Skeletal Maturity Assessment using Calcification Stages of Mandibular Canine; A Cross-Sectional Study

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OBJECTIVE: The objective of this study was to establish a relationship between skeletal maturity, as evaluated through cervical vertebral maturation, and the calcification stages of mandibular canines.

METHODOLOGY: Carried out at the Orthodontics, Department of Saidu College of sDentistry in Swat, this correlational study employed a non-probability consecutive sampling technique involving 130 participants. Inclusion criteria encompassed high-quality pre-treatment panoramic and lateral cephalometric radiographs, of children age 8 to 16 displaying normal growth and development. Exclusion criteria considered conditions such as congenital anomalies, severe dental issues, and systemic medical conditions impacting maturation. Panoramic radiographs and the Gleiser and Hunt method were used to score mandibular canine calcification stages, while skeletal maturation was evaluated using lateral cephalograms and the CVM method proposed by Baccetti et al. Associations were explored using the Chi-square test and Spearman's rank correlation, with a significance threshold of $P < 0.01$.

RESULTS: The study comprised 130 participants (mean age 11.86 ± 1.76 years, 63 females and 67 males) with assessed canine calcification stages: MCC 1 (1.54%), MCC 2 (30.00%), MCC 3 (24.62%), MCC 4 (13.85%), MCC 5 (29.23%), and MCC 4 (0.77%). A significant correlation existed between canine calcification stages and CVM stages ($p < 0.001$). Notably, a perfect correlation was found between cervical maturation stage and calcification stage ($r = 0.96$).

CONCLUSION: The calcification stages of mandibular canines offer a clinically valuable indicator for assessing skeletal maturity.

KEYWORDS: Skeletal maturity assessment, Calcification stages, Mandibular canine, Cervical vertebral maturation (CVM), Cross-sectional study, Lateral cephalometric radiograph

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INTRODUCTION

Traditionally, the ideal timing for orthodontic growth modification treatment has been linked to the pinnacle of skeletal maturity in developing individuals.[1] Understanding the growth events in orthodontics is crucial for accurate diagnosis, treatment planning, appliance selection, and achieving desired treatment outcomes. Detecting periods of rapid growth or growth spurts can greatly aid in addressing skeletal irregularities in patients. Various techniques have been documented for identifying maturation indicators that denote stages of bone development across different age groups.[3] Hand-wrist radiographs and the stages of cervical vertebral maturation have been extensively investigated as sign of skeletal developmental stage.[4]

The method of cervical vertebral maturation (CVM), introduced by Baccetti et al.[5], is an accepted and definitive approach for estimating skeletal maturity.[1] By conducting an analysis of the structural characteristics of the 2nd, 3rd, and 4th cervical vertebrae on lateral cephalograms, the growth phase can be identified.[6] The benefit of this approach lies in its reliance on the lateral cephalogram, a commonly employed radiographic tool in orthodontic diagnosis and

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treatment planning. Nevertheless, it doesn't serve as a universally applicable diagnostic tool for every patient. Therefore, to ensure logical treatment planning for growing individuals, the recognition of additional reliable diagnostic tools would be highly beneficial.[7]

Dental maturation stages can also provide insights into the growth stage of an individual.[4-7] Evaluation of dental development can be accomplished through tooth eruption, the process of tooth mineralization, encompassing crown and root development stages. Among these, dental mineralization has been acknowledged as the most dependable method for assessing dental maturation.[8,9] On the other hand, skeletal maturation (SM) involves a series of physiological changes within the body. This process is characterized by a phenomenon in which the rate of progression may vary among developing individuals due to differences in their biological timing.[10] Consequently, both bodily maturation and chronological age have proven inadequate in reliably gauging SM, primarily due to the significant divergence in the initiation of pubertal growth spurts (PGS).[11] Additionally, panoramic radiographs, routinely taken in orthodontic practice, can serve as a definitive diagnostic tool for dental maturation stages.[12] These radiographs are important for patients in need of orthodontic treatment and can minimize their exposure to radiation. This approach is straightforward, practical, and more convenient to implement when compared to other existing methods. Evaluating dental maturity can be additionally linked to forecasting an individual's growth stages.[13]

The rationale for the study lies in exploring the potential connection between skeletal maturity, as indicated by cervical vertebral maturation, and dental development, as indicated by the calcification stages of the mandibular canine. The aim of the study was to assess skeletal maturity using calcification stages of the mandibular canine.

METHODOLOGY

This descriptive correlation study was done at the Department of Orthodontics, Saidu College of Dentistry, Swat, from April 10, 2023, to September 10, 2023, using a non-probability consecutive sampling method. Approval was granted by the hospital's ethical review board (ERB No, 133-ERB/023).

The sample size was calculated to be 11, taking into account a 5% Type 1 error and 10% power of the test, while considering an anticipated correlation coefficient of $r = 0.82$ between skeletal maturity and mandibular canine calcification.[1] However, to ensure normality, we opted for a sample size of 130 cases.

Inclusion criteria encompassed the availability of excellent quality pre-treatment panoramic and lateral cephalometric radiographs, along with children aged 8 to 16 years displaying Typical growth and maturation. Conversely, exclusion criteria comprised cases involving Radiographs of children exhibiting congenital anomalies, syndromes, or congenitally absent teeth, as well as patients with severe dental or periodontal conditions that could potentially influence dental maturation. Additionally, patients with systemic medical conditions or medications known to impact skeletal or dental development, those with a history of craniofacial trauma or surgery, and individuals with severe systemic or medical conditions affecting craniofacial growth and development.

The research incorporated de-identified digital orthopantomograms and lateral cephalogram records from 130 orthodontic patients undergoing treatment. Radiograph anonymization was performed by a non-affiliated radiograph technician for the study. Radiographs not meeting the inclusion criteria were omitted from the analysis.

The panoramic radiographs were used to assess the calcification stages of the right mandibular canine, employing the modified Gleiser and Hunt method for simplified scoring, reduced from 10 to 5 stages.[24] Additionally, the growth phase of skeletal maturation will be determined on lateral cephalograms following the CVM (Cervical vertebral maturation) method introduced by Baccetti et al.

The data underwent statistical analysis using SPSS version 24.0. Mean and standard deviation (SD) were computed for numerical variables like age, while qualitative variables such as gender, MCC, and tooth mineralization stages were analyzed using frequency and percentage calculations. Relationships between variables were assessed through the Chi-square test and Spearman's rank correlation. The statistical significance threshold was established at $P < 0.01$.

RESULTS

The mean age was 11.86 ± 1.76 years. Females were 63 (48.46%) and males were 67(51.54%). Age was normally distributed shown by bell shape histogram. (Fig1)

Canine calcification stages were evaluated among the 130 participants included in the study. The distribution of participants across different stages of canine calcification was as follows: MCC1 (Mandibular canine calcification)was observed in 2 participants (1.54%), MCC 2 in 39 participants (30.00%), MCC 3 in 32 participants (24.62%), MCC 4 in 18 participants (13.85%), MCC 5 in 38 participants (29.23%), and MCC 4 in 1 participant (0.77%). (Fig 2)

Table 1 presents a cross tabulation of the stages of canine calcification and cervical vertebral maturation (CVM) stages. The distribution of participants across different stages is

Table 1: Association of stages of canine calcification and CVM stages MCC (mandibular canine calcification) CS (CVM stage)

Canine calcification stages	CVM stages						p-value*
	CS1, N = 14'	CS2, N = 32'	CS3, N = 37'	CS4, N = 34'	CS5, N = 12'	CS6, N = 1'	
MCC 1	2 (14.29)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	<0.001
MCC 2	11 (78.57)	28 (87.50)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
MCC 3	1 (7.14)	4 (12.50)	27 (72.97)	0 (0.00)	0 (0.00)	0 (0.00)	
MCC 4	0 (0.00)	0 (0.00)	8 (21.62)	10 (29.41)	0 (0.00)	0 (0.00)	
MCC 5	0 (0.00)	0 (0.00)	1 (2.70)	24 (70.59)	12 (100.00)	1 (100.00)	

Fig 1: Age distribution

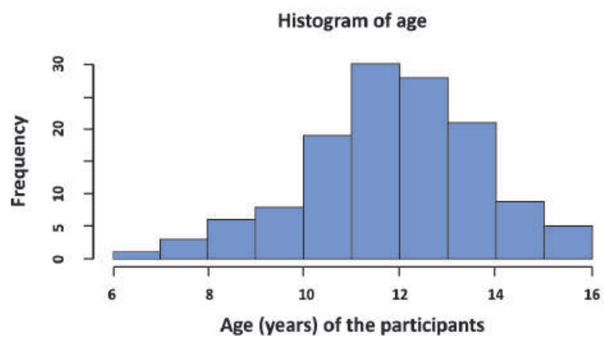


Fig 2: Distribution of canine maturation stages

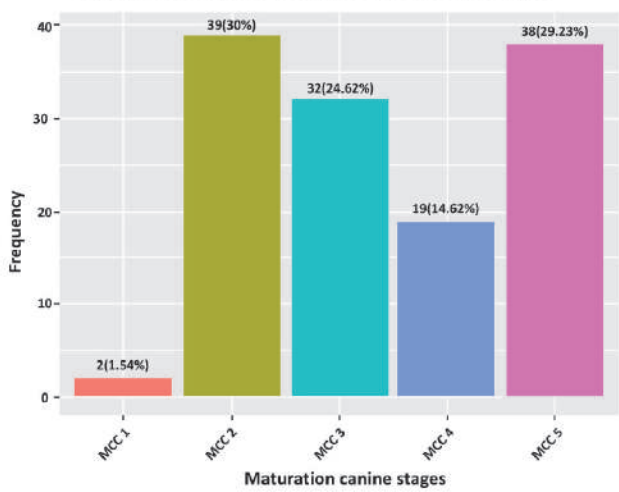


Table 2: Association of stages of canine calcification and CVM stages in male and female MCC (mandibular canine calcification) CS (CVM stage)

gender	Canine calcification stages	CVM stages						p-value
		CS1	CS2	CS3	CS4	CS5	CS6	
male	MCC 1	1 (11.11)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	<0.001
	MCC 2	8 (88.89)	15 (93.75)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
	MCC 3	0 (0.00)	1 (6.25)	13 (72.22)	0 (0.00)	0 (0.00)	0 (0.00)	
	MCC 4	0 (0.00)	0 (0.00)	4 (22.22)	6 (37.50)	0 (0.00)	0 (0.00)	
	MCC 5	0 (0.00)	0 (0.00)	1 (5.56)	10 (62.50)	7 (100.00)	1 (100.00)	
female	MCC 1	1 (20.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)		<0.001
	MCC 2	3 (60.00)	13 (81.25)	0 (0.00)	0 (0.00)	0 (0.00)		
	MCC 3	1 (20.00)	3 (18.75)	14 (73.68)	0 (0.00)	0 (0.00)		
	MCC 4	0 (0.00)	0 (0.00)	5 (26.32)	4 (22.22)	0 (0.00)		
	MCC 5	0 (0.00)	0 (0.00)	0 (0.00)	14 (77.78)	5 (100.00)		

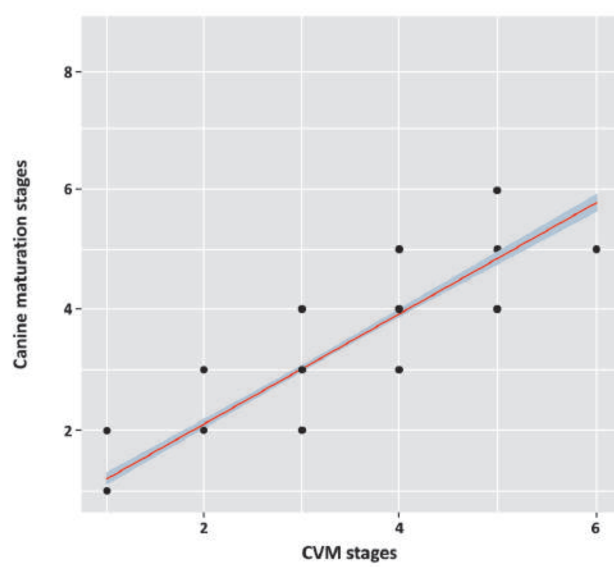
*Fisher exact test

as follows: For MCC 1, 2 participants (14.29%) were in CS1, while no participants were observed in the other stages. For MCC 2, 11 participants (78.57%) were in CS1 (Cervical vertebral maturation stage) 28 participants (87.50%) were in CS2, and no participants were in the remaining stages. For MCC 3, 1 participant (7.14%) was in CS1, 4 participants (12.50%) were in CS2, and 27 participants (72.97%) were in CS3. For MCC 4, 8 participants (21.62%) were in CS3, 10 participants (29.41%) were in CS4, and no participants were in the other stages. For MCC 5, 1 participant (2.70%) was in CS3, 24 participants (70.59%) were in CS4, all 12 participants in CS5 (100.00%) were in CS5, and the only participant in CS6 (100.00%) was in CS5. MCC4 was observed in 1 participant (2.70%) in CS3. The p-value indicates a statistically significant association between canine calcification stages and CVM stages ($p < 0.001$).

Table 2 also presents a cross tabulation of the stages of canine calcification and cervical vertebral maturation (CVM) stages in male and female .The p-value indicates a statistically a highly significant association between canine calcification stages and CVM stages ($p < 0.001$).

The correlation between cervical maturation stage and calcification stage was perfect ($r=0.96$) and highly statistically significant ($p<0.001$). The regression equation and co-efficient of determination is shown in Fig 3.

Fig 3: Correlation of Canine calcification and CVM stages



DISCUSSION

The findings of this research have significant implications for orthodontics, as accurately assessing an individual's growth maturation status is essential for diagnosis, treatment planning, and achieving successful treatment outcomes.

The primary duty of an orthodontist involves evaluating an individual's growth status and gathering information about their remaining growth potential to ensure the effective treatment of malocclusion with skeletal causes. Hence, it is essential to record the potential direction, magnitude, and potentially the timing of a patient's growth. Every child undergoing a standard growth pattern encounters a pubertal growth spurt. Nevertheless, it is crucial to acknowledge that there are differences in the initiation, duration, pace, and scope of this growth during puberty for each individual.[14,15]

Consequently, orthodontists rely on various assessment methods, including chronological age, stage of dental development, tracking standing height measurements on growth charts, monitoring the progression of secondary sexual characteristics, and utilizing radiographic measurements of skeletal maturation to make informed treatment decisions.[16]

The current study employed the MCC stages to assess growth phases, considering that mandibular canine calcification starts at four months and completes by seven years, with permanent canines typically emerging between 9 to 10 years of age. Panoramic radiographs were used to identify calcification stages, and prior research had already established a strong connection between developmental stages and mandibular canines.[17] Hypodontia occurrence in permanent canines was found to be rare (0.18%-0.29%), with minimal morphological variations in their development, emphasizing the reliability of using this tooth as a growth marker.[18-20]

The choice of age range (8 to 16 years) for the study aligned with similar investigations by other researchers and was considered relevant as orthodontic interventions are often performed within this age bracket[21] he current study found a significant link between CVM Stages 1, 2, and 3, as well as MCC Stages 2, 3, and 4, in relation to skeletal age and calcification stages. Conversely, CVM Stages 4, 5, and 6 corresponded with the full development of mandibular canines, specifically Stage 5. This indicates that the stages of canine calcification predominantly mirror growth status during the early phases, consistent with earlier studies conducted by Džemidžic et al.[22-24]

Nasir ZB,et al.cunducted a study in pakistan with the mean age of the sample was 13.29±1.86 years. The Hassel and Farman CVM stages on a lateral cephalometric radiograph and Dimerijan canine calcification stages on a panoramic radiograph showed a significant positive correlation (r= 0.785, p= 0.000).25 Overall, while both studies support the correlation between cervical maturation stages and canine calcification stages, our study provides more detailed information and a larger sample size, and it identifies an exceptionally strong correlation between these developmental stages.

To support their findings, the study referenced a prior cross-sectional study conducted on 300 orthodontic patients in the same age group. This study utilized the Gleiser and Hunt method to assess mandibular canine calcification and the CVM method developed by Baccetti et al. to evaluate skeletal maturation phases. The results of this previous study also indicated positive correlations between CVM Stages 1, 2, 3, and mandibular canine calcification Stages 2, 3, 4, reaffirming the clinical relevance of using canine calcification stages as a marker for assessing skeletal maturity.[1]

LIMITATIONS

While the study makes valuable contributions, it is important to recognize several limitations. Among the limitations are the modest sample size of 130 participants, potentially restricting the broad applicability of the conclusions. Moreover, the confined age bracket of 8 to 16 years might limit how widely the results can be applied across different populations.

The study was done at a single institution, introducing potential biases related to the patient population. Exclusion criteria may have introduced selection bias, and variations in radiograph quality could affect the accuracy of the assessments. The Gleiser and Hunt method's subjective scoring and the absence of causal inference were other limitations. Ethnic and genetic influences were not explored, and the clinical application of the findings may require further validation. Finally, the simplification of calcification stages may not fully capture the complexity of growth maturation.

Our current study provides valuable insights into the correlation between CVM staging and MCC stages as markers for growth maturation assessment. While the findings support the clinical relevance of mandibular canine calcification stages in evaluating skeletal maturity, Acknowledging the study's constraints is crucial, highlighting the necessity for additional research to validate and broaden these findings within a more diverse and comprehensive range of patients.

CONCLUSION

Based on our research and data analysis, a significant association appears to exist between the calcification stages of mandibular canines and skeletal maturity. It's important to note that this conclusion is context-specific, and to determine the broader applicability and reliability of this correlation across various populations and settings, further research is warranted.

CONFLICT OF INTEREST

None to declare

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