Correlation of Molecular Patterns and Spatial Eruption Dynamics of Canines in Tamil Paediatric Population

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**Abstract:** The spatial orientation of canines during eruption is affected by numerous genetic and environmental factors. Adjacent teeth, especially the lateral incisors, play a crucial role in guiding this process.[(Litsas & Acar, 2011)](https://paperpile.com/c/EsXIQM/5YAie) Any anomalies in the development or positioning of lateral incisors can disrupt the normal eruption path of canines. For example, the absence or malformation of lateral incisors may not provide the necessary guidance, resulting in ectopic eruption or impaction of canines.[(Becker et al., 1981)](https://paperpile.com/c/EsXIQM/3rzo9)Additionally, the shape of the alveolar bone and the available space within the dental arch are significant factors influencing eruption patterns.[(Jonasson et al., 2018)](https://paperpile.com/c/EsXIQM/hqaAh)While eruption patterns have been extensively studied in Western populations, there is limited research on Tamilian pediatric patients. Regional differences in eruption timing, jaw structure, and genetic predisposition require population-specific studies to improve clinical decision-making. [(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/EsXIQM/IG6jU+JV4I8+lWSZf), [(Merchant et al., 2022; Pandiyan et al., 2022)](https://paperpile.com/c/EsXIQM/Wa8i9+zKQGz), [(Chokkattu et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/EsXIQM/1ehdO+CImcc) Variations in dietary habits, such as consuming fibrous foods that promote jaw development, may also affect eruption sequences.[(Proffit et al., 2019)](https://paperpile.com/c/EsXIQM/MHZs3) In addition to spatial and structural determinants, tooth eruption is regulated by molecular signals originating from the dental follicle. Genetic factors such as mutations in MSX1, PAX9, and RUNX2 have been implicated in altered eruption timing and anomalies.[(Marya et al., 2022)](https://paperpile.com/c/EsXIQM/7iXKd), [(Jain & Verma, 2022; Marya et al., 2022)](https://paperpile.com/c/EsXIQM/7iXKd+1pJ7b), [(Wadhwani et al., 2022)](https://paperpile.com/c/EsXIQM/o5oH5)

**Keywords:** Spatial Orientation & Eruption Patterns, Common Eruption Anomalies, Impact of Arch Space and Skeletal Structure on Canine Eruption

# Introduction

## Correlation of Molecular Patterns and Spatial Eruption Dynamics of Canines in Tamil Paediatric Population

​Cuspids, or canine teeth, are crucial for both the functional and aesthetic aspects of the dental arch. Positioned strategically in the upper (maxilla) and lower (mandible) jaws, they are vital for chewing, maintaining the stability of the arch, and ensuring correct occlusal relationships.The eruption of canines is a complex developmental process, marked by their distinct spatial orientation and extended eruption path. Unlike incisors and premolars, canines develop closer to the jaw's basal region, which results in a delayed eruption timeline.[(Becker & Chaushu, 2015)](https://paperpile.com/c/EsXIQM/xBHHK)This extended path can encounter various obstacles, such as limited space, dental crowding, and primary teeth anomalies, potentially leading to issues like impaction, ectopic eruption, transposition, transmigration, or agenesis.[(Ericson & Kurol, 1988)](https://paperpile.com/c/EsXIQM/38ucI)The spatial orientation of canines during eruption is affected by numerous genetic and environmental factors. Adjacent teeth, especially the lateral incisors, play a crucial role in guiding this process.[(Litsas & Acar, 2011)](https://paperpile.com/c/EsXIQM/5YAie) Any anomalies in the development or positioning of lateral incisors can disrupt the normal eruption path of canines. For example, the absence or malformation of lateral incisors may not provide the necessary guidance, resulting in ectopic eruption or impaction of canines.[(Becker et al., 1981)](https://paperpile.com/c/EsXIQM/3rzo9)Additionally, the shape of the alveolar bone and the available space within the dental arch are significant factors influencing eruption patterns.[(Jonasson et al., 2018)](https://paperpile.com/c/EsXIQM/hqaAh)While eruption patterns have been extensively studied in Western populations, there is limited research on Tamilian pediatric patients. Regional differences in eruption timing, jaw structure, and genetic predisposition require population-specific studies to improve clinical decision-making. [(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/EsXIQM/IG6jU+JV4I8+lWSZf), [(Merchant et al., 2022; Pandiyan et al., 2022)](https://paperpile.com/c/EsXIQM/Wa8i9+zKQGz), [(Chokkattu et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/EsXIQM/1ehdO+CImcc) Variations in dietary habits, such as consuming fibrous foods that promote jaw development, may also affect eruption sequences.[(Proffit et al., 2019)](https://paperpile.com/c/EsXIQM/MHZs3) In addition to spatial and structural determinants, tooth eruption is regulated by molecular signals originating from the dental follicle. Genetic factors such as mutations in MSX1, PAX9, and RUNX2 have been implicated in altered eruption timing and anomalies.[(Marya et al., 2022)](https://paperpile.com/c/EsXIQM/7iXKd), [(Jain & Verma, 2022; Marya et al., 2022)](https://paperpile.com/c/EsXIQM/7iXKd+1pJ7b), [(Wadhwani et al., 2022)](https://paperpile.com/c/EsXIQM/o5oH5)Unlike other teeth, canines follow a prolonged and spatially complex eruption path due to their initial position near the basal jaw. This makes them more susceptible to anomalies, including impaction and transposition. The clinical challenge lies in predicting these deviations early, especially within region-specific populations such as Tamilian pediatric patients, where skeletal patterns and dietary habits may influence eruption trajectories. [(Adel et al., 2023)](https://paperpile.com/c/EsXIQM/0prLk), [(Subramanian & Harikrishnan, 2023)](https://paperpile.com/c/EsXIQM/Wvgac), [(Solanki et al., 2023)](https://paperpile.com/c/EsXIQM/yxrxo) This perspective explores the spatial orientation and anomalies of canine eruption with a focus on their diagnostic and therapeutic relevance in this ethnic group.

## Spatial Orientation & Eruption Patterns

Maxillary canines have one of the longest and most intricate eruption paths among all permanent teeth. They develop deep within the alveolar bone, near the floor of the nasal cavity, and must undergo significant vertical and horizontal movement to reach their final position in the dental arch. During the mixed dentition phase, maxillary canines initially lie mesial and superior to the developing premolars and later move downward, rotating and shifting buccally or palatally to achieve proper occlusion. The eruption sequence of maxillary canines is typically guided by the lateral incisors and first premolars. However, any disruption in this sequence can lead to ectopic eruption, impaction, or even transposition with adjacent teeth.[(Aslan & Üçüncü, 2015)](https://paperpile.com/c/EsXIQM/9Yt9i)Several factors can contribute to disturbances in maxillary canine eruption, making them one of the most commonly impacted teeth after third molars. Some of these factors include: Arch Length Discrepancy: A lack of space within the maxillary arch can prevent the canine from erupting normally, leading to displacement or impaction..[(Litsas & Acar, 2011)](https://paperpile.com/c/EsXIQM/5YAie) Genetic Predisposition: Research indicates that the impaction of maxillary canines frequently occurs within families, implying a genetic influence on tooth dimensions, arch configuration, and eruption timing. Delayed Resorption of Deciduous Canines: Prolonged retention of primary canines can cause permanent canines to deviate from their intended eruption path.[(Manne et al., 2012)](https://paperpile.com/c/EsXIQM/ZpVmT)Abnormal Eruption Angulation: Typically, maxillary canines emerge at an angle of about 11° to 18° relative to the midline. Angles outside this range may heighten the likelihood of impaction. Local Obstructions: The presence of extra teeth, odontomas, or cystic formations can obstruct the normal eruption route of maxillary canines.[(Power & Short, 1993)](https://paperpile.com/c/EsXIQM/KCEaw)Maxillary canine impaction affects 2% of the population, with a higher prevalence in females due to delayed skeletal development.Since palatal impactions are more common than buccal ones, accurate localization and treatment planning require advanced 3D imaging techniques like Cone Beam Computed Tomography (CBCT).[(Shah\* et al., 2024)](https://paperpile.com/c/EsXIQM/f99B0)Mandibular canines have a more straightforward eruption path compared to maxillary canines. They form slightly ahead of their final position, gradually ascending into the dental arch. However, their eruption can be affected by various skeletal and dental factors. Mandibular canines typically erupt at ages 9-10 in females and 10-11 in males, following a more predictable sequence than maxillary canines.[(Agastra et al., 2023)](https://paperpile.com/c/EsXIQM/iqXMF)They play a vital role in maintaining lower anterior alignment, significantly contributing to occlusal stability and arch integrity.Despite their more predictable eruption pattern, mandibular canines can still experience positional anomalies. Influencing factors include: Premature Loss of Deciduous Canines: Early loss of primary canines can cause mesial drift of incisors, reducing space for permanent canines.[(Martins-Júnior & Marques, 2012)](https://paperpile.com/c/EsXIQM/Nhk5t)Mandibular Growth Variability: Different mandibular growth patterns can affect the timing and angulation of canine eruption, especially in Class II and Class III skeletal patterns.[(Björk & Skieller, 1977)](https://paperpile.com/c/EsXIQM/aqWS8)Crowding & Space Deficiency: Discrepancies in arch length in the lower jaw may lead to lingual displacement of canines, often resulting in a “double row” appearance. Periodontal Factors: Due to their location in dense cortical bone, mandibular canines are at a higher risk of gingival recession if they erupt outside the alveolar ridge. Pathological Barriers: Although rare, cysts, odontomas, or dense bone trabeculation can hinder mandibular canine eruption.[(Proffit et al., 2019)](https://paperpile.com/c/EsXIQM/MHZs3)Research found that disturbances in mandibular canine eruption are less common than maxillary canine anomalies, but when they occur, they often result in severe crowding and malocclusion. Lingual displacement of mandibular canines is frequently observed, necessitating careful intervention to avoid undesirable aesthetic and functional outcomes.

## Common Eruption Anomalies

Canine eruption anomalies, such as impaction, transposition, transmigration, and agenesis, pose significant clinical challenges that require early diagnosis and strategic intervention. Impaction, particularly in maxillary canines, is influenced by arch length discrepancies, genetic predisposition, and ectopic eruption paths, often requiring surgical exposure and orthodontic traction.[(Bharathi et al., 2022)](https://paperpile.com/c/EsXIQM/cAwgC) An impacted canine on the palate illustrated the success of CBCT-guided diagnosis combined with TAD-supported traction, achieving proper alignment without damaging periodontal tissues. Transposition, a rare dental anomaly where canines switch places with adjacent teeth, necessitates careful biomechanical planning to prevent root resorption and periodontal complications.[(Mavani et al., 2022)](https://paperpile.com/c/EsXIQM/YO16B) A canine-premolar transposition experienced positive outcomes from TAD-assisted distalization and selective reshaping, resulting in an aesthetically pleasing and functional bite [(Wasserstein et al., 1997)](https://paperpile.com/c/EsXIQM/X7y2G). Transmigration, which primarily affects mandibular canines, involves abnormal movement across the midline and often requires extraction if the misalignment is severe. Predictive indicators, such as a crown inclination greater than 25°, can help identify cases that may benefit from early surgical reorientation [(Joshi, 2001)](https://paperpile.com/c/EsXIQM/gNs7P)[(Javid, 1985)](https://paperpile.com/c/EsXIQM/9oGqD). Canine agenesis, although rare, disrupts occlusal stability and aesthetics, necessitating orthodontic space closure, prosthetic replacement, or reshaping of adjacent teeth. [(Polder et al., 2004)](https://paperpile.com/c/EsXIQM/KL2N5) Bilateral canine agenesis was treated using space closure, composite build-ups, and veneers to produce the best outcomes. Advanced imaging techniques, such CBCT, are critical for accurate diagnosis, while personalised treatment strategies incorporating orthodontic, surgical, and prosthetic procedures help optimise patient results, preventing malocclusion and functional problems. [(Kapila & Nervina, 2015; Polder et al., 2004)](https://paperpile.com/c/EsXIQM/KL2N5+mR2Dw)

## Impact of Arch Space and Skeletal Structure on Canine Eruption

A significant observation was the strong correlation between available arch space and canine eruption patterns. When the dental arch lacked sufficient space, canines tended to erupt at a steeper angle, increasing the risk of impaction. This was particularly evident in maxillary canines, where crowding often led to palatal displacement. These findings emphasize the importance of early space management strategies, such as guided expansion or selective extractions, to create a more favorable eruption path .[(Becker & Chaushu, 2015)](https://paperpile.com/c/EsXIQM/xBHHK) Skeletal structure also played a crucial role. Patients with Class II skeletal patterns—characterized by a smaller or retruded upper jaw—were more likely to have palatally displaced canines. This suggests that jaw position influences canine eruption, which could guide orthodontists in identifying high-risk patients early. Conversely, patients with Class III skeletal patterns (more prominent lower jaws) generally had better eruption angles, possibly due to a more spacious maxilla[(Di Carlo et al., 2019)](https://paperpile.com/c/EsXIQM/z8c1w)

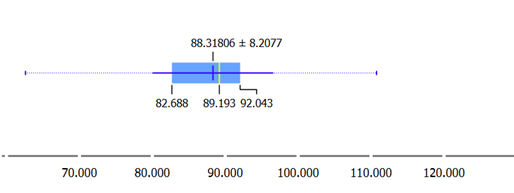
## Study Population & Methodology

The study focused on 50 paediatric patients of Tamilian descent aged 5 to 13 years. Before beginning the investigation, ethical permission was sought and granted. Furthermore, informed consent was obtained from the guardians of the participating children, ensuring that all ethical concerns were addressed. Canine abnormalities and their spatial location within the maxilla and mandible were investigated using radiographic evaluation techniques, which included the use of panoramic radiographs (OPGs). Several criteria were rigorously examined during this examination. Canines that had not erupted by the expected age were classified as affected, while any canines spotted crossing the midline were reported as examples of transmigration. The study also analyzed transposition, which refers to the relative positioning of canines in relation to adjacent teeth. Additionally, the absence of canine tooth germs on radiographs was recorded as agenesis, and cases of ectopic eruption were noted by tracking deviations in the normal eruption path along with the necessary angular measurements. Canine positioning was further evaluated through several key metrics. The angulation of the canines was measured, specifically determining the angle formed between the long axis of the canine and the occlusal plane. Furthermore, the vertical position of each canine was assessed by measuring the distance from the cusp tip to the occlusal plane. The study also included an evaluation of the extent to which the canine teeth overlapped with neighboring teeth, providing insights into their spatial relationships within the dental arch [(Alqerban et al., 2011)](https://paperpile.com/c/EsXIQM/tZf3A)

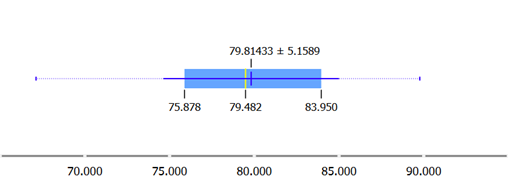
## Eruption Angle Analysis & Key Findings

The study revealed significant variability in the eruption angles of maxillary and mandibular canines. Maxillary canines displayed a broader range of angles, spanning from 62.61° to 110.75°, with an average angle of 88.32° (SD: 8.29°). In contrast, mandibular canines demonstrated less variability, ranging from 67.12° to 89.77°, and presenting a mean angle of 79.81° (SD: 5.21°). Figure 1& 2, Table 1. The analysis further uncovered a complex distribution of maxillary canine angles, as evidenced by the multiple peaks in both boxplots and violin plots. Figure 3 & 4 Scatter plot shows the relationship between mandibular and maxillary canine for each individual(Nikalje et al., 2024) (Chehelgerdi et al., 2023). The red dashed line represents where the measurements would be equal. Most points fall above this line, indicating that maxillary canines are typically larger than mandibular canines for the same individual. Figure 5 Additionally, a weak positive correlation of 0.278 between the eruption angles of maxillary and mandibular canines indicated that their eruption dynamics are influenced by genetic and environmental factors independently.The variability in eruption angles of maxillary canines observed in this study aligns with existing literature. Research indicates that maxillary canines often exhibit significant mesial inclination during eruption, reaching a peak around 9 years of age before adjusting to a more vertical position as they emerge into the oral cavity. This mesial inclination is considered a normal developmental pattern, facilitating the canine's navigation through the alveolar bone to its final position in the dental arch [(Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv) In contrast, mandibular canines demonstrate less variability in their eruption angles. Studies suggest that the eruption path of mandibular canines is more linear, with fewer deviations compared to their maxillary counterparts. This consistent trajectory may contribute to the lower incidence of impaction observed in mandibular canines. [(Camilleri & Scerri, 2003; Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv+L3xCc)The weak positive correlation between the eruption angles of maxillary and mandibular canines suggests that while both sets of canines undergo complex eruption processes, they are influenced by distinct genetic and environmental factors. This independence is further supported by studies indicating that ectopic eruption of maxillary canines does not necessarily predict similar patterns in mandibular canines, emphasizing the need for individualized assessment in orthodontic diagnosis and treatment planning.[(Batwa & Alzain, 2018; Camilleri & Scerri, 2003; Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv+L3xCc+pXATk)

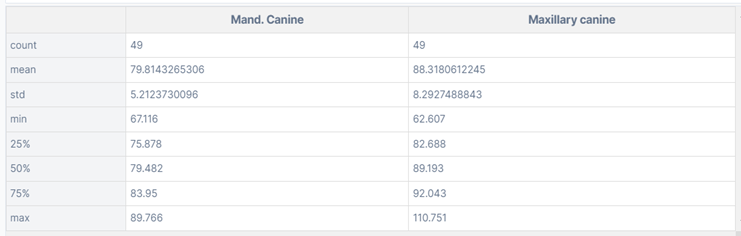
**Figure 1:** Maxillary Canine Eruption Angle Mean and SD



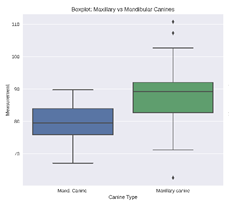
**Figure 2:** Mandibular Canine Eruption Angle Means and SD



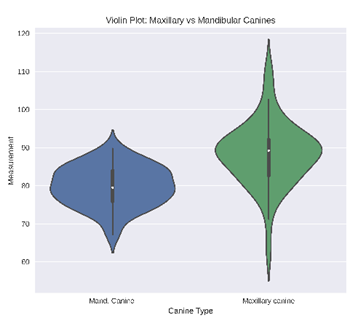
**Table 1:** Mandibular & Maxillary Canine Eruption Angle Means and SD



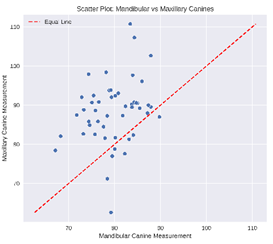
**Figure 3:** Box Plot Analysis: Maxillary vs. Mandibular Canines



**Figure 4:** Violin Plot Mandibular vs. Maxillary Canines



**Figure 5:** Scatter Plot Mandibular vs. Maxillary Canines



## Molecular and Genetic Correlation with Spatial Eruption Dynamics

In addition to spatial and skeletal factors, molecular mechanisms are pivotal in the regulation of tooth eruption. The eruption of canines is orchestrated by a series of molecular signals emanating from the dental follicle, which influence osteoclast recruitment, bone remodeling, and root formation, thereby facilitating the tooth's emergence through the alveolar bone [(Marks & Schroeder, 1996)](https://paperpile.com/c/EsXIQM/OZCMg) Key molecules involved in this process include Parathyroid Hormone-related Protein (PTHrP), which promotes alveolar bone resorption, as well as Sonic Hedgehog (SHH) and Bone Morphogenetic Proteins (BMPs), which govern the growth and guidance of erupting teeth .[(Wise et al., 2002)](https://paperpile.com/c/EsXIQM/UBKWC) The transcription factor RUNX2, crucial for osteoblast differentiation, also significantly influences the timing of eruption. Genetic variants in MSX1, PAX9, and EDA have been associated with eruption disorders such as impaction, agenesis, and delayed eruption, highlighting the genetic complexity of this process [(Vastardis, 2000)](https://paperpile.com/c/EsXIQM/5dlNV). However, these genetic associations remain largely unexplored in region-specific cohorts, such as the Tamil pediatric population, who may exhibit unique gene-environment interactions due to dietary habits, skeletal growth patterns, and ethnic genetic backgrounds.[(Muthuswamy Pandian et al., 2022; Ramakrishnan et al., 2023)](https://paperpile.com/c/EsXIQM/dI1MH+Tn8Vs), [(Merchant et al., 2022)](https://paperpile.com/c/EsXIQM/zKQGz), [(Sreevarun et al., 2023)](https://paperpile.com/c/EsXIQM/zruK6)The study's observation of a weak positive correlation between maxillary and mandibular canine eruption angles may indicate independent genetic regulation of eruption pathways. This finding is consistent with existing literature, which suggests that anomalies in upper and lower canines often do not co-occur, implying site-specific gene expression [(Batwa & Alzain, 2018; Camilleri & Scerri, 2003; Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv+L3xCc+pXATk). Furthermore, environmental epigenetic factors, such as the fibrous diet prevalent in rural South Indian regions, may affect mechanotransduction pathways and gene activation involved in bone remodeling and eruption These findings advocate for an integrative diagnostic model that combines spatial analysis with molecular profiling to enhance the prediction of eruption anomalies and to personalize treatment strategies. [(Chokkattu et al., 2023)](https://paperpile.com/c/EsXIQM/d8i5j), [(Laghari et al., 2023; Ramakrishnan et al., 2023)](https://paperpile.com/c/EsXIQM/Tn8Vs+EMzQB), [(Muthuswamy Pandian et al., 2022)](https://paperpile.com/c/EsXIQM/dI1MH)

## Clinical Implications & Orthodontic Considerations

A comprehensive understanding of canine eruption dynamics is essential for orthodontists to predict and manage potential impaction risks effectively. Early identification through clinical and radiographic assessments, including panoramic radiographs and CBCT scans, allows for timely intervention, minimizing complications.[(Botticelli et al., 2011)](https://paperpile.com/c/EsXIQM/e4af5) Space management plays a critical role, with selective extraction of primary canines or premolars often necessary to facilitate proper eruption.[(Power & Short, 1993)](https://paperpile.com/c/EsXIQM/KCEaw) In cases of maxillary constriction or skeletal class II malocclusions, adjunctive therapies such as rapid maxillary expansion (RME) or functional appliances can create sufficient space and optimize alignment.[(Parkin et al., 2012)](https://paperpile.com/c/EsXIQM/asby7) Non-surgical approaches, including serial extractions, space regaining appliances, and guided eruption techniques, help reduce the likelihood of impaction, while orthodontic traction with fixed appliances is effective in borderline cases.[(Ristaniemi et al., 2022)](https://paperpile.com/c/EsXIQM/kSexo) While surgical exposure combined with orthodontic traction remains the standard for impacted canines, early intervention strategies can significantly reduce the need for invasive procedures, improving treatment efficiency and patient comfort. By incorporating these preventive and corrective measures into routine orthodontic evaluations, clinicians can enhance treatment predictability, ensure functional occlusion, and achieve better aesthetic outcomes.(41)

# Conclusion & future perspectives

The findings of the study underscore notable differences in the eruption angles of maxillary and mandibular canines, with maxillary canines demonstrating a broader range and higher mean angle. This variability corroborates existing literature, which suggests that maxillary canines often follow a more intricate and prolonged eruption pathway, thereby increasing their susceptibility to impaction [(Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv). Conversely, mandibular canines typically exhibit a more linear and predictable trajectory, potentially contributing to their relatively lower incidence of eruption anomalies [(Camilleri & Scerri, 2003; Fernández et al., 1998)](https://paperpile.com/c/EsXIQM/wPrhv+L3xCc).Crucially, the weak correlation between maxillary and mandibular eruption angles implies that their eruption dynamics are independently regulated, possibly due to distinct genetic and molecular signaling pathways. This observation is consistent with emerging research that emphasizes the role of genes such as MSX1, PAX9, and RUNX2, as well as signaling proteins like PTHrP, SHH, and BMPs, in controlling localized eruption processes .[(Vastardis, 2000; Wise et al., 2002)](https://paperpile.com/c/EsXIQM/5dlNV+UBKWC) Considering the genetic diversity and unique environmental exposures of the Tamil pediatric population, including high-fiber diets that may influence epigenetic pathways, there is a pressing need to incorporate molecular diagnostics in future eruption studies[(Jonasson et al., 2018)](https://paperpile.com/c/EsXIQM/hqaAh). The integration of cone-beam computed tomography (CBCT), spatial orientation analysis, and gene-based profiling could facilitate accurate prediction of eruption anomalies and enable earlier clinical intervention.This comprehensive, multidisciplinary approach advocates for a transition toward personalized orthodontics, empowering clinicians to anticipate eruption deviations prior to the manifestation of clinical symptoms, thereby enhancing outcomes with minimal invasiveness and increased efficiency. The findings support the hypothesis that spatial eruption patterns may be influenced by distinct genetic mechanisms. Future studies incorporating molecular diagnostics could enable early, personalized interventions for at-risk pediatric populations.

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