JOURNAL OF HEALTHCARE SCIENCES

Volume 5 Issue 8 2025, Article ID: JOHS2025001091

http://dx.doi.org/10.52533/JOHS.2025.50807

e-ISSN: 1658-8967

Review

Tooth Eruption Disorders from Delayed Eruption to Ectopic Eruption Management

Raed Mohammed Alamoudi[1*], Doaa Makki Alharbi[2], Nada Said Alzahrani[3], Maan Ahmed Aldoughan[4], Abdulaziz Saad Alharbi[5], Saleh Mohammed Alrashed[6]

[1] *Department of Pediatric Dentistry, Al Thager Hospital, Jeddah, Saudi Arabia*
[2] *Department of Dentistry, Prince Mohammed bin Abdulaziz Hospital, Medina, Saudi Arabia*
[3]*Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia*
[4]*College of Pediatric Dentistry, King Faisal University, Al Ahsaa, Saudi Arabia*
[5]*Dental Department, Private Dental Clinic, Medina, Saudi Arabia*
[6]*College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia*

Correspondence should be addressed **Raed Mohammed Alamoudi**, Department of Pediatric Dentistry, Al Thager Hospital, Jeddah, Saudi Arabia, Email: raed.m.alamoudi@gmail.com

Received: 07 August 2025, Reviewed: 17 August 2025, Accepted: 26 August 2025, Published: 27 August 2025.

Abstract

Tooth eruption is a highly coordinated biological process that allows teeth to migrate from their developmental positions within the jawbone to their functional positions in the oral cavity. Disruption of this process can lead to a range of clinical anomalies, including delayed eruption, ectopic eruption, and primary failure of eruption (PFE). These anomalies present significant clinical challenges due to their profound implications for occlusal development, periodontal health, and overall patient quality of life. The etiology of eruption anomalies is multifactorial, encompassing local mechanical obstructions (retained deciduous teeth, odontomas, fibrous hyperplastic tissue), systemic disturbances (endocrine or nutritional deficiencies), and genetic conditions such as cleidocranial dysostosis, Trisomy 21, and mutations in the parathyroid hormone 1 receptor (PTH1R) gene associated with PFE. Ectopic eruptions, commonly affecting the first permanent molars and maxillary canines, can result in root resorption of adjacent teeth, arch length deficiencies, and long-term malocclusions if not detected early. Meanwhile, PFE is a rare clinical entity wherein teeth fail to respond to the physiological forces of eruption despite the absence of any physical obstruction, making traditional orthodontic treatments ineffective. This review analyzes the pathogenesis, clinical presentation, and diagnostic advances associated with delayed and ectopic eruption and PFE, while evaluating available treatment approaches, ranging from interceptive and surgical interventions to prosthodontic rehabilitation. Emphasis is placed on early detection, multidisciplinary collaboration, and personalized clinical planning to optimize outcomes. By synthesizing recent evidence, this review aims to guide clinicians in effectively managing eruption anomalies, highlighting the role of early intervention, precision diagnosis, and long-term patient monitoring.

Keywords: *Tooth eruption, eruption anomalies, primary failure of eruption, ectopic eruption, genetic etiologies, treatment approaches*

Introduction

The process by which teeth transition from their developmental location within the jawbone to their ultimate functional area within the oral cavity is known as tooth eruption, a highly coordinated biological phenomenon (1). The development of periodontal ligaments, bone metabolism, cellular activity, and molecular signaling pathways all interact intricately to control the exact and systematic order of this process (2). Establishing a functional and aesthetically pleasing dentition is facilitated when teeth erupt in a predictable time frame and spatial arrangement. Delays in eruption, ectopic eruption, and primary failure of eruption (PFE) are among the clinical abnormalities that occur when the eruption process is changed or interfered with (3). These disruptions affect occlusion, aesthetics, periodontal health, and general quality of life, with important ramifications for both the patient and the clinician (4).

It is a common clinical finding when a tooth emerges later than would be expected for the patient's age and sex (5, 6). This phenomenon is known as delayed eruption. Its causes are varied and include systemic factors like hypothyroidism, hypoparathyroidism, malnourishment, and some syndromes like cleidocranial dysostosis and Trisomy 21, as well as local mechanical factors like retained deciduous teeth, fibrotic or thickened gingival tissue, and extra teeth (7). Long-term periodontal compromise, ectopic tooth positioning, and deficiencies in arch space can result from delayed eruption if left untreated (8). Ectopic eruption is the deviation of a tooth from its normal emergence path, which frequently affects neighboring teeth and results in structural abnormalities such as root resorption or loss of arch length (9).

Most often seen in maxillary canines and first permanent molars, ectopic eruption is often caused by genetic predisposition, abnormal tooth morphology, or deficiencies in arch length (10). From localized tissue damage and occlusal discrepancies to complex malocclusions that make subsequent restorative and orthodontic treatments more difficult, the clinical sequelae can vary widely (11, 12). The rare disorder known as primary failure (PFE) of eruption, which is linked to mutations in genes like parathyroid hormone 1 receptor PTH1R that impact the cellular and molecular machinery necessary for tooth eruption, is a particularly difficult form of eruption anomalies (13, 14). Although there is no mechanical obstruction, PFE usually affects posterior teeth and manifests as a clinical stop in the eruption process (15). Its clinical management is complicated by its resistance to conventional orthodontic treatments, which makes an early and precise diagnosis essential (16). Summing up the most recent research on the pathophysiology, clinical manifestation, diagnostic developments, and therapeutic approaches for delayed eruption, ectopic eruption, and primary failure of eruption is the goal of this review. This review highlights the importance of early detection and focused intervention in maximizing clinical outcomes and maintaining long-term oral health by showcasing best practices and advancements in the multidisciplinary approach necessary for effective patient care.

Methodology

A narrative review methodology was used to conduct this literature review, which concentrated on peer-reviewed research that was published between 2015 and 2025. Numerous databases, including PubMed, ProQuest, the Cochrane Library, and Google Scholar, were searched for relevant literature. Medical Subject Headings (MeSH) and keywords like “tooth eruption anomalies,” “delayed eruption,” “ectopic eruption,” “primary failure of eruption,” “PTH1R,” and “orthodontic intervention” were used in the review. Using Boolean operators (AND, OR) the search combined these terms to narrow down the results and restrict the studies to those that were published in English and involved human subjects. Studies concentrating on the pathophysiology, clinical manifestations, diagnostic techniques, and therapeutic approaches associated with tooth eruption abnormalities met the inclusion criteria. Randomized controlled trials, case reports, observational studies, systematic reviews, meta-analyses, and clinical practice

http://dx.doi.org/10.52533/JOHS.2025.50807

guidelines were all considered for inclusion. Exclusion criteria included papers discussing syndromic abnormalities unrelated to tooth eruption studies that solely focused on animal or in vitro experiments and case reports with inadequate clinical details. The full texts were carefully examined after titles and abstracts were vetted for relevancy. The methodological quality and clinical applicability of the chosen papers were evaluated critically. Studies that offered long-term clinical outcomes, improvements in the accuracy of diagnostics (like CBCT and genetic screening), and evidence-based treatment approaches were given particular attention. Three main areas of clinical relevance, pathogenesis and epidemiology, diagnostic advancements, and clinical management strategies, were the focus of the thematic organization of the extracted data. This method enabled a comprehensive interdisciplinary analysis of tooth eruption abnormalities and their clinical relevance, laying the groundwork for evidence-based clinical practice and future research avenues.

Discussion

Eruption disorders: pathogenesis and etiology

The physiological process of tooth eruption includes a complex and tightly controlled series of events, interactions between bone metabolism, periodontal ligament dynamics, cellular activity, and the complex molecular signaling of the alveolar bone and dental follicle (17). Cellular mediators like osteoclasts and odontoclasts, as well as the resorption of alveolar bone, play a major role in determining the start of this process (18). This process enables teeth to transition from their developmental locations within the jaw to their intended locations within the oral cavity in a typical clinical setting (19, 20). When this intricately synchronized process is disturbed, eruption anomalies occur. These irregularities fall into three general categories: primary failure of eruption (PFE), ectopic eruption, and delayed eruption (21, 22). Systemic conditions, syndromic abnormalities, or mechanical barriers are frequently involved in the pathophysiology of delayed eruption (23). Mechanical barriers that can divert the eruption path or prevent tooth emergence include retained deciduous teeth, odontomas, fibrous tissue, and extra teeth (like mesiodens) (24, 25). The natural eruption pathway can be restored in these cases by removing the obstruction, so early detection is essential to clinical intervention. Systemic factors can also have a big impact; alterations in metabolism and mineralization of the alveolar bone and dentition have been linked to delayed tooth eruption in endocrine disorders such as hypothyroidism and hypoparathyroidism (26). Systemic health plays a crucial role in the dentition's developmental timeline as evidenced by the association between delayed tooth eruption and nutritional deficiencies, particularly those in vitamin D (27, 28). Because of alterations in bone metabolism and craniofacial growth patterns, syndromic disorders like cleidocranial dysostosis and Trisomy 21 have long been known to be linked to delayed or aberrant eruption patterns (29). An alternative clinical problem is ectopic eruption. Ectopic eruption, which is characterized as an aberrant eruption path that departs from its intended position within the arch, is commonly seen in maxillary canines and first permanent molars (30, 31). Ectopic eruption can cause a variety of clinical symptoms, from minor displacement and deficiencies in arch length to severe root resorption of neighboring teeth and the development of intricate malocclusions (32, 33). Disparities in arch length, aberrant tooth morphology, and genetic variables that impact the timing and spatial location of eruption all have an impact on the phenomenon. With roots in the molecular and cellular biology of tooth development, primary failure of eruption (PFE) has a unique etiology (34). In PFE, a rare but important clinical entity, teeth do not respond to eruptive forces even in the absence of mechanical obstruction (35). This condition is often linked to mutations in the parathyroid hormone receptor (PTH1R) gene (3). The unique clinical presentation frequently manifests as a stop in the eruption process and affects posterior teeth (22). It is crucial to have an early and precise diagnosis because traditional orthodontic treatments that apply extrusive forces are often ineffective and can cause ankylosis.

http://dx.doi.org/10.52533/JOHS.2025.50807

Diagnostic methods and Imaging techniques

In the clinical management of eruption anomalies, an early and precise diagnosis is essential because it directs treatment planning and has a substantial impact on long-term results. The diagnostic process commences following a comprehensive clinical examination that includes a review of the patient's medical and dental history, a dentition inspection, an alveolar ridge palpation, and an evaluation of the arch relationships (1). In many cases, a clinical examination can reveal early warning indicators of an underlying eruption anomaly, such as palpable bulges, delayed or abnormal primary tooth loss, asymmetries in the arch, or obvious arch discrepancies (23, 36). A radiographic examination is a crucial supplement to clinical evaluation (37, 38). Panoramic and intraoral periapical or bitewing radiographs are the cornerstones of diagnostic protocols in routine practice, offering vital details regarding tooth position, angulation, and root development status (39). The clinician can use the panoramic radiograph to determine the dentition's overall development, identify teeth that are impacted or ectopically positioned, and check nearby structures for pathology like cystic lesions, odontomas, and extra teeth that could obstruct the eruption pathway. For complicated cases, Cone-Beam Computed Tomography (CBCT) has become an indispensable tool (40, 41). Its three-dimensional representation makes it possible to precisely evaluate the spatial relationships between tooth bone contours and important anatomical features. When evaluating the proximity of the ectopic tooth to neighboring roots, planning the surgical exposure of impacted teeth, and evaluating the viability of interceptive treatments, CBCT is particularly helpful (42). Clinical studies that have shown improved diagnostic accuracy, fewer intraoperative complications, and improved clinical outcomes when used appropriately have validated its role (43, 44). Further advancements in diagnosis are related to the increasing significance of molecular and genetic testing in suspected PFE cases. A considerable portion of PFE patients have been found to have mutations in the PTH1R, which enables early differentiation from ankylosis and offers useful information for clinical decision-making (45). Given that conventional orthodontic techniques are mainly ineffective for this anomaly, the ability to genetically confirm the diagnosis of PFE has significant implications for clinical planning, patient counseling, and establishing reasonable treatment expectations. The ability to detect changes early and intervene promptly is made possible by routine radiographic monitoring of patients exhibiting abnormal eruption patterns (14). A comprehensive diagnostic procedure that serves as the basis for focused and effective intervention strategies is ensured by the combination of clinical examination, traditional and advanced imaging, and appropriate molecular testing.

Clinical considerations and management strategies

The nature and severity of the eruption anomaly, the patients' medical condition, and long-term functional and aesthetic objectives must all influence the clinical approach to managing eruption anomalies. Early removal of the obstructing element permits the permanent tooth to erupt naturally in situations of delayed eruption brought on by mechanical obstruction, such as retained deciduous teeth or supernumerary teeth (46, 47). Likewise, surgical excision and exposure techniques can be used to treat odontomas and fibrous tissue, paving the way for the delayed tooth to erupt on its own or with orthodontic support (48). Since ectopic eruption can result in root resorption and deficiencies in arch length, it is especially important to monitor it closely when it affects maxillary canines and first permanent molars (49). When separators, Halterman appliances, or distalization appliances are used early on, the ectopically positioned tooth can be redirected into its proper path (50, 51). A successful outcome in cases where the ectopic tooth poses a threat to the root of a neighboring tooth requires a multidisciplinary approach that combines the expertise of an orthodontist, oral surgeon, and periodontist (52). The long-term effects of ectopic eruptions can be lessened with prompt use of interceptive treatments, which will lessen the need for more involved restorative procedures in later life. It's critical to distinguish PFE from ankylosis

http://dx.doi.org/10.52533/JOHS.2025.50807

early on because traditional orthodontic treatments like applying extrusive forces have been linked to ankylosis (53). A highly customized approach is necessary for patients who present with PFE (54, 55). When paired with prosthodontic and restorative procedures, segmental osteotomies can provide long-term functional and aesthetic advantages (56). Although this procedure is usually postponed until craniofacial growth is finished, in some cases, extraction and implant placement may offer a permanent solution for damaged teeth. Managing eruption anomalies linked to syndromes like Trisomy 21 and cleidocranial dysostosis requires additional considerations (57). A multidisciplinary approach involving pediatricians, endocrinologists, oral and maxillofacial surgeons, and orthodontists is necessary for these patients. The patient's overall health may require systemic medical treatments, whereas oral and maxillofacial interventions concentrate on surgically exposing impacted teeth, extracting extra teeth, and coordinating intricate orthodontic procedures to correct abnormal tooth and jaw morphology (58). Both supportive and preventive actions, such as educating parents and patients, are equally important. The advantages of regular clinical and radiographic monitoring, as well as early clinical warning signs, should be explained to patients. Better clinical outcomes, prompt intervention, and increased compliance are all made possible by education. Palliative approaches are recommended when clinical abnormalities are resistant to treatment. These approaches emphasize maintaining patient quality of life, occlusal function, and aesthetics. It is expected that continued research into tissue engineering and molecular genetics will lead to future developments in the clinical management of eruption anomalies (59). The combination of advancements in digital planning and three-dimensional printing technologies, with the potential for targeted biological treatments to stimulate tooth eruption, could lead to more predictable and patient-centered outcomes (60). In the meantime, physicians must keep using an all-encompassing evidence-based strategy that places a high value on early detection, accurate diagnosis, and customized multidisciplinary treatment plans.

Conclusion

Tooth eruption anomalies include a variety of clinical conditions that impact patients from a wide range of demographic backgrounds. These abnormalities, which include primary failure of eruption, ectopic eruption, and delayed eruption, have a significant impact on how a functional and aesthetically pleasing dentition develops. Early detection, accurate diagnosis, and customized treatment planning are made possible by an understanding of their pathophysiology and clinical manifestations. To reduce long-term periodontal or occlusal disturbances, root resorption, and deficiencies in arch length, early intervention is essential. Advances in diagnostics, such as CBCT and genetic testing for PTH1R mutations, allow physicians to distinguish between these abnormalities and adjust clinical procedures appropriately. Meanwhile, effective avenues for handling even the most difficult cases are provided by developments in surgical methods, interceptive orthodontics, and interdisciplinary cooperation. Future studies should keep concentrating on the clinical implementation of new technologies and therapies, as well as the molecular causes of tooth eruption abnormalities. Clinicians can improve patient outcomes, simplify treatment, and maintain long-term oral health by combining advancements in precision medicine with clinical practice. In the end, the foundation of optimal clinical practice for treating tooth eruption abnormalities continues to be a patient-centered multidisciplinary approach.

Disclosure

Conflict of interest

There is no conflict of interest.

Funding

No funding.

Ethical considerations

This study is a narrative review of previously published literature and does not involve any original data collection involving human or animal subjects. Therefore, ethical approval was not required.

http://dx.doi.org/10.52533/JOHS.2025.50807

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection, analysis and final writing of the manuscript.

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