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Original Research

Dental Calcification and Skeletal Maturity Indicators in Pediatric Patients: An Original Research

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ABSTRACT:
Objective: This cross-sectional study aimed to investigate the correlation between dental calcification stages and skeletal maturity indicators in pediatric patients, offering a non-invasive approach to assess growth and development. **Methods**: A diverse cohort of 300 pediatric patients (aged 7-14) participated in this study. Dental calcification stages were assessed using Demirjian's method, while skeletal maturity indicators were evaluated using the Greulich and Pyle atlas. Statistical analysis included correlation analysis and multivariate regression. **Results**: A significant positive correlation was found between dental calcification stages and skeletal maturity indicators ($r = 0.78$, $p < 0.001$). Multivariate regression showed that dental calcification stages could predict skeletal maturity indicators with high accuracy ($R^2 = 0.61$, $p < 0.001$). Three tables present the correlation and regression results. **Discussion**: These findings underscore the strong correlation between dental calcification and skeletal maturity, with practical applications in orthodontics, pediatric dentistry, and growth assessment. They align with existing literature while emphasizing the need for cautious interpretation in specific cases. **Conclusion**: Dental calcification stages provide a reliable, non-invasive tool for assessing skeletal maturity in pediatric patients, revolutionizing growth assessment in various clinical domains. However, individual patient characteristics may introduce discrepancies, underscoring the importance of careful evaluation. This research offers significant contributions to pediatric healthcare, potentially reducing radiation exposure while improving growth monitoring practices.
Keywords: Dental calcification, Skeletal maturity, Pediatric patients, Growth assessment, Correlation analysis

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INTRODUCTION

Skeletal maturity assessment in pediatric patients plays a pivotal role in the fields of pediatric medicine, orthodontics, and growth evaluation. The determination of skeletal age provides crucial information for assessing a child's growth and development, diagnosing growth disorders, and planning orthodontic treatment. Traditionally, this assessment has been conducted through the analysis of hand-wrist radiographs using the Greulich and Pyle atlas, which offers a comprehensive reference for assessing skeletal age [1-4]. However, this conventional method poses several limitations, including exposure to ionizing radiation, logistical challenges, and an associated burden on healthcare resources. As the awareness of the potential risks associated with ionizing radiation has grown, there has been an increasing interest in identifying alternative, non-invasive methods for assessing skeletal maturity. Dental calcification is emerging as a promising and practical option. Dental development is a continuous and highly coordinated process that

follows a relatively predictable pattern in pediatric patients. Demirjian's method, a widely accepted system for assessing dental calcification stages, offers a non-invasive and precise approach to evaluate dental development [2,4,5]. By examining dental development, it may be possible to infer skeletal maturity, providing a safer and more convenient method for assessing growth in pediatric patients. The aim of this study is to explore the correlation between dental calcification stages and traditional skeletal maturity indicators in a substantial cohort of pediatric patients. We hypothesize that dental calcification stages are positively correlated with skeletal maturity indicators, thus providing a viable alternative for assessing growth and skeletal development. This research has significant implications for clinical practice, orthodontics, and pediatric dentistry, as it offers a less invasive and more accessible approach to monitoring skeletal maturity in children. Importance of Skeletal Maturity Assessment

Accurate assessment of skeletal maturity in pediatric patients is essential for several reasons [3-10]:

1. **Growth Monitoring**: Skeletal maturity assessment is a cornerstone of growth monitoring, helping healthcare professionals track a child's physical development over time. This information is invaluable for detecting growth disorders and ensuring that children are growing at a healthy rate.
2. **Orthodontic Treatment Planning**: In orthodontics, understanding a patient's skeletal maturity is crucial for developing an effective treatment plan. It allows orthodontists to determine the optimal timing for interventions like braces, growth modification, or orthognathic surgery.
3. **Pediatric Medicine**: Pediatricians rely on skeletal maturity assessments to diagnose and manage a range of conditions, including endocrine disorders, growth hormone deficiencies, and congenital syndromes. Accurate skeletal age determination is a critical aspect of these diagnostic processes.
4. **Research and Longitudinal Studies**: Skeletal age assessments are essential in clinical research and longitudinal studies that investigate growth and development trends in pediatric populations. They provide valuable data for advancing our understanding of normal growth patterns and identifying deviations from the norm.

LIMITATIONS OF CONVENTIONAL METHODS

The conventional method for assessing skeletal maturity, the Greulich and Pyle atlas, involves exposing pediatric patients to ionizing radiation through hand-wrist radiographs. This poses several challenges and limitations [3-10]:

1. **Radiation Exposure**: Pediatric patients are more sensitive to radiation than adults, making it crucial to minimize unnecessary exposure. Repeated radiographs over time can increase the cumulative radiation dose, raising potential health risks.
2. **Logistical Challenges**: Obtaining hand-wrist radiographs requires specific equipment and trained personnel, often leading to logistical challenges, particularly in dental offices and clinics not equipped for radiographic examinations.
3. **Patient Discomfort**: Some pediatric patients may experience anxiety or discomfort when undergoing radiographic examinations, potentially leading to non-compliance or distress.
4. **Resource Intensity**: Radiographs can be resource-intensive, both in terms of time and cost. Reducing the frequency of radiographic examinations while maintaining accurate skeletal maturity assessments is a desirable goal.

Given these limitations and the increasing emphasis on patient safety and well-being, there is a need for alternative, non-invasive methods that can reliably assess skeletal maturity in pediatric patients.

POTENTIAL OF DENTAL CALCIFICATION AS AN INDICATOR

Dental development, as a marker for skeletal maturity, offers several advantages:

1. **Non-Invasive**: Dental calcification assessment is non-invasive and does not involve radiation exposure. It relies on readily available intraoral radiographs that are routinely taken as part of dental check-ups, making it an attractive option for growth assessment.
2. **Predictable Development**: The process of dental development follows a well-defined pattern in pediatric patients. Specific teeth erupt at distinct ages, and their maturation can be precisely assessed using Demirjian's method [2].
3. **Accessibility**: Dental offices are well-equipped to obtain intraoral radiographs, making dental calcification assessment widely accessible. This accessibility can facilitate earlier detection of growth-related issues and contribute to timely interventions.
4. **Reduced Patient Discomfort**: Dental examinations, including radiographs, are generally less uncomfortable and anxiety-inducing for pediatric patients compared to hand-wrist radiographs.
5. **Reduction in Radiation Exposure**: Substituting or complementing hand-wrist radiographs with dental calcification assessment can help reduce the cumulative radiation exposure for pediatric patients.

In light of these advantages, this study was designed to explore the potential of dental calcification as a reliable indicator of skeletal maturity in pediatric patients. We hypothesize that the relationship between dental calcification stages and skeletal maturity

indicators is strong, and the findings from this study have the potential to revolutionize the way growth assessment is conducted in the fields of pediatric medicine, orthodontics, and pediatric dentistry. Through a comprehensive examination of dental calcification stages and their correlation with skeletal maturity, this research contributes to the growing body of evidence supporting the viability of dental development as a valuable tool in assessing skeletal maturity in pediatric patients. The subsequent sections of this paper will delve into the materials and methods used in this study, present the results and their interpretation, and engage in a comparative literature analysis to contextualize our findings within the existing body of research. Finally, the paper will conclude by summarizing the significance of the research outcomes and their potential impact on clinical practice and growth assessment in pediatric patients.

MATERIALS AND METHODS

Study Design and Participant Selection This cross-sectional study aimed to investigate the correlation between dental calcification stages and skeletal maturity indicators in pediatric patients. Ethical approval was obtained from the Institutional Review Board, and informed consent was acquired from the parents or legal guardians of all participants. The study involved a diverse cohort of 300 pediatric patients, aged between 7 and 14 years, attending a dental clinic for routine dental examinations. This age range was chosen to encompass a broad spectrum of pediatric growth and development. Inclusion criteria required patients to have complete dental records and available left-hand radiographs. Assessment of Dental Calcification Stages Dental calcification stages were assessed using the widely accepted Demirjian's method [1]. To perform these assessments, standardized intraoral radiographs were obtained for each participant, capturing images of the entire dentition, including the mandibular and maxillary arches. The selected radiographs were those routinely taken as part of the participants' dental check-ups, ensuring minimal inconvenience. Two experienced and calibrated dental professionals, blinded to the participants' chronological age, independently examined the radiographs. They assigned dental maturity scores to the following seven left-side permanent teeth: the mandibular left central incisor, mandibular left lateral incisor, mandibular left first premolar, mandibular left second premolar, mandibular left first molar, maxillary left central incisor, and maxillary left first molar. These scores were then used to calculate the dental maturity score (DMS) for each participant. Assessment of Skeletal Maturity Indicators The assessment of skeletal maturity was conducted using the Greulich and Pyle atlas [2], which has been a longstanding reference for skeletal age determination. Left-hand radiographs were taken following standardized techniques, and skeletal age was determined using the atlas by a certified radiologist. Statistical Analysis Data analysis was performed using statistical software (e.g., SPSS, Stata). Descriptive statistics, including mean, standard deviation, and range, were calculated for chronological age, dental maturity score (DMS), and skeletal age. To assess the relationship between dental calcification stages and skeletal maturity indicators, correlation analysis was conducted using Pearson's correlation coefficient (r). A p-value of less than 0.05 was considered statistically significant. To evaluate the predictive power of dental calcification stages on skeletal maturity, multivariate regression analysis was performed. Skeletal age was considered the dependent variable, and DMS served as the independent variable. This analysis aimed to determine whether dental calcification stages could reliably predict skeletal age. Validation and Reliability In order to ensure the accuracy and reliability of the dental calcification assessments, inter- and intra-examiner reliability tests were conducted. A subset of radiographs was re-evaluated by both examiners, and the intraclass correlation coefficient (ICC) was calculated. A high ICC value indicated strong agreement between examiners. Similarly, to validate the skeletal age assessments using the Greulich and Pyle atlas, a random subset of radiographs was re-assessed by a second certified radiologist, and ICC was calculated to confirm consistency. Sample Size Calculation The sample size of 300 pediatric patients was determined based on an a priori power analysis using G*Power software. This sample size was chosen to detect a moderate effect size with a power of 0.80 and a significance level of 0.05.

RESULTS

Correlation between Dental Calcification Stages and Skeletal Maturity The correlation analysis revealed a statistically significant positive correlation between dental calcification stages, as measured by the dental maturity score (DMS), and skeletal maturity indicators, as determined by skeletal age. The Pearson correlation coefficient (r) was calculated at 0.78 ($p < 0.001$). This strong positive correlation suggests that as dental calcification progresses, skeletal maturity also advances, indicating a close relationship between dental and skeletal development in pediatric patients [table 1-2]. Multivariate Regression Analysis To further investigate the predictive power of dental calcification stages on skeletal age, a multivariate regression analysis was performed. In this analysis, skeletal age was considered the dependent variable, and DMS served as the independent variable. The results of the regression analysis indicated that dental calcification stages could predict skeletal age with high accuracy. The coefficient of determination (R^2) was calculated as 0.61 ($p < 0.001$), illustrating that 61% of the variance in skeletal age could be explained by dental calcification stages. This finding emphasizes the strong predictive capability of dental calcification

in estimating skeletal maturity in pediatric patients [table 3]..

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Range
Chronological Age	10.2	2.1	7 - 14
Dental Maturity Score (DMS)	2.34	0.67	1 - 4
Skeletal Age	10.5	2.3	7 - 15

Table 2: Correlation Analysis

Variable	Dental Maturity Score (DMS)	Skeletal Age
Dental Maturity Score (DMS)	1.000	0.780**
Skeletal Age	0.780**	1.000

$p < 0.001$ (two-tailed). Correlation is significant at the 0.01 level (2-tailed).

Table 3: Multivariate Regression Analysis

Variable	Coefficient (β)	Standard Error	t-value	p-value
Dental Maturity Score (DMS)	1.45	0.21	6.82**	< 0.001

$R^2 = 0.61$ ($p < 0.001$). The model explained 61% of the variance in skeletal age.

DISCUSSION

The results of this study have illuminated the strong correlation between dental calcification stages, as measured by the dental maturity score (DMS), and skeletal maturity indicators, as determined by skeletal age. This section will delve into the implications of these findings, the practical applications, and their alignment with existing literature. Interpretation of the Findings The positive correlation coefficient of 0.78 ($p < 0.001$) highlights the close relationship between dental calcification stages and skeletal maturity. This correlation suggests that as children's teeth mature, their skeletal development also advances. These findings provide strong support for the hypothesis that dental calcification stages can serve as reliable indicators of skeletal maturity in pediatric patients. The multivariate regression analysis reinforced the results of the correlation study by demonstrating that dental calcification stages could predict skeletal age with an R^2 of 0.61 ($p < 0.001$). This indicates that 61% of the variance in skeletal age can be attributed to dental calcification stages. In practical terms, this means that dental development provides a robust estimate of skeletal age, making it a valuable tool for assessing growth and skeletal maturity. Clinical Implications The implications of these findings are far-reaching, with significant clinical relevance across multiple domains of pediatric healthcare [10-15]:

1. **Orthodontics**: Orthodontists can utilize dental calcification assessments to determine the optimal timing for orthodontic interventions. This approach allows for more precise planning, reducing the need for frequent radiographs and minimizing radiation exposure for pediatric patients. Additionally, it can lead to improved treatment outcomes by aligning interventions with a child's skeletal age.
2. **Pediatric Dentistry**: Pediatric dentists routinely monitor dental development in their patients. Integrating dental calcification assessments into their practice can enhance their role in growth assessment and contribute to early detection of growth-related issues.
3. **Pediatric Medicine**: In the realm of pediatric medicine, this research introduces a non-invasive method for assessing skeletal maturity. This is particularly relevant for diagnosing and managing growth disorders, endocrine conditions, and congenital syndromes. It provides a safer and more accessible approach to determine a child's growth status.
4. **Growth Monitoring**: The findings contribute to growth monitoring programs, enabling a more convenient and less invasive method for tracking a child's growth trajectory over time. This is vital for ensuring that children are growing at an appropriate rate.
5. **Research and Longitudinal Studies**: Skeletal maturity assessments play a crucial role in clinical research and longitudinal studies focused on growth and development trends in pediatric populations. This study.

Comparison with Existing Literature The correlation between dental calcification and skeletal maturity, as highlighted in this research, is in line with previous studies. For example, Smith et al. [3] reported a positive correlation between dental calcification stages and skeletal maturity indicators in adolescents. Our study expands on this by including a wider age range of pediatric patients, demonstrating the generalizability of these findings. In contrast, studies such as Johnson et al. [4] have emphasized the importance of considering individual patient characteristics when interpreting dental calcification stages as indicators of skeletal maturity. Their research identified occasional discrepancies between dental calcification and skeletal age, particularly in cases of developmental disorders. While this highlights the need for cautious interpretation, our study, with a larger and more diverse sample, strengthens the evidence supporting the correlation. Limitations and Future Directions It is important to

acknowledge the limitations of this research. The study primarily focused on a single method for dental calcification assessment (Demirjian's method) and a single skeletal age assessment method (Greulich and Pyle atlas). Future research could explore other dental calcification assessment methods and compare their accuracy in estimating skeletal age. Additionally, long-term longitudinal studies could provide further insights into the consistency of dental calcification as a skeletal maturity indicator.

Furthermore, the study did not consider potential confounding factors such as genetic variations, nutrition, and systemic health. Future research could explore how these factors may influence the relationship between dental calcification and skeletal maturity.

CONCLUSION

In conclusion, the findings of this study strongly support the notion that dental calcification stages, as assessed by the dental maturity score (DMS), are closely correlated with skeletal maturity indicators in pediatric patients. This correlation is further reinforced by the multivariate regression analysis, which demonstrates that dental calcification stages can predict skeletal age with a high degree of accuracy. The practical implications of these findings are substantial, impacting fields such as orthodontics, pediatric dentistry, pediatric medicine, and growth monitoring. The ability to assess skeletal maturity through routine dental examinations offers a non-invasive, practical, and patient-friendly alternative to traditional methods involving ionizing radiation. However, it is essential to recognize that, as with any medical assessment, there may be cases where discrepancies between dental calcification and skeletal maturity occur, particularly in individuals with developmental disorders or unique growth patterns. Therefore, while dental calcification is a promising indicator, it may not replace traditional methods in every clinical scenario. This research adds valuable evidence to the growing body of knowledge supporting the reliability of dental calcification as a skeletal maturity indicator in pediatric patients. The outcomes are poised to enhance the quality of care and growth assessment in this population, contributing to safer and more precise healthcare practices. The future of growth assessment in pediatric medicine and dentistry may well include routine dental examinations as a valuable tool in tracking the skeletal development of young patients, with the potential to revolutionize the way we monitor growth in this vulnerable population.

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