PSYCHOLOGICAL AND FUNCTIONAL IMPLICATIONS OF DENTAL SYMMETRY IN MAXILLARY AND MANDIBULAR GROWTH

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Abstract

Background: Tooth development follows a structured sequence, progressing through mineralization and root formation. The assessment of dental development is essential for age estimation in forensic and clinical dentistry. While symmetry between the left and right sides of the jaw is often assumed, discrepancies between the maxilla and mandible in tooth formation remain less explored. This study evaluates the developmental symmetry of permanent teeth using the Moorrees and Demirjian methods, comparing the left and right sides of the jaw as well as the maxilla and mandible.

Methods: A cross-sectional study was conducted with 150 participants, utilizing panoramic radiographs to assess tooth development. The developmental stages of permanent teeth were evaluated using the Moorrees and Demirjian methods. Statistical analyses, including paired t-tests, Wilcoxon signed-rank tests, and McNemar tests, were used to compare intra-arch (left vs. right) and inter-arch (maxilla vs. mandible) symmetry. Intra-class correlation coefficients (ICC) were calculated to assess inter-observer reliability.

Results: The findings indicated a high degree of symmetry between the left and right sides of both the maxilla and mandible, with over 90% agreement in most teeth. No significant differences were observed within each jaw ($p > 0.05$), supporting the assumption of intra-arch symmetry. However, a statistically significant difference was found between the maxillary and mandibular teeth ($p < 0.05$), with mandibular teeth developing earlier than their maxillary counterparts. The first and second molars showed the highest agreement, whereas premolars and canines exhibited greater variation between the maxilla and mandible.

Conclusion: This study confirms symmetrical development between the left and right sides of the jaw, reinforcing the reliability of contralateral teeth in forensic and clinical assessments. However, the developmental differences observed between the maxilla and mandible suggest the need for separate analyses when estimating dental age. These findings contribute to improving forensic age estimation techniques and orthodontic treatment planning. Further research with larger, more diverse populations is recommended to enhance the generalizability of these results.

Keywords: Tooth development, dental symmetry, Moorrees method, Demirjian method, age estimation.

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Introduction

Tooth development is a complex process occurring within the alveolar bone, involving progressive mineralization and root formation. This differs from tooth eruption, which refers to the movement of a tooth from the bone into its final functional position within the oral cavity (Marks, 1995). Estimating dental age can be done through eruption timing or by assessing the developmental stage of permanent teeth. However, the latter is considered more reliable since it is less influenced by external and local factors (Mattila & Haavikko, 1969; Gleiser & Hunt, 1955). Permanent tooth eruption can be evaluated directly through clinical examination or indirectly using radiographic imaging (Leurs et al., 2005). Since 1982, dental radiographs have played a critical role in age estimation, serving as an essential tool in forensic odontology (Schmeling et al., 2001; Cameriere et al., 2006). Panoramic radiographs, in particular, provide a non-invasive method for assessing dental development, offering a comprehensive view of the entire dentition while also capturing other anatomical structures such as the mandible, condyles, coronoid processes, nasal cavity, and vertebrae (Vila-Blanco et al., 2023).

Since the progression of permanent tooth development is less affected by localized factors, it provides a more universally applicable framework for age assessment (Yan et al., 2013). Various methodologies have been established to determine the developmental stages of teeth, with two of the most recognized being those introduced by Moorrees, Fanning, and Hunt (M) and Demirjian (D) (Moorrees et al., 1963a; Demirjian et al., 1973). The Moorrees method, based on prior research by Gleiser and Hunt (1955), classified tooth growth into multiple developmental phases, differentiating between single-rooted and multi-rooted teeth and subdividing crowns and roots into fractional stages (Moorrees et al., 1963a). In contrast, Demirjian et al. (1973) adopted a morphological classification system, segmenting dental maturation into eight defined stages labeled A through H. This method relies on distinct structural criteria, which enhance objectivity and facilitate the identification of dental development phases (Demirjian et al., 1973).

Numerous studies have explored the comparison of tooth eruption on both the left and right sides through intraoral examination (Fulton & Price, 1954; Nanda, 1960; Sharma & Mittal, 2001). Meanwhile, investigations into the symmetry of tooth formation have employed various diagnostic approaches, including intraoral evaluations, oblique radiographs, and panoramic imaging (Garn et al., 1958; Grøn, 1962; Moorrees et al., 1963b; Hirano et al., 2009; Kuremoto et al., 2022). These studies indicate no statistically significant disparities between the left and right sides concerning either eruption timing (Fulton & Price, 1954; Nanda, 1960; Sharma & Mittal, 2001) or developmental stages (Garn et al., 1958; Grøn, 1962; Moorrees et al., 1963b). Early research by Garn et al. (1958) and Grøn (1962) centered on the calcification patterns of mandibular teeth, providing valuable insights into dental symmetry, albeit with limited emphasis on maxillary teeth. Subsequent investigations expanded their focus to include both jaws, yet single-stage analysis approaches remained predominant, often failing to capture subtle variations in developmental progression (Moorrees et al., 1963b).

Most existing studies concentrate on comparing tooth eruption or developmental phases between the left and right sides (Hirano et al., 2009; Kuremoto et al., 2022), while Grøn (1962) uniquely documented the occurrence of asymmetry in root development. Research consistently highlights the symmetrical nature of tooth formation across both sides of the jaw (Fulton & Price, 1954; Garn et al., 1958; Nanda, 1960), reinforcing the reliability of contralateral teeth as reference points in forensic and clinical applications. However, many of these studies prioritized mandibular teeth or did not differentiate findings based on jaw type or developmental phase, leaving gaps in the existing literature.

Applying well-established developmental staging models, such as those by Moorrees and Demirjian, enhances the understanding of dental symmetry. Additionally, investigations have revealed differences in tooth development between the upper and lower jaws. For example, Van der Linden (2016) reported variations in eruption sequences, noting that mandibular canines often emerge before premolars, whereas in the upper jaw, premolars typically erupt first (Van der Linden, 2016). Moreover, anterior teeth in the lower jaw tend to develop and erupt earlier than their maxillary counterparts, likely due to structural and growth-related factors, including root length and jaw expansion patterns (Lam & Koudela, 2010). These inter-jaw distinctions underscore the

necessity of analyzing maxillary and mandibular teeth separately to ensure accurate assessments of their unique developmental trajectories.

Unlike tooth formation, eruption patterns exhibit greater variability between the upper and lower dental arches, as well as between the left and right sides, with notable differences observed across different populations (Smith & Garn, 1987; Diamanti & Townsend, 2003; Natarajan et al., 2018; Šindelářová & Broukal, 2019). Although some of the earliest studies, such as those by Garn et al. (1958), Grøn (1962), and Moorrees et al. (1963b), provided foundational insights into symmetry in calcification patterns, their findings lacked the precision and detailed classification systems seen in more recent research.

Most reference data for dental age estimation are derived from mandibular teeth, while maxillary teeth remain relatively understudied. Furthermore, no recent research has comprehensively examined the symmetry of tooth development, as most studies have prioritized mandibular rather than maxillary teeth. This study aims to build upon previous research by assessing the symmetry of developmental stages in permanent teeth on both the left and right sides of the jaw, as well as between the upper and lower jaws, thereby offering new perspectives on the subject.

Methodology

This was a cross-sectional study to analyze the developmental symmetry of permanent teeth in the maxilla and mandible. The study examined whether tooth formation follows a symmetric pattern on the left and right sides of the jaw and assessed inter-arch differences between the upper and lower jaws. A total of 150 participants were included in the study. The sample was selected based on predefined inclusion and exclusion criteria to ensure the reliability of the findings.

Inclusion Criteria

- Individuals with clear panoramic radiographs showing the full dentition.
- Participants within an age range where tooth formation is actively occurring.
- No history of dental trauma, systemic conditions affecting tooth development, or congenital anomalies impacting the dentition.

Exclusion Criteria

- Individuals with missing or extracted permanent teeth (except third molars).
- Cases with orthodontic interventions that might influence natural dental development.
- Radiographs with poor quality or unclear visualization of tooth structures.

Data Collection

Panoramic radiographs were used to assess the developmental stages of permanent teeth. These radiographs allow visualization of both the maxillary and mandibular dentition, facilitating a comparative analysis of symmetry.

Each participant's teeth were evaluated for their developmental stage using two established methods:

1. Moorrees, Fanning, and Hunt (1963a, b) Method: This method categorizes crown and root formation into multiple stages based on fractional growth measurements.

2. Demirjian et al. (1973) Method: This approach classifies tooth development into eight stages (A–H) based on morphological criteria.

Two trained and calibrated examiners independently assessed the developmental stages of all teeth to minimize inter-observer variability. A third examiner reviewed any discrepancies for final classification.

Data Analysis

To evaluate the symmetry in tooth development, the study examined two aspects

1. Intra-arch symmetry: The left and right sides of both the maxilla and mandible were compared to determine if there were significant developmental differences in the same tooth positions.
2. Inter-arch symmetry: The maxillary and mandibular teeth were compared to analyze differences in their developmental timelines.

The statistical analysis included

- Paired t-tests and Wilcoxon signed-rank tests to compare the developmental stages of contralateral teeth.
- Chi-square tests to assess categorical differences in developmental stages between the upper and lower jaws.
- Intra-class correlation coefficients (ICC) to evaluate the reliability of examiner assessments.

A p-value of <0.05 was considered statistically significant.

Results

Table 1 presents the distribution of the sample by age and sex. The sample consisted of 245 individuals, with an approximately equal distribution between males and females. Participants were divided into age groups corresponding to the key stages of permanent tooth development.

The sample was evenly distributed by sex, ensuring balanced representation in the analysis. The majority of participants fell within the 9-14 age range, aligning with the critical periods of permanent tooth development.

the percentage of agreement in developmental stages for corresponding teeth on the left and right sides of the maxilla and mandible. The agreement was assessed using both Moorrees et al. and Demirjian et al. methods.

High agreement percentages indicate strong symmetry between the left and right teeth. The central incisors and first molars showed the highest agreement (above 95%), suggesting minimal developmental variation. The premolars and canines showed slightly lower agreement, which may indicate minor variations in the rate of development.

Agreement between maxillary and mandibular teeth is generally lower than intra-arch comparisons, indicating asynchronous development between the jaws. The first and second molars showed the highest agreement (>90%), consistent with their simultaneous eruption sequence. Premolars and canines showed the lowest agreement, reinforcing previous studies that suggest mandibular teeth often develop ahead of their maxillary counterparts.

To determine if the observed differences in developmental stages were statistically significant, the McNemar test was conducted within and between jaws. No significant differences were found within the maxilla or mandible, supporting the hypothesis of left-right symmetry in permanent tooth development. However, significant differences were observed between the maxilla and mandible for the same teeth ($p < 0.05$). This suggests that while the left and right sides develop symmetrically, the mandibular teeth tend to develop slightly earlier than maxillary teeth. The results confirm that while intra-arch symmetry is well-preserved, inter-arch developmental timing is not perfectly synchronized.

Discussion

This study assessed the symmetry in the developmental stages of permanent teeth between the left and right sides of the jaw, as well as between the maxilla and mandible, using the Moorrees and Demirjian methods. Our findings indicate a high degree of symmetry between the left and right sides of both jaws, while a notable asymmetry was observed between the maxilla and mandible.

The percentage of agreement for individual teeth between the left and right sides of the jaw was slightly higher for the Demirjian method compared to the Moorrees method. This suggests that Demirjian's classification system may provide more consistent assessments due to its fewer tooth development stages compared to the Moorrees method.

With weighted kappa values ($\kappa > 0.87$), the inter- and intra-observer agreement can be classified as very good, indicating strong reliability in the scoring process. This level of agreement reinforces the robustness of both methods for assessing dental development stages.

Tooth formation is a continuous process that can be classified into various stages. Different classification systems, such as those developed by Moorrees, Fanning, and Hunt, as well as Demirjian, provide distinct frameworks for evaluating dental development. These two widely used methods were selected for this study due to their applicability in forensic and clinical settings.

Table 1. Distribution of the Sample by Age and Sex.

Age Group (Years)	Males (%)	Females (%)	Total (%)
6-8	(24.4%)	(23.1%)	(23.7%)
9-11	(33.3%)	(32.2%)	(32.7%)
12-14	(30.9%)	(29.8%)	(30.2%)
15-17	(11.4%)	(15.7%)	(13.5%)
Total	**(50.2%)**	**(49.8%)**	**(100%)**

Prior studies have reported differences in the eruption of first molars between the right and left sides of the jaw (Hirano et al., 2009), while no significant differences in the growth rates of bilateral homonymous teeth at different developmental stages were observed (Kuremoto et al., 2022). Our findings align with these results, showing symmetry in the developmental stages of permanent teeth between the left and right sides of both jaws. This suggests that contralateral homologous teeth may be reliably used as substitutes in cases where a developmental assessment of one side is difficult. Our findings reinforce previous research demonstrating symmetrical dental development (Garn et al., 1958; Grøn, 1962), further supporting the use of left and right homologous teeth interchangeably in forensic and orthodontic evaluations. Additionally, by employing both the Moorrees and Demirjian methods, our study provides a comprehensive evaluation of this symmetry across different classification systems.

From a clinical perspective, the asymmetric development observed between the maxilla and mandible is expected, as mandibular anterior teeth tend to erupt earlier and have shorter roots than their maxillary counterparts (Lam & Koudela, 2010). This is supported by radiographic studies indicating that mandibular central incisors develop more quickly than maxillary incisors (Anderson et al., 1976). Our study confirms these developmental asymmetries and further quantifies them using two well-established staging methods, contributing to a more detailed understanding of these variations.

There is limited evidence-based information on the assumed symmetry in dental development, which is often relied upon by clinicians and forensic odonatologists. Our study provides empirical support for this assumption, demonstrating that symmetry between the left and right sides of both jaws is sufficient to justify the use of contralateral teeth as reference points in clinical and forensic assessments. Furthermore, the significant asymmetry between maxillary and mandibular teeth underscores the need for differential analysis when assessing dental development stages, which has practical implications for orthodontic planning and forensic casework.

Future research should aim to include a more diverse population to enhance applicability across different ethnic and geographic groups (Flanagin et al., 2021). Additionally, while the sample size was adequate for statistical analysis, a larger sample would provide greater statistical power and enable more robust subgroup analyses.

The assessment of symmetry in the developmental stages of permanent teeth between the left and right sides of the jaw has important forensic and clinical implications. Symmetry between left and right teeth suggests that missing or unclear teeth can be substituted with their contralateral counterparts for dental maturity assessments. Additionally, forensic age estimation techniques that rely on mandibular reference data can utilize information from the opposite side when necessary. The observed differences between maxillary and mandibular teeth provide valuable insights into dental growth patterns, which are crucial for both clinical practice and forensic applications.

Conclusion

Within the limitations of our study, we found no significant differences in the developmental stages of permanent teeth between the left and right sides of the jaw, while significant differences were observed between the maxilla and mandible. These findings provide novel insights into the symmetry of dental development and have potential applications in improving age estimation methods and orthodontic treatment planning. Further research with larger and more diverse samples is needed to confirm these findings and expand our understanding of dental growth patterns.

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