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**Review Article**

# Management and outcomes of apexification procedures in traumatized immature teeth

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## ABSTRACT

The oral health of pediatric patients is a significant concern, with dental injuries being a common occurrence in this vulnerable population. Traumatic injuries to immature teeth, characterized by incomplete root development and open apices, present unique challenges that require specialized clinical management. Understanding the anatomy and developmental characteristics of immature teeth is crucial for effective management. Historically, apexification procedures relied on calcium hydroxide, but advancements in dental pulp biology led to regenerative endodontics, a transformative approach that preserves pulp vitality while promoting apical closure. Contemporary techniques include calcium hydroxide apexification, mineral trioxide aggregate (MTA) apexification, and regenerative endodontics, each with its advantages and considerations. Patient selection, radiographic assessment, choice of biocompatible materials, and post-operative care are key components of contemporary apexification protocols. Advanced imaging modalities like cone-beam computed tomography (CBCT) enhance diagnostic accuracy. Challenges in apexification procedures include infection control, the risk of root fractures, and dealing with resorption phenomena. Moreover, pediatric patients require special attention to address compliance and psychological factors. The long-term outcomes of apexification procedures extend beyond clinical and radiographic parameters and encompass growth and development as well as the quality of life of pediatric patients. Preservation of arch integrity, prevention of malocclusion, and maintaining oral health-related quality of life are vital considerations.

**Keywords:** Apexification, Immature teeth, Dental trauma, Regenerative endodontics, Biocompatible materials, Pediatric dentistry

## INTRODUCTION

Traumatic dental injuries represent a global health concern in permanent dentition and stand as the leading cause of pulpal necrosis.[1] These injuries occur in the oral region in 85% of these cases.[2] On a global scale, approximately one billion individuals grapple with trauma-related issues, and among them, one-third experience injuries to their

immature teeth, which have the potential to lead to pulp necrosis.[3,4]

Therefore, the oral health of pediatric patients remains a subject of profound concern. Injuries to immature teeth are a pervasive occurrence within this demographic, frequently stemming from accidents, falls, or sports-related incidents. These traumas vary in severity, ranging from superficial enamel fractures to more profound disruptions that penetrate the pulp and impede the physiological maturation of tooth roots.[5] It is within this realm of dental injuries, with particular emphasis on immature teeth, that the narrative of apexification procedures unfolds.

Among the various dental traumas encountered, injuries to immature teeth, characterized by incomplete root development and open apices, necessitate specialized clinical management.[6] Traumatic events leading to pulp exposure and arrested apical development pose intricate challenges that demand precise attention and tailored therapeutic interventions. The understanding of apexification procedures necessitates an intricate comprehension of the anatomy and developmental characteristics inherent to immature teeth. Immature teeth, typified by their incomplete root formation and apical foramina, occupy a distinct niche within the dental landscape. At the crux of comprehending the challenges and management nuances associated with immature teeth is an appreciation of their structural idiosyncrasies. Unlike their fully matured counterparts, these teeth possess open apices and underdeveloped root structures.[7] The apical foramen, which in mature teeth is tightly sealed, remains patent in immature teeth, permitting communication between the root canal system and the periapical tissues. This structural immaturity renders these teeth uniquely susceptible to the ingress of microorganisms, which can precipitate infections, and jeopardizes their vitality when subjected to traumatic injuries.[8] The open apices, conversely, provide an avenue for the manipulation of regenerative endodontic procedures—a pivotal advancement in contemporary dental care.[9] The intricate process of tooth development unfolds in well-defined stages, culminating in the emergence of a fully formed tooth. During the developmental journey, teeth transition through the bud, cap, and bell stages, ultimately undergoing odontogenesis and morpho-differentiation.[10] For immature teeth, this process is notably arrested or incomplete. Immature permanent teeth, whether incisors, canines, or premolars, typically harbor wide open apices and minimally developed roots. This arrested development, while characteristic of immature dentition, imparts a unique set of vulnerabilities and management exigencies that set it apart from mature teeth.[8]

Consequently, this review endeavors to delve into the intricate domain of apexification procedures, with a primary focus on their meticulous management and the outcomes they yield when applied to traumatized immature teeth.

## METHODS

This study is based on a comprehensive literature search conducted on 08 October 2023, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the management and outcomes of apexification procedures in traumatized immature teeth. There were no restrictions on date, language, participant age, or type of publication.

## DISCUSSION

The vulnerability of immature teeth to traumatic dental injuries looms large in the pediatric population. Trauma-induced dental injuries in children often manifest as enamel fractures, dentin exposure, or pulpal involvement. Immature teeth, due to their incomplete root formation and thin dentinal walls, are particularly susceptible to pulp exposures in cases of severe trauma.[11] The repercussions of such injuries extend beyond immediate clinical concerns, potentially impairing the future health of these teeth. Furthermore, the potential for disrupted apical development necessitates prompt and appropriate clinical intervention. A profound comprehension of the anatomy and development of immature teeth serves as the foundational underpinning for the subsequent discussion on apexification procedures.[12] The unique structural features and developmental characteristics of these teeth, coupled with their heightened vulnerability to trauma, underscore the imperative nature of specialized clinical management, which forms the crux of the ensuing discourse on apexification techniques.

Apexification is a non-surgical method that enables the formation of an apical barrier in teeth with open apices, boasting success rates ranging from 81% to 100%, as reported in follow-ups spanning 1 to 15 years.[13-15] The inception of apexification procedures can be traced back to the mid-20th century, a period that witnessed pioneering efforts to address the challenges posed by open apices in immature permanent teeth. Early apexification techniques primarily relied on the application of calcium hydroxide as an intracanal medicament.[16] This approach aimed to induce apical closure by promoting hard tissue formation, a process that could extend over several months. While effective in many cases, this method had inherent limitations, including protracted treatment durations and variable success rates, which prompted continued exploration of alternative strategies. The early reliance on calcium hydroxide-based apexification encountered challenges such as coronal leakage, microbial ingress, and issues associated with the mechanical properties of induced hard tissue.[17] Furthermore, the protracted treatment timeline often subjected patients to extended periods of dental morbidity, while the predictability of

complete apical closure remained uncertain. The understanding of dental pulp biology and advancements in tissue engineering marked a pivotal turning point in apexification procedures. Regenerative endodontics, also known as pulp revitalization or revascularization, emerged as a transformative paradigm shift. This approach hinged on the harnessing of the innate regenerative potential of the dental pulp to encourage the formation of vital tissue within the root canal space.[18] Notably, this technique offered the prospect of restoring apical closure while preserving the vitality of the pulp tissue, which was previously deemed inconceivable.

Contemporary apexification protocols require a discerning approach to patient selection based on rigorous diagnostic criteria. Typically, candidates include pediatric patients with immature teeth affected by traumatic injuries that have resulted in pulp exposure, necrosis, or arrested apical development.[19] Importantly, these protocols offer a viable alternative to tooth extraction, even in cases that were previously considered unrecoverable. The selection process involves a comprehensive clinical assessment, including a thorough radiographic evaluation, to determine the suitability of the tooth for apexification procedures.

Within contemporary apexification techniques, three predominant approaches take precedence. The first approach involves calcium hydroxide apexification, which, although traditional, remains a relevant therapeutic option.[20] It involves applying calcium hydroxide as an intracanal medicament to stimulate apical closure by inducing hard tissue formation. However, this method may necessitate multiple appointments over an extended treatment duration. The second approach is mineral trioxide aggregate (MTA) apexification, which has gained prominence due to its superior sealing properties and biocompatibility. MTA apexification entails placing MTA as an apical barrier to promote tissue regeneration and effectively seal the root canal system.[21] This approach has demonstrated enhanced success rates and expedited treatment timelines. The third approach, regenerative endodontics, also known as revascularization or pulp revitalization, represents a paradigm shift. It seeks to harness the innate regenerative potential of dental pulp stem cells to facilitate the formation of vital tissue within the root canal space. This approach offers the potential not only for apical closure but also for preserving pulp vitality. The choice of biocompatible materials plays a pivotal role in contemporary apexification. Materials such as MTA, biodentine, and other bioceramics have gained favor due to their superior sealing properties and tissue compatibility.[22,23] These materials minimize the risk of microleakage, create a biologically favorable environment, and contribute to the overall success of the procedure.

Radiographic assessment remains indispensable in contemporary apexification protocols, enabling precise monitoring of apical closure progression, evaluation of the integrity of the apical barrier, and the detection of periapical pathology.[25] Advanced imaging modalities, such as cone-beam computed tomography (CBCT), have further enhanced the accuracy and diagnostic capabilities in this regard. Post-operative care and follow-up are paramount to ensuring the success of apexification procedures. A meticulous follow-up regimen includes radiographic evaluation and clinical assessment to monitor the progress of apical closure, healing, and overall tooth vitality. This iterative process aids in the early identification and management of potential complications or treatment failures.[26]

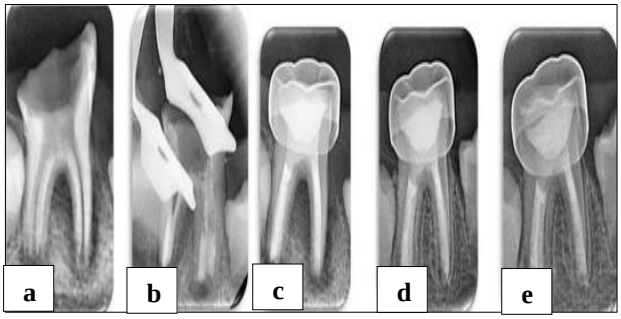


**Figure 1: Apexification using MTA as an apical plug: (a) preoperative; (b) after placement of the apical plug; (c) postoperative; (d) 6-months follow-up; and (e) 12-months follow-up.[24]**

The management of traumatized immature teeth through apexification procedures, while undoubtedly effective, is not without its complexities and potential pitfalls. These challenges span infection control, root fractures, resorption phenomena, and considerations related to patient compliance and psychological factors, underscoring the imperative need for meticulous clinical acumen. Infection control stands as a paramount concern in apexification procedures, given the open apices and communication between the root canal system and periapical tissues in immature teeth.[27] The vulnerability of these teeth to microbial ingress necessitates scrupulous disinfection and prevention strategies. Challenges may arise due to the complexity of the root canal system and the potential for intracanal medication to become extruded.[28] Ensuring aseptic conditions, selecting appropriate antimicrobial agents, and employing meticulous instrumentation techniques are imperative to mitigate the risk of persistent or recurrent infections.[29] The inherent structural fragility of immature teeth poses a notable challenge in apexification procedures. Root fractures, particularly in teeth with thin dentinal walls, are a plausible complication.[30,31] These fractures may occur during access preparation, instrumentation, or even due to occlusal forces. Radiographic assessment and careful instrumentation are crucial to minimize the risk of iatrogenic root fractures. However, the potential for these complications necessitates a proactive approach to identifying and addressing root fractures promptly when they do occur. External and internal resorption phenomena pose intricate challenges in apexification cases.[32,33] Internal resorption, which may be idiopathic or related to trauma, can undermine the integrity of the root structure and jeopardize treatment outcomes.

External resorption, initiated by inflammatory responses or traumatic insults, can further complicate apexification efforts. The early identification of resorptive lesions through radiographic assessment is pivotal. Managing resorption requires a tailored approach, which may include re-treatment, surgical intervention, or diligent monitoring.

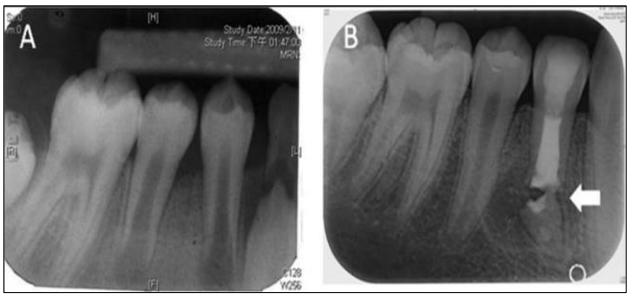


**Figure 2: Treatment complication of apexification in a ten-year-old boy, the diagnosis of #44: Pulp necrosis and chronic apical abscess; the presence of apical fistula (A) pre-op radiograph, and (b) the one year and 3-month follow-up of a case treated with Ca(OH) 2 apexification showed the apical fracture.[34]**

Pediatric patients undergoing apexification procedures present unique considerations related to compliance and psychological factors. The apprehension and anxiety associated with dental treatments, particularly among children, can influence their cooperation and the overall treatment experience.[35] Patient education, communication, and behavior management strategies are essential to alleviate anxiety and ensure optimal compliance. Moreover, the psychological impact of trauma and dental procedures on young patients must not be underestimated, necessitating a patient-centered and empathetic approach.[36] The judicious application of apexification procedures in the management of traumatized immature teeth yields outcomes that extend far beyond immediate clinical success. In terms of success criteria, the delineation is multifaceted and encompasses several dimensions. Radiographic closure, as demonstrated through radiographic assessment, remains a primary indicator of treatment success.[25] The obliteration of the open apex and the absence of periapical pathology signal a positive outcome. Clinical resolution is another fundamental criterion for success, encompassing the alleviation of pain, inflammation, and symptoms.[37] Clinically asymptomatic teeth with intact coronal restorations contribute to the overall therapeutic triumph. Preservation of vitality is essential, particularly in cases where regenerative approaches are employed, signifying not only apical closure but also the continued functionality of the dental pulp.[38] Functional restoration is integral to assessing success, gauging the ability of the treated tooth to fulfil its functional role in mastication and articulation.

The impact of apexification procedures on growth and development in pediatric patients is noteworthy. These young patients often grapple with the concurrent stages of growth and development. Preservation of traumatized immature teeth through successful apexification contributes to maintaining arch integrity, preventing adjacent tooth migration, and averting malocclusion.[39] Furthermore, it promotes the normal eruption and development of permanent successors, thereby safeguarding the overall harmony of the dental arch. Therefore, the influence of these treatments on the developing dentition and occlusion is a critical consideration in treatment planning and management.

## CONCLUSION

Apexification procedures, addressing the unique challenges posed by traumatic injuries to immature teeth, have evolved significantly over the years. They offer a range of techniques to preserve tooth vitality and promote apical closure. The success of apexification procedures is multifaceted, encompassing clinical, radiographic, and functional criteria. Beyond immediate outcomes, these procedures impact the growth and development of pediatric patients, ensuring the integrity of their dental arch and oral health-related quality of life. While challenges like infection control, root fractures, and patient compliance exist, apexification procedures remain a valuable tool for preserving immature teeth. A comprehensive understanding of the anatomy and developmental characteristics of immature teeth, coupled with advancements in dental pulp biology, has paved the way for contemporary techniques that offer promising long-term outcomes. Ultimately, apexification procedures contribute not only to the clinical success of treating traumatized immature teeth but also to the overall well-being of pediatric patients.

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