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Genetic Choreography: Insights into the Complex Genetic Landscape of Children's Tooth Development

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Abstract

This concise overview distills key insights from recent research on the genetic factors influencing tooth development, encompassing primary tooth eruption to dental anomalies. A groundbreaking genome-wide association study identified significant genetic control over primary tooth eruption timing, revealing associations with craniofacial traits and genetic variants that influence eruption. The study delved beyond timing, exploring the links between delayed tooth eruption and genetic disorders, and offered foundational insights with potential implications for developmental delays. The objective is to provide a comprehensive understanding of the complex genetic framework that guides tooth development and its possible implications for future clinical applications and advancements in oral healthcare. In children, tooth development involves intricate cellular and molecular processes, including epithelial mesenchymal interactions. Signaling pathways play a crucial role in children's tooth development, with genes associated with early positioning being integral components. Moreover, dental anomaly development is influenced by genetic, epigenetic, and environmental factors, causing disruptions that lead to structural variations impacting both oral health aesthetics and functionality. The time of primary tooth eruption and the formation of dental structures are all controlled by genes. Genes affect tooth eruption timing, tooth development signaling pathways, ethnicity, and genetic variations on dental outcomes.

Keywords: Genetic control; Primary tooth eruption; Genetic variants; Successional tooth formation; Gene expression analysis; Tooth morphogenesis; Dental anomalies

1 Introduction

This article review provides a glimpse into recent research on the genetic determinants of tooth development, spanning from the emergence of primary teeth to the study of dental anomalies. Notably, a groundbreaking genome-wide association study has shed light on the substantial genetic influence governing the timing of primary tooth eruption. This research has unveiled compelling associations between primary tooth eruption timing and craniofacial traits, as well as specific genetic variants that play a crucial role in influencing the eruption process. Moving beyond mere timing considerations, the study has delved into the intricate connections between delayed tooth eruption and various genetic disorders. These findings not only contribute to our understanding of tooth development but also lay the groundwork for potential implications in addressing developmental delays.

In essence, the research signifies a significant step forward in unravelling the intricate interplay between genetics and tooth development. By identifying key genetic factors influencing primary tooth eruption and exploring their broader connections to craniofacial traits and disorders, the study provides a comprehensive perspective. The implications extend beyond dental insights, offering valuable information that may contribute to the understanding and potential

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management of developmental delays associated with genetic variations. This holistic approach to studying tooth development underscores the broader significance of genetic research in the realm of human health and developmental biology.

1.1 Aims

The text aims to highlight the intricate genetic control of tooth development in children, primary tooth eruption timing, uncovering associations with craniofacial traits and genetic variants. It delves into the links between delayed tooth eruption and genetic disorders, offering foundational insights for addressing developmental delays.

2 Material and methods

The research method used in this article is a literature review. Relevant scientific articles discussing the genetic aspects of children's tooth development, including primary tooth eruption, genetic signaling pathways, and dental anomalies, were collected from reputable national and international journals. The selected studies were analyzed qualitatively by examining research findings related to genetic, epigenetic, and environmental factors involved in odontogenesis. The analyzed data were then synthesized to provide a comprehensive overview of the complex genetic mechanisms regulating tooth development in children and their implications for oral health.

3 Results and discussion

Primary tooth eruption is a complex and highly regulated process [1]. Research has highlighted the significance of major signaling pathways, such as the bone morphogenetic protein (BMP)/TGFβ, Wnt, and Shh pathways, in the genetic regulation of tooth development [2]. Disruption of genes involved in these pathways has been shown to result in severe aberrations of tooth development, including complete tooth agenesis or arrest of tooth development at early stages. Results from both ALSPAC and NFBC1966 were combined and showed that there is a genetic influence on the timing and reasons for delayed primary tooth eruption, as well as other craniofacial characteristics. This statement is reinforced by research conducted by Siew-Ging Gong, et al. [3] Siew Ging Gong, et al., which identified the key genes involved in tooth formation by gene expression analysis and various techniques. Moreover, genome-wide association studies have been conducted to identify genetic determinants of dental maturation in children, providing insights into the polygenic architecture of pediatric dental development [4]. These studies have highlighted the complex interplay of genetic and environmental factors in regulating dental maturation, tooth calcification, and eruption.

In humans, the development of teeth involves several distinctive cellular and molecular interaction processes [5] Puthiyaveetil, et al., [6] explain that the completion of epithelial-mesenchymal interactions and transition brings about varied changes in tooth development. The behavior of another cell or an autocrine effect would be initiated by one cell through the signaling of growth factor molecules. Homeobox genes have been identified as direct genetic regulators of odontogenesis, determining the position, number, size, and shape of teeth [7]. These genes exert control during different stages of tooth development, influencing processes such as cytodifferentiation, enamel and dentin formation, and the sequential determination of tooth type and size.

The research findings pertaining to signaling pathways in the development of children's teeth are expansive and encompass a variety of genetic and molecular aspects [8]. Numerous genes associated with the early positioning and development of teeth are integral components of signaling pathways, playing regulatory roles in morphogenesis. Notably, the Wnt signaling pathway emerges as a pivotal player in tooth development, embryogenesis, tissue homeostasis, and wound repair. Additionally, the TGF-β and BMP signaling pathways have been identified as crucial factors in the formation of tooth roots. Additionally, genetic factors are associated with dental caries and periodontal disease in children, highlighting the influence of genetics on oral health. [9]

Furthermore, investigations have demonstrated a significant correlation between the genetic anomaly known as short root anomaly (SRA) and specific signaling pathways. This underscores the paramount importance of these pathways in the intricate process of root development. Ongoing research initiatives, such as the NIH-funded investigation led by Huojun Cao and Eric Van Otterloo, are dedicated to unravelling the precise relationships between genetic redundancies and their governance of the intricate processes involved in tooth development. The anticipated outcomes of this research are poised to bring about substantial advancements in the understanding of tooth development. Moreover, the findings may serve as a cornerstone for potential applications in clinical practice. By elucidating the intricate interplay of genetic factors within signaling pathways, this ongoing research has the potential to pave the way for innovative approaches and interventions in the realm of dental care.

3 factors play a crucial role in the development of dental anomalies: genetic, epigenetic, and environmental. Putri, et al., [10] confirmed that genetic factors significantly influence tooth development in children in Indonesia. Dental anomalies often result from disturbances in tooth development caused by various etiological factors. Genetic mechanisms contribute to the likelihood of an individual inheriting a specific tooth pattern observed in parents or siblings, including gender differences. Epigenetic mechanisms, on the other hand, involve environmental factors such as chemicals, pharmaceuticals, aging, and dietary intake, all of which contribute to the formation of a unique tooth pattern. The repeated signaling molecules received by protein receptors and induced by transcription factors during the interaction between epithelial and mesenchymal tissues in different stages of tooth development play a crucial role in the continued transcription process, leading to tooth anomalies.

Tooth developmental anomalies encompass deviations in the size, shape, number, quality, or quantity of tooth structure, leading to alterations in dentitions. The intricate process of normal tooth development involves the engagement of multiple genes. However, disruptions in this intricate process can occur due to the complex interplay of genetic, epigenetic, and environmental factors, ultimately leading to the manifestation of dental anomalies. The consequences of these anomalies extend beyond mere structural variations, impacting the overall harmony and functionality of the dentition, thereby posing challenges that span both the functional and aesthetic aspects of oral health. Understanding the multifaceted nature of these factors is pivotal for addressing and managing dental anomalies comprehensively.

The occurrence of dental anomalies, such as microdontia, macrodontia, hypodontia, and developmental defects of enamel, among a group of children with growth hormone deficiency (GHD) [11]. The study has successfully established a notable association between GHD and dental anomalies concerning both the number and size of teeth. The research was conducted with a representative sample size comprising 101 Caucasian children, including 33 diagnosed with GHD and 68 healthy, normal-height subjects. Results from the study revealed a significantly higher occurrence of dental anomalies among children with GHD compared to their healthy counterparts, suggesting a potential correlation between growth hormone deficiency and disturbances in dental development. This discovery underscores the significance of delving into the genetic foundations of tooth development and its possible implications for comprehending and addressing dental abnormalities and diseases. Understanding the interplay between growth hormone deficiency and dental anomalies contributes valuable insights for both the medical and dental fields. Studies have also focused on genetic causes of abnormal tooth development and their implications for clinical care. Genetic tooth anomalies, including those related to the number and shape of teeth, have been a subject of investigation to improve diagnostic and treatment strategies for patients with dental issues. [12] [13].

Table 1 Extraction Data

Author	Year	Research Results
Fatemifar, G., et al.	2013	A genome-wide association study demonstrated a strong genetic influence on the timing of primary tooth eruption. Several genetic variants were identified as being associated with eruption timing and craniofacial characteristics. The study also revealed links between delayed tooth eruption and genetic disorders, providing important insights into developmental delays and genetic regulation of tooth eruption[1].
Siew-Ging Gong, C., et al.	2014	This study investigated the genetic regulation of human tooth development by analysing the expression of candidate regulatory genes, including the fibroblast growth factor (FGF) family. The findings identified key genes involved in successional tooth formation and clarified molecular mechanisms underlying tooth morphogenesis in human embryos [3]
Puthiyaveetil, J. S. V., et al.	2016	Epithelial–mesenchymal interactions were shown to be fundamental to children's tooth development. Reciprocal signaling between oral ectoderm and mesenchymal tissues guides tooth crown formation, with enamel and dentin originating from distinct tissues and meeting at the dentin-enamel junction, ensuring proper tooth morphogenesis [6].
Wang, J., & Feng, J. Q.	2017	The study highlighted the critical role of genetic signaling pathways in tooth development. Wnt signaling was identified as essential for tooth development and embryogenesis, while TGF-β and BMP pathways were crucial for tooth root formation. Associations between short root anomaly (SRA) and specific signaling pathways were also reported, emphasizing their regulatory importance [8].

Putri, A. S., et al.	2022	Genetic factors were found to strongly influence tooth development in Indonesian children, exceeding environmental influences. Ethnicity contributed to variations in dental development timing and rates. Several genetic variants were associated with delayed tooth eruption and increased orthodontic treatment needs, highlighting population-specific genetic effects [10].
Hendrik, Y. C., Langit, K. S., & Auerkari, E. I.	2022	Tooth development was shown to be regulated by genetic, epigenetic, and environmental factors. More than 300 genes were identified as contributors to odontogenesis, interacting through signaling molecules. Mutations in key genes such as *MSX1*, *PAX9*, *AXIN2*, and *EDA* were associated with dental anomalies [14].
Khan, M. I., et al.	2022	Dental developmental anomalies affecting tooth size, shape, number, and structure were linked to disruptions in normal genetic regulation. The study emphasized that interactions among genetic, epigenetic, and environmental factors play a central role in causing dental disharmony with functional and aesthetic consequences.[5]
Chen, S., et al.	2022	The study identified genes involved in early tooth development, including those encoding signaling molecules, receptors, and transcription factors. Comparative transcriptomic analyses revealed that core developmental genes and their expression patterns are highly conserved across vertebrates, underscoring their evolutionary and developmental importance.[15]
Torlińska-Walkowiak, N., et al.	2023	This study reported a significantly higher prevalence of dental anomalies, including microdontia, macrodontia, hypodontia, and enamel defects, among children with growth hormone deficiency (GHD). Based on a sample of 101 children, the findings indicated a strong association between GHD and disturbances in tooth number and size, highlighting systemic genetic influences on dental development.[11]

4 Conclusion

The collective findings from studies on early tooth developmental genetics in children highlight the crucial roles of genetic, epigenetic, and environmental factors in shaping dental outcomes. Genome-wide association studies demonstrate a strong genetic influence on the timing of primary tooth eruption, providing valuable insights into developmental delays and their potential associations with craniofacial characteristics. In addition, investigations into gene expression, signaling pathways, and molecular mechanisms offer a comprehensive understanding of the complex processes involved in tooth morphogenesis.

The coordinated interactions between epithelial and mesenchymal tissues regulate the progressive development of tooth crowns, emphasizing the importance of cellular communication in normal odontogenesis. Key signaling pathways, including Wnt, TGF-β, and BMP, play essential roles in tooth development by influencing embryogenesis, tissue homeostasis, and root formation. Furthermore, ethnicity and genetic variation contribute to diverse patterns of dental development across populations. Dental anomalies such as microdontia, macrodontia, and hypodontia are closely associated with genetic factors and reflect the intricate interplay of genetic, epigenetic, and environmental influences. Growth hormone deficiency (GHD) is also linked to an increased prevalence of dental anomalies, underscoring the systemic impact of genetic factors on tooth development. These findings collectively provide a strong foundation for understanding the genetic regulation of children's tooth development and its implications for preventing and managing dental abnormalities and diseases.

Compliance with ethical standards

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Disclosure of Conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study

References

[1] Fatemifar, G., Hoggart, C. J., Paternoster, L., Kemp, J. P., Prokopenko, I., Horikoshi, M., ... & Evans, D. M. (2013). Genome- wide association study of primary tooth eruption identifies pleiotropic loci associated with height and craniofacial distances. *Human Molecular Genetics*, *22*(18), 3807-3817.

[2] Thesleff, I. (2015). Molecular genetics of tooth development. In *Principles of developmental genetics* (pp. 393-405). Academic Press.

[3] Siew-Ging Gong, & Claudio Cantù. (2014). Expression analysis of candidate genes regulating successional tooth formation in the human embryo. Frontiers in Physiology, 5, 445. https://doi.org/10.3389/fphys.201 4.00445

[4] Grgic, O., Prijatelj, V., Dudakovic, A., Vucic, S., Dhamo, B., Trajanoska, K., ... & Wolvius, E. B. (2023). Novel genetic determinants of dental maturation in children. Journal of Dental Research,

[5] Khan, M. I., Ahmed, N., Neela, P. K., & Unnisa, N. (2022). The human genetics of dental anomalies. Global Medical Genetics, 9(02), 076-081.

[6] Puthiyaveetil, J. S. V., Kota, K., Chakkarayan, R., Chakkarayan, J., & Thodiyil, A. K. P. (2016). Epithelial–Mesenchymal interactions in tooth development and the significant role of growth factors and genes with emphasis on mesenchyme–A review. Journal of clinical and diagnostic research: JCDR, 10(9), ZE05.

[7] Suryadeva, S., & Khan, M. B. (2015). Role of homeobox genes in tooth morphogenesis: a review. Journal of clinical and diagnostic research: JCDR, 9(2), ZE09.

[8] Wang, J., & Feng, J. Q. (2017). Signaling pathways critical for tooth root formation. Journal of Dental Research, 96(11), 1221-1228.

[9] Wang, X., Willing, M. C., Marazita, M. L., Wendell, S., Warren, J. J., Broffitt, B., ... & Levy, S. M. (2012). Genetic and environmental factors associated with dental caries in children: the Iowa Fluoride Study. Caries research, 46(3), 177-184.

[10] Putri, A. S., Soedarsono, N., Nehemia, B., Atmadja, D. S., & Ubelaker, D. H. (2022). Age estimation of individuals aged 5– 23 years based on dental development of the Indonesian population. Forensic Sciences Research, 7(2), 115-123.

[11] Torlińska-Walkowiak, N., Majewska, K. A., Sowińska, A., Kędzia, A., & Opydo-Szymaczek, J. (2023). Developmental enamel defects and dental anomalies of number and size in children with 16. 102(3), 349-356. growth hormone deficiency. Scientific Reports, 13(1), 14707.

[12] Klein, O. D., Oberoi, S., Huysseune, A., Hovorakova, M., Peterka, M., & Peterkova, R. (2013, November). Developmental disorders of the dentition: an update. In American Journal of Medical Genetics Part C: Seminars in Medical Genetics (Vol. 163, No. 4, pp.318-332).

[13] Harvati, K. (2020). Dental student creates coronavirus e-book for children. British Dental Journal, 228(9), 665.

[14] Hendrik, Y. C., Langit, K. S., & Auerkari, E. I. (2021, July). The Genetic, Epigenetic, and Environmental Factors of Dental Abnormalities Development: Literature Review. In Journal of Physics: Conference Series (Vol. 1943, No. 1, p. 012084). IOP Publishing.

[15] Chen, S., Xie, H., Zhao, S., Wang,S., Wei, X., & Liu, S. (2022). The genes involved in dentinogenesis. Organogenesis, 18(1), 2022373.