	3.4	13.8	**37.9**	34.5	10.3	100	
CS 3	n	0	0	0	0	0	8	12	8	28	
	%	0	0	0	0	0	28.6	**42.9**	28.6	100	
CS 4	n	0	0	0	0	0	5	24	27	56	
	%	0	0	0	0	0	8.9	42.9	**48.2**	100	
CS 5	n	0	0	0	0	0	2	9	27	38	
	%	0	0	0	0	0	5.3	23.7	**71.1**	100	
CS 6	n	0	0	0	0	0	1	2	13	16	
	%	0	0	0	0	0	6.3	12.5	**81.3**	100	
Total	n	0	0	0	6	18	36	61	80	201	
	%	0	0	0	3	9	17.9	30.3	39.8	100	

when analyzing these correlations in each gender, with significant correlation values in both genders (p<0.001) and with the second molar as the most correlated tooth (r=0.588 in females, r=0.812 in males), followed by the first premolar in females (r=0.527) and second premolar in males (r=0.802) and the canine (r=0.566 in females, r=0.701 in males) (Table 3). Thus, based on the three teeth with the highest correlation values, the associations between the stages of both methods were evaluated without considering gender, to look for a possible replacement of methods, finding a significant association in the three associations (p<0.001); however, it was the lower canine that best identified these associations, finding that vertebral stage CS1 is mostly associated with Demirjian stage E (41.2%), CS2 with stage F (37.9%), CS3 with G (42.9%), CS4 with H (48.2%), CS5 with H (71.1%) and CS6 with H (81.3%), (p<0.001) (Table 4).

DISCUSSION

Main Discussion

It is crucial to accurately determine when to begin orthopedic treatment in orthodontics, as the success of the treatment depends on the timing of therapy initiation. Applying orthopedic appliances at the wrong time can lead to minimal or no favorable bone growth response. Carpal radiography is traditionally used as the *"gold standard"* imaging method to determine a person's stage of bone growth.[24] However, in orthodontic practice, several essential radiographs, including panoramic and lateral cephalometric radiographs, are already necessary to begin treatment. Researchers have explored alternative imaging methods to replace carpal radiography to avoid additional radiation exposure and higher costs for practical reasons. One proposed method uses lateral head radiography based on Bacceti's approach, which has been extensively studied and employed in orthodontic clinics. Although this method has been criticized for its low reproducibility, proper training of the clinician evaluator can minimize the measurement unreliability.[15,25]

A lateral cephalometric radiograph may not be necessary for all young patients, particularly if their facial appearance indicates balanced bone growth or only slight alterations in the bone bases. In such cases, dental calcification stages can be evaluated using a panoramic radiograph as an alternative method for assessing bone maturation. However, it's important to note that this alternative method requires further study across various racial groups with different environmental factors, as results may differ from those reported in current scientific literature.

To address this, our research aimed to determine the correlation between dental calcification stages observed in panoramic radiographs and cervical vertebral maturation assessed through lateral cephalometric radiographs in Mexican individuals. The study focused on three teeth with the strongest correlation values between the two methods to identify which tooth, based on its root calcification, had the most significant association with the stages of maturation of the cervical vertebrae.

The findings revealed that the lower canine was the tooth most closely associated with these stages. Specifically, the onset of the growth peak, identified as stage CS3 according to Baccetti, was mainly associated with stage G of dental calcification (42.9%). In contrast, stage CS4, which represents the end of the growth peak, was primarily linked with stage H (48.2%). Additionally, bone maturation stages indicating the conclusion of bone growth were predominantly related to stage H of dental calcification in CS5 (71.1%) and CS6 (81.3%).

These results suggest significant clinical applications. For instance, when a patient requires a mandibular propulsor in orthodontic practice, it's crucial to recognize the onset of the growth peak (CS3), which may correspond to 50% of stage H of the lower canine on a panoramic radiograph.

Some research studies have found similar results correlating cervical maturation and dental development, although they identified a different dental piece as the most associated.[4,5,9] However, for a Latin American community like the Mexican individuals evaluated in this study, these results could serve as a starting point for further research in this region. In this way, this study demonstrates a correlation between the stages of cervical maturation and dental calcification in Mexican individuals. Dentists can consider these correspondences in their clinical practice.

Our study has a limitation concerning its external validity. Although it employs an appropriate methodological design, the results cannot be generalized due to uncontrolled biological variables. Additionally, only ra-diographs that met the selection criteria were included, preventing a probabilistic calculation. Future studies should consider these factors.

CONCLUSIONS

Based on the sample results, the stage of bone development can be identified by examining dental calcification on panoramic radiographs, primarily using the lower canine as a reference. This knowledge can help determine the stage of cervical calcification, which can inform an effective treatment plan, particularly orthopedic treatment in growing individuals.

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CONFLICT OF INTERESTS

The authors have no conflict of interest to disclose.

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María Dolores Tatiana Orozco Alvarez: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software.

Graciela Toribia Cardenas Pinedo: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software.

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