Vital Pulp Therapy in Traumatic Crown Fractures

Vital Pulp Therapy in Traumatic Crown Fractures:

A Modern Clinical Guide

By

Vasudha Chathley, Dakshita Joy Sinha,
Prem Prakash and Pratishtha Tanwar

Cambridge
Scholars
Publishing

Vital Pulp Therapy in Traumatic Crown Fractures:
A Modern Clinical Guide

By Vasudha Chathley, Dakshita Joy Sinha, Prem Prakash
and Pratishtha Tanwar

This book first published 2026

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-0364-6972-6
ISBN (Ebook): 978-1-0364-6973-3

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

PREM PRAKASH

Traumatic dental injuries (TDIs) represent approximately 5 percent of traumas faced by dentition, with a notably higher occurrence in pediatrics and young individuals. The maxillary centrals and laterals are most commonly susceptible to dentoalveolar trauma to permanent teeth [(1)]. Around 80% of these injuries involve the maxillary central incisors, while the maxillary lateral incisors are affected in about 16% of cases. Children between the ages of 6 and 12 who have immature or young permanent teeth are most likely to experience TDIs [(2)]. The risk for these injuries increases due to active play, sports activities, and falls that are common in this age group. Early and effective treatment is crucial to minimize long-term effects such as tooth loss or aesthetic concerns [(3)].

There are several classifications used to categorize traumatic dental injuries, and Ellis and Davey's classification system is one of the most widely adopted. This system uses a numerical scale (I to VIII) to describe the extent of the fracture and to differentiate between varying levels of severity. It broadly divides the fractures into two categories: 'simple fractures,' which typically involve only affected dentin or enamel, and 'complicated fractures,' which involve the pulp. The detailed classification allows clinicians to identify the severity of the injury and plan appropriate treatment strategies.

A complicated crown fracture, which is one of the most typical types of TDI, involves a break of both the enamel, dentin layers, with the pulp becoming susceptible to external environment. This exposure puts the tooth at an increased risk for infection, inflammation, and further damage. Complicated crown fractures represent as much as one-third of all cases of dental trauma, with the most frequently impacted tooth being maxillary centrals. Given central role of these teeth in both function (such as biting and speaking) and appearance, any trauma to them may have a noteworthy effect on the patient's overall well-being. Direct trauma, such as a fall, sports-related injury, or accident, may result in these fractures.

Ellis and Davis Classification (1970)

Class I	Simple Crown fracture with enamel involvement
Class II	Extended crown fracture with involvement of dentin but no pulpal involvement
Class III	Extended crown fracture with pulpal involvement
Class IV	Non- vital tooth with or without loss of crown tissues
Class V	Traumatically avulsed tooth
Class VI	Fracture of the root with or without loss of crown structure
Class VII	Displacement of the tooth without fracture of crown or root
Class VIII	Fracture of the crown en masse and its replacement
Class IX	Traumatic Injury to primary dentition

Figure 1.1: Ellis and Davey's Classification

If not properly treated, the risk of complications increases, and this can result in a need for extensive restorative procedures to preserve the tooth and maintain its function [(4)].

Following a complicated crown fracture, several complications can arise, some of which may not be immediately apparent but could worsen over time. Tooth discoloration is one of the first visible signs of injury, particularly if the pulp has been damaged. When the pulp becomes inflamed or necrotic, it can lead to internal staining of the tooth, resulting in a noticeable color change that may affect the patient's appearance. In addition to aesthetic concerns, tooth mobility can occur if the trauma damages the periodontal ligament, which anchors the tooth in the jaw. This may result in loose or shifting teeth, increasing the risk of further injury or the need for extraction.

Another significant complication is malocclusion, which refers to a misalignment of the teeth that can affect both function and appearance. Malocclusion caused by traumatic dental injuries may lead to difficulty in chewing, speaking, or maintaining proper oral hygiene. Additionally, if the fracture involves the pulp, pulp necrosis can develop. Pulp necrosis is the pathological death of dental pulp tissue resulting from an irreversible loss of vascular supply, often due to trauma, bacterial invasion ,or chronic

inflammation. This can result in infection, abscess formation, and eventually tooth loss if not treated promptly. Chronic pain and discomfort are also common symptoms associated with pulp necrosis, which may necessitate root canal therapy or even tooth extraction in severe cases.

In more severe instances, the consequences of traumatic dental injuries can extend beyond the tooth itself. If the injury involves the supporting structures of the tooth, such as the alveolar bone or periodontal ligament, it may lead to more complex issues like jaw fractures or soft tissue injuries. Furthermore, untreated or poorly managed traumatic dental injuries can lead to long-term consequences, including improper tooth eruption patterns, developmental issues with the surrounding teeth, or even malformation of the permanent dentition.

Beyond the physical and functional effects, traumatic dental injuries can also have psychological implications, particularly for children and adolescents. The visible nature of dental trauma—especially when it involves the front teeth—can lead to embarrassment, self-consciousness, and a decrease in self-esteem. The emotional toll of dental trauma should not be underestimated, and it underscores the significance of physical care while addressing mental impact through supportive care and, when necessary, counselling [5].

The primary goal in treating traumatic dental injuries, especially those involving pulp exposure, is to select a treatment plan that focuses on preserving pulp vitality. Preserving pulp vitality is essential for sustaining the tooth's physiological functions, promoting continued root development, and preventing pathological complications, as the pulp provides essential nutrients and supports the formation of surrounding dentin. However, managing traumatic pulp exposures presents a significant challenge for many clinicians. This difficulty is especially pronounced in young patients with immature teeth, where the anatomy of the tooth plays a central role in treatment complexity.

Immature teeth, which typically have thin, underdeveloped roots, wide root canals, and open apices, present a unique set of challenges. These teeth are more vulnerable to damage, as their root structure is still forming and lacks the strength seen in fully matured teeth. The wide root canals and open apices can make it difficult to achieve proper sealing during endodontic procedures, increasing the risk of infection or further damage. Additionally, the residual dentin in these teeth is often weaker than in fully developed

teeth, further compromising the tooth's overall integrity and making it more susceptible to fracture and other complications.

If pulp vitality cannot be preserved in these immature teeth, it can lead to a range of long-term complications. The failure to maintain a healthy pulp can result in the development of pulp necrosis, leading to infection and the eventual need for more invasive treatments such as root canal therapy, which can be less effective in immature teeth. In some cases, the tooth may have to be taken out, especially if the infection spreads to surrounding tissues. This can cause significant functional and aesthetic problems, particularly in the case of front teeth [3].

Furthermore, once the pulp is compromised, the tooth's root development may be halted, leading to incomplete root formation and an underdeveloped root structure. This can result in a weak and unstable tooth, which may require ongoing monitoring and intervention. If the root does not fully mature, the tooth may have a higher risk of fractures, mobility, or even eventual loss. These issues complicate treatment not only in the immediate aftermath of the injury but can create challenges for the patient's dental care throughout their life. Restorative options may be limited, and the tooth's prognosis over time could be poor, requiring complex and frequent interventions.

The initial management of traumatic dental injuries (TDIs) play a significant function in determining the outcomes for the affected tooth long term. Any shortcomings or delays in providing proper care can lead to a cascade of complications, potentially resulting in a lifelong treatment cycle. These complications can require frequent and sometimes complex interventions, significantly increasing the overall cost of treatment over the years. If the initial injury is not appropriately addressed, it may lead to complications like pulp necrosis, root fractures, or even the loss of the tooth, all of which may require extensive restorative or surgical treatments. This not only increases the patient's burden on the pocket but also adversely affects their long-term dental health and overall quality of life. Thus, effective and timely management of TDIs is essential to minimize both the clinical and economic consequences of these injuries [7].

Research has shown that In comparison to fully grown, mature teeth, immature teeth are more likely to sustain root fractures. This is due to the fact that immature teeth have thinner, less mineralized roots that are still developing, which makes them more susceptible to fractures under trauma. The presence of an open apex (root tip) and wider root canals further

complicates the treatment of these injuries, as it is difficult to adequately seal and protect the tooth from infection or further structural damage. Studies have indicated that, in immature teeth, trauma can impede proper root development and cause early root fractures, often requiring long-term treatment and follow-up care.

Even in cases where the young patient's teeth have completed root formation, maintaining pulp vitality is still crucial. The pulp has significant impact in piquing the ongoing secondary and tertiary dentinogenesis, especially in the tooth's cervical region.

This natural process of dentin deposition strengthens the structure of the tooth, helping in minimizing the likelihood of root fractures occurring later in life. When the pulp remains healthy and functional, it contributes to the ongoing development and reinforcement of the tooth, enhancing its resilience against future traumatic events.

Given the importance of pulp vitality in preventing long-term complications, its use is considered like cornerstone in the treatment of dentition which underwent trauma. VPT techniques, including IPC, DPC as well as pulpotomy, are designed to maintain pulp vitality, stimulate reparative dentinogenesis, and facilitate natural healing of the tooth. By promoting the continued development of dentin and encouraging root maturation, these treatments not only address the immediate injury but also help ensure the stability of the tooth over time. The preservation of pulp vitality through such interventions lowers the possibility of root fracture, infection, and other complications that could necessitate more invasive procedures, such as root canal therapy or tooth extraction, down the road.

So the preservation of pulp vitality through appropriate VPT interventions is essential in the early management of traumatic dental injuries. It not only promotes the health and function of the tooth but also helps minimize the need for lifelong, costly treatments, improving the overall prognosis for the patient. By prioritizing pulp preservation, clinicians can significantly reduce the risk of future complications, contributing to better outcomes for both the patient's oral health and their financial well-being [(8)].

Clinically, several well-established vital pulp therapy (VPT) interventions are available to maintain health of remaining pulpal tissue. These procedures aim to maintain pulp health and function, preventing necrosis and reducing the requirement of more extensive interventions like RCT. It is especially beneficial for young patients, as it supports continued root and

dentin development, ensuring proper tooth maturation and long-term oral health [9].

One of the most common VPT techniques is Direct pulp capping(DPC) entails covering the exposed pulp tissue at the injury site with a protective covering. This intervention is primarily suggested when there has been a recent, limited, and pinpoint-sized pulp exposure. DPC is most successful if pulp remains vital, meaning it is still free from infection or significant damage. Main goal of this approach is to isolate the exposed pulpal tissue from bacterial infiltration, establish a biologically favorable environment for healing, and stimulate the deposition of reparative dentin for safeguarding pulpal tissue [10].

Procedure typically involves thoroughly cleaning the exposed site to remove any debris or microbes. The pulpal tissue which has been exposed is then immediately protected with biocompatible substance, notably MTA, biodentine & $Ca(OH)_2$. These biocompatible materials are specifically chosen for their ability to promote dentin formation and stimulate the pulp to regenerate and seal the exposure site. Calcium hydroxide, for example, is known for its ability to encourage the formation of a hard, protective barrier of secondary dentin, while MTA has the added advantage of superior sealing properties and biocompatibility, making it highly effective in preventing bacterial infiltration.

DPC is usually recommended for minor, recent pulp exposures in which the pulp is still in good condition and free from infection. The tooth should also be asymptomatic, with no signs of pain or inflammation, which would indicate that the pulp is still in a reversible stage of injury. If done correctly, this treatment allows for the sustained vitality of the pulp, ensuring the preservation of tooth health and facilitating continued root development. The goal is to avoid more invasive treatments and enable the tooth to heal naturally, without the necessity for pulpectomy [10].

However, its outcomes depend on several elements like size and location of the site, time elapsed since injury, health of the pulp, and the quality of the restorative material used all play a role in determining whether the treatment will be successful. If the pulp exposure is too large, or if there are signs of infection, it may not be the appropriate approach, and alternative interventions, such as pulpotomy or RCT has to be considered.

Primary aim of partial pulpotomy (PP), commonly known as Cvek pulpotomy is to preserve healthy, deeper pulp intact while removing the

coronally damaged or inflamed pulp tissue that remains unaffected by the injury or inflammation. This technique is typically used in cases where the pulp is only damaged in its coronal region, allowing remaining healthy pulp to continue functioning normally. The procedure aims to maintain pulp vitality, ensuring that the tooth can continue to develop properly, particularly in immature teeth with incomplete root formation [11].

Animal studies have offered insightful explanations of the behavior of the pulp following traumatic exposure. In cases where the pulp was mechanically exposed and left untreated, research found that the initial inflammatory response was minimal within the first few hours post-trauma. Over the following days, the inflammation was typically Restricted to the coronal segment of the pulp, extending approximately 2-3 millimeters into the pulp tissue after a week. This observation suggests that the deepest part of the pulp, which is closer to the root, remains unaffected by the trauma in most cases [12].

Based on these findings, it is believed that removing the inflamed coronal pulp tissue during a Cvek pulpotomy can allow the deeper, healthy pulp to remain vital and functional. By carefully excising only the damaged portion, this procedure helps to prevent further spread of infection or inflammation, while maintaining the tooth's ability to continue developing and forming dentin. This approach provides a viable alternative to more invasive procedures, such as full pulpotomy or pulpectomy, offering possibility to save the teeth while promoting natural healing without the need for extensive intervention.

In essence, partial pulpotomy is founded on the principle saying pulpal injury is often localized to the coronal region, and by removing just the affected tissue, the tooth can maintain its vitality. This technique has shown promising results, particularly in younger patients with immature teeth, where preserving pulp function is crucial for the continued growth and stability of the tooth [13].

Full or complete pulpotomy(CP) is a procedure in endodontics involving the complete excision of the pulpal tissue of crown, extending down till remaining vital pulp stumps so leaving the deeper, healthy pulp intact. After removing the inflamed pulp tissue, the next step is to achieve hemostasis—ensuring that any bleeding from the exposed pulp is effectively controlled. Once this is accomplished, to facilitate tissue repair and preserve the viability of the remaining healthy pulp , pulp capping material is applied over it [14].

Primary goal of both PP and CP procedures remains to eliminate tissue which has undergone irreversible inflammation or structural damage as a result of traumatic injury, while preserving the remaining healthy or minimally inflamed pulpal tissue. In cases of trauma or infection, the coronal pulp often becomes the site of most inflammation, and by removing this compromised tissue, the chance of healing is better. Meanwhile, healthy pulpal tissue that remains in the root is protected and allowed to continue its normal function, which is essential for the tooth's long-term health, particularly in younger patients whose teeth are still developing.

Full pulpotomy, in particular, is commonly indicated in cases where the pulp exposure extends beyond a minor injury, and the coronal pulp is significantly damaged or infected. By removing the entire coronal pulp, the clinician ensures that any infection or irreversible damage is fully addressed. Following tissue removal, the pulp capping material acts as a protective barrier, promoting the healing of the residual healthy pulp while preserving its vitality and functional integrity.

This procedure, like partial pulpotomy, allows the tooth to prevent the need for more invasive interventions, such as root canal therapy or extraction, especially in cases of immature teeth, where maintaining pulp vitality is essential for ongoing root maturation and development. By carefully managing the inflammation and infection while promoting pulp healing, pulpotomy procedures can help preserve both the function and structure of the tooth in the long term.

In the past decade, significant developments in the knowledge of field of pulp biology, along with development and new available bioactive materials, have led to renewed interest in pulpotomy as a more conclusive procedure for permanent teeth. Traditionally, pulpotomy has been considered primarily for immature teeth or teeth with exposed pulp due to trauma. However, recent research has explored its potential as a viable option for mature, carious teeth, offering a promising alternative to more invasive procedures such as root canal therapy. This shift in focus highlights the evolving approach to pulp preservation and the emphasis on maintaining pulp vitality, even in mature teeth, as a way to promote healing and prevent the need for extraction.

Despite the promising advances, much of the research surrounding pulpotomy in mature teeth has concentrated on those affected by caries. While pulpotomy has shown success in maintaining the vitality particularly incorporating the use of bioactive materials that support tissue regeneration

and healing, it is still not universally applicable. In carious teeth, the pulp may be irreversibly compromised, and pulpotomy may only be effective in eliminating the disease while maintaining pulp function. However, there are limitations, especially when the pulp has been exposed to significant bacterial infection or when the tooth structure is severely weakened.

In comparison, treatment of pulpal tissue which is non vital in immature permanent dentition presents distinct challenges. Techniques such as revitalization and apexification have been explored as potential treatments in immature teeth with necrotic or devitalized pulps.. These procedures aim to eliminate infection, stimulate healing, and encourage the continued development of the tooth's root. While they can be successful in addressing the immediate issue of infection, studies have indicated that these treatments do not consistently result in predictable continued root development. The roots often fail to mature properly, leaving them thin, underdeveloped, and more susceptible to fractures. This incomplete root development can compromise the long-term structural integrity of the tooth, potentially elevating the risk of future complications, including root fractures or eventual tooth loss.

While pulpotomy has gained attention as a conclusive treatment for permanent teeth, its most predictable success remains in the treatment of immature dentition with pulpal exposure/ reversible pulpitis. For non-vital immature teeth, revitalization and apexification procedures show promise in disease elimination but may not result in the ideal root development needed for the long-term durability of the tooth. The ongoing research into bioactive materials and pulp biology holds potential for improving these treatments, offering better outcomes for permanent teeth [(15)].

At this time, there is not enough evidence to make a determination of the long-term success of orthodontic movement in teeth that have undergone revitalization procedures. While revitalization offers a promising approach for managing non-vital immature teeth, especially by attempting to stimulate root development and eliminate infection, the ability of these revitalized teeth to withstand orthodontic forces remains uncertain. Studies have yet to conclusively establish whether revitalized teeth can be safely and effectively moved with orthodontic treatment without risking complications such as root resorption, fracture, or further weakening of the tooth structure [(16)].

Given this uncertainty, maintaining vitality of the pulp in both immature and mature teeth is still the primary goal. Maintaining the pulp's health in

immature teeth is essential for the tooth's immediate function as well as for the ongoing growth of the roots and overall stability of the tooth. In mature teeth, where pulpotomy or other vital pulp treatments are applied, retaining pulp vitality helps avoid more invasive procedures and contributes to the long-term strength of the tooth, particularly when orthodontic treatment or other restorative procedures are needed.

While revitalization and similar procedures offer hope for treating non-vital immature teeth, additional research is required to comprehensively elucidate their implications., particularly regarding orthodontic treatment. Until more definitive evidence is available, the preservation of pulp vitality should remain a cornerstone of dental treatment strategies, ensuring the health, function, and stability of both immature and mature teeth throughout their life cycle.

PP has several advantages over CP particularly in terms of preserving pulp vitality and promoting long-term tooth health. One of the primary benefits is retaining healthy pulpal tissue present in crown aspect which supports continued pulp vitality and regenerative potential. This tissue is important because of its pivotal role in the healing process with tissue regeneration. By maintaining this healthy pulp, the procedure allows for a better healing potential compared to CP, which involves complete removal of coronal pulpal tissue. Retained coronal pulp can continue to produce vital biological components necessary for the tooth’s recovery, aiding in the formation of reparative dentin and promoting optimal healing.

Additionally, preserving the coronal pulp in a partial pulpotomy ensures that there is ongoing dentin deposition, which is essential for enhancing structural integrity and long-term durability. The cervical region of the tooth, situated near the root, is particularly susceptible to structural compromise and external influences if not adequately supported by healthy pulp tissue. By allowing the pulp to remain vital and functional, partial pulpotomy helps stimulate the ongoing formation of dentin, thus providing better structural integrity to the tooth. In contrast, in a complete pulpotomy with complete coronal pulp removal, remaining dentin becomes weaker and more prone to future fractures, as it lacks the natural protective and reparative capabilities provided by the pulp tissue.

Therefore, partial pulpotomy offers significant advantages in terms of preserving tooth vitality and strength, especially in cases involving immature teeth or teeth with minimal pulp exposure. This approach helps to ensure the continued development of root with overall stability, minimizing

chances of complications such as fractures & enhancing viability and functional outlook [17].

Although this may be less significant in fully developed permanent teeth, full pulpotomy prevents the physiological formation of dentin, potentially increasing the chances of fracture in structurally fragile dentition [18].

The extent of pulpal exposure, the severity of the primary injury, any concurrent luxation injuries, and the amount of time that passes between the accident and treatment can all have a significant impact on pulp healing [1].

For a long time, root canal therapy (RCT) has been the accepted alternative to vital pulp therapy, particularly in cases where preserving pulp vitality is no longer feasible. As outlined by the European Society of Endodontology (ESE) in its 2006 guidelines , pulpectomy is traditional choice of treatment for mature teeth with irreversibly damaged or infected pulp. This involves the removal of the pulp tissue entirely with thorough cleaning, disinfecting and sealing them to prevent further infection. While highly effective, RCT is a more invasive procedure and typically requires more time, expertise, and resources compared to vital pulp therapies.

In contrast, pulpotomies, which aim to preserve part of the pulp tissue, are generally considered simpler and less time-consuming procedures. They focus on sparing the healthy, deeper pulp tissue and only excising diseased coronal pulp tissue affected by inflammation or infection. This approach can be much more efficient, as it requires less preparation and fewer steps to complete, making it a faster procedure overall. Additionally, pulpotomies are often more cost-effective than full pulpectomies or root canal treatments, as they involve less complex equipment and fewer materials.

Given these factors, pulpotomies are increasingly considered a favorable treatment option, particularly in immature teeth or cases where pulp vitality can be preserved. They offer the potential to avoid the requirement of more invasive techniques, such as root canal therapy, to maintain the tooth's natural vitality and structure. By removing only the damaged portion of the pulp, pulpotomies also contribute to the long-term health of the tooth, supporting continued root development and minimizing the risk of complications such as root fractures.

Overall, while root canal treatment remains a crucial tool for treating mature teeth with irreversibly damaged pulp, pulpotomies provide a simpler, faster, and more affordable alternative in cases where pulp preservation is still possible. As a result, pulpotomies are becoming an increasingly attractive

option in modern dental practice, particularly in young patients or teeth with partial pulp involvement [19].

Leading dental associations emphasized by saying fractures—in which there is exposure of pulp—should be managed with vital pulp therapy (VPT), regardless of whether the tooth is mature or immature. According to their recommendations, pulp capping or pulpotomy, which both seek to maintain the pulp tissue's vitality, are the main treatment options in these situations.

The objective of these treatments is maintaining vitality, well- being, and functional integrity of pulpal tissue in both mature & immature permanent teeth, rather than opting for more invasive procedures like root canal therapy. Vital pulp therapy methods, such as pulp capping(which involves covering the exposed pulp with a biocompatible substance) or pulpotomy (where only the remaining coronal pulp is left intact while the damaged pulp is removed), are designed to protect the pulp from infection and further damage while promoting healing and continued root development.

These approaches are especially important in young patients with immature teeth, where preserving pulp vitality is crucial for continued root growth and proper tooth development. For mature teeth, while the pulp may be more vulnerable to permanent damage, maintaining vitality through VPT can still provide significant advantages in terms of preserving tooth structure, avoiding the need for more invasive treatments, and ensuring long-term tooth health.

Despite the general recommendation to treat complicated crown fractures with vital pulp therapy (VPT), some studies have raised concerns about the success rate of different VPT techniques, particularly pulp capping. Studies have indicated that teeth that undergo pulp capping might experience more pulpal necrosis than teeth that undergo pulpotomy. For example, a study done using retrospective observation found that during a five-year study, it was discovered , incidence of pulpal death was three times more prevalent in teeth that underwent pulp capping (45.5%), contrasting the 13.6% observed in teeth treated with partial pulpotomy. This suggests that, while pulp capping is a viable treatment, it may be less predictable in terms of maintaining pulp vitality compared to pulpotomy [20].

Further supporting these findings, research conducted by Wang et al. in 2017 examined the results of treatment for 375 teeth with intricate crown fractures and concluded that the incidence of pulp decay was significantly

more prevalent in teeth managed with pulp capping in comparison to those treated with partial or full pulpotomy procedures. In this study, more than half of the pulps treated with pulp capping (57.1%) became necrotic, a significantly higher rate than the 10.1% observed in partial pulpotomy cases, 9.8% in complete pulpotomy cases, and 6.1% in cases that required retreatment with pulpotomy following an initial direct pulp capping [21].

These findings highlight that while pulp capping can be a useful intervention, particularly for small, recent pulp exposures, it may carry a higher risk of failure when compared to partial or complete pulpotomy. This is likely due to the fact that pulp capping relies on the preservation of pulpal tissue that is exposed, which may be more susceptible to infection or inflammation. In contrast, pulpotomy techniques, which remove a larger portion of the affected pulp, may help eliminate compromised tissue and reduce the risk of necrosis, thus offering a more reliable long-term outcome in certain cases.

Dental professionals generally have little understanding of the best course of action for treating dental trauma. Regardless the recommendations, Removal of pulp is often performed as an emergency intervention; however, preserving pulp vitality remains a fundamental priority in endodontic management, particularly in immature teeth. Even though maintaining pulp vitality is the main objective for all teeth, the current guidelines' justification for selecting pulp capping over pulpotomy is dubious, making it particularly challenging for dental professionals to decide on the best course of action for complex crown fractures.

The type of pulpotomy agent plays a very important role to determine the success rate for vital pulp therapy (VPT). Over the years, a variety of pulpotomy agents have been recommended, ranging from traditional materials like formocresol and glutaraldehyde to more modern options, including haemostatic medicaments, electrosurgery, lasers, zinc oxide-eugenol, collagen-based materials, and calcium-based agents. These agents have all been utilized at different stages in dental practice, with varying degrees of success.

Among the most widely accepted pulpotomy agents today is mineral trioxide aggregate (MTA). MTA has taken place as a preferred agent for pulpotomy instead of calcium hydroxide, owing to its superior properties in terms of apexogenesis (root development), disinfection capabilities, biocompatibility, and lack of cytotoxicity. Calcium hydroxide and MTA both work in a similar manner, which helps stimulate dentin formation. This

property makes MTA an ideal material for pulpotomy, as it promotes the tissue regeneration in the pulp and aids in continued development in the root, particularly in immature teeth [22].

In addition to MTA, newer pulpotomy agents have emerged in recent years, further expanding treatment options. Biodentine, a bioactive material that promotes dentinogenesis and offers excellent sealing properties, has gained significant attention as a promising alternative. Likewise, bone morphogenetic protein (BMP) has demonstrated potential in promoting tissue regeneration and facilitating the healing of pulp tissue. Bioactive glass and hydroxyapatite are other materials that have been studied for their ability to encourage pulp healing and dentin formation.

Moreover, advancements in regenerative dentistry have also led to the exploration of platelet concentrates, which contain growth factors that help accelerate tissue healing and repair. In addition to these modern materials, there has been growing interest in natural alternatives that may play a role in pulpotomy. A variety of botanical extracts have been proposed as viable pulpotomy agents owing to their antimicrobial and tissue regenerative traits. Particularly, Nigella sativa (black seed), Curcuma longa (turmeric), Thymus vulgaris (thyme), oil from Allium sativum (garlic), and Aloe barbadensis Miller (aloe vera) have attracted considerable attention in this context. While further research is required to substantiate their effectiveness, these natural substances represent a promising frontier in dental pulp therapy.

Choosing an appropriate pulpotomy agent is required for the effectiveness and extended successful outcomes of vital pulp therapy. Traditional agents like formocresol and calcium hydroxide have been largely replaced by more modern and bioactive agents like MTA & Biodentine have shown to be highly effective due to their enhanced biocompatibility, ability to promote dentin formation, and support for pulp healing. As research continues, new agents, including regenerative and natural alternatives, may further improve the predictability and success of pulpotomy treatments [23].

References

1. Andersson L. Epidemiology of traumatic dental injuries. J Endod. 2013;39 (3 Suppl):2-5.
2. Glendor U.Epidemiology of traumatic dental injuries--a 12 year review of the literature. Dent Traumatol. 2008;24(6):603-11.
3. Altun C, Cehreli ZC, Güven G, Acikel C. Traumatic intrusion of primary teeth and its effects on the permanent successors: a clinical

follow-up study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107(4):493-8.
4. Díaz JA, Bustos L, Brandt AC, Fernández BE. Dental injuries among children and adolescents aged 1-15 years attending to public hospital in Temuco, Chile. Dent Traumatol. 2010;26(3):254-61.
5. Pavuluri C, Nuvvula S. Management of Traumatic Injury to Maxillary Central Incisors associated with Inverted Mesiodens: A Case Report. Int J Clin Pediatr Dent. 2013;6(1):30-2.
6. Keasberry J, Munyombwe T, Duggal M, Day PF. A study of factors that influence the number of visits following traumatic dental injuries. Br Dent J. 2013;214(11):E28
7. Katebzadeh N, Dalton BC, Trope M. Strengthening immature teeth during and after apexification. J Endod. 1998;24(4):256–9.
8. da Rosa WLO, Piva E, da Silva AF. Disclosing the physiology of pulp tissue for vital pulp therapy. Int Endod J. 2018;51(8):829-46.
9. Kodonas K, Fardi A, Gogos C, Economides N. Scientometric analysis of vital pulp therapy studies. Int Endod J. 2021;54(2):220-30.
10. Ghoddusi J, Forghani M, Parisay I. New approaches in vital pulp therapy in permanent teeth. Iran Endod J. 2014;9(1):15-22.
11. Donnelly A, Foschi F, McCabe P, Duncan HF. Pulpotomy for treatment of complicated crown fractures in permanent teeth: A systematic review. Int Endod J. 2022;55(4):290-311.
12. Cox CF, Bergenholtz G, Fitzgerald M, Heys DR, Heys RJ, Avery JK, et al. Capping of the dental pulp mechanically exposed to the oral microflora - a 5 week observation of wound healing in the monkey. J Oral Pathol. 1982;11(4):327-39.
13. Fong, C.D. & Davis, M.J. Partial pulpotomy for immature permanent teeth, its present and future. Pediatr Dent.2002;24(1):29-32.
14. Krastl, G., Weiger, R., Filippi, A., Van Waes, H., Ebeleseder, K., Ree, M. et al. Endodontic management of traumatized permanent teeth: a comprehensive review. Int Endod J. 2021;54(8):1221-45.
15. Silujjai J, Linsuwanont P. Treatment Outcomes of Apexification or Revascularization in Nonvital Immature Permanent Teeth: A Retrospective Study. J Endod. 2017;43(2):238-45.
16. Chaniotis A. Orthodontic Movement after Regenerative Endodontic Procedure: Case Report and Long-term Observations. J Endod. 2018 Mar;44(3):432-7.
17. El Kharroubi S, Drouri S, Doumari B, Laslami K, Jabri M. A Partial Pulpotomy in Traumatized Permanent Incisors With Pulp Exposure. Cureus. 2023;15(10):e46432.

18. Chailertvanitkul P, Paphangkorakit J, Sooksantisakoonchai N, Pumas N, Pairojamornyoot W,Leela-Apiradee N, et al. Randomized control trial comparing calcium hydroxide and mineral trioxide aggregate for partial pulpotomies in cariously exposed pulps of permanent molars. Int Endod J. 2014;47(9):835-42.
19. Bjørndal L, Simon S, Tomson PL, Duncan HF. Management of deep caries and the exposed pulp. Int Endod J.2019;52(7):949-73.
20. Wang G, Wang C, Qin M. Pulp prognosis following conservative pulp treatment in teeth with complicated crown fractures-A retrospective study. Dent Traumatol. 2017;33(4):255-60.
21. Hecova H, Tzigkounakis V, Merglova V, Netolicky J. A retrospective study of 889 injured permanent teeth. Dent Traumatol. 2010;26(6):466-75.
22. Akhlaghi N, Khademi A. Outcomes of vital pulp therapy in permanent teeth with different medicaments based on review of the literature. Dent Res J 2015;12(5):406-17.
23. Jha S, Goel N, Dash BP, Sarangal H, Garg I, Namdev R. An Update on Newer Pulpotomy Agents in Primary Teeth: A Literature Review. J Pharm Bioallied Sci. 2021;13(Suppl 1):57-61.

CHAPTER 2

REVIEW OF LITERATURE

PRATISHTHA TANWAR

S. Pankaj et al. (2025)[1] performed post hoc investigation by data integration from 3 randomized trials on pulpotomy treatments. The research groups consisted of 220 mature molar teeth with exposure due to caries and SIP, which received either CP or PP using ProRoot MTA. They underwent monitoring for 1 year. They assessment encompassed radiographic and clinical results, also including testing for sensibility of pulpal tissue using EPT and cold test. The findings revealed that tooth subjected to PP demonstrated consistent responses after testing by both EPT and the cold test in contrast to those treated with CP.

Zhang et al. (2025)[2] conducted a thorough examination in relation to pulpotomy being a therapeutic approach about management of pulpitis-affected dentition, covering principles of pulpal defense & repair, several options available for management, the Pulpitis classification, interventions & assessments for pulpotomy outcome. MTA, Biodentine, and iRoot showed exceptional achievement in these procedures. Also, review highlighted the updated Wolters classification, which monitors the course of inflammatory changes of pulp, may offer more effective guidance for treatment decisions. However, it was pointed out that limitations still exist in this technique, particularly the demand for more refined techniques for assessing integrity of pulpal tissue and the necessity for higher-quality ex-vitro studies for understanding long-term conclusions.

Priya Ramar K et al. (2025)[3] intended for assessment of success rates in dentition using pulpotomy as treatment approach and checking clinical observations and radiographic findings with 3Mixtatin, compared to MTA. The study found that 3Mixtatin consistently yielded noteworthy results, with success ranging from 90.5%-95.7% clinically and success from 83.4% to 91.3% radiographically. MTA also showed similarly high success rates. These results suggest that it is a promising option as pulpotomy agent in

pediatric dentition due to its effective antibacterial and bio-inductive properties.

A. Saeed et al. (2025) [4] offered an in-depth assessment of various VPT techniques and their outcomes. The review found that IPC validated successful results of approximately 94% after 24 months, which was higher than DPC (88.8%) & pulpotomy (82.6%). While different IPC agents showed similar success rates, newer agents like MTA and silver diamine fluoride (SDF) were found offering greater potential in comparison with the more traditional Ca(OH)2. Additionally, even though RCT is a comprehensive intervention, it has proven effective for management of more complicated conditions.

N. Almutairi (2024)[5] inspected determinants, management protocols, medications, and contributing factors of failure in pulpotomy with comparison with other techniques. The success in this technique is influenced by multiple aspects, including selection of agents, definitive restorative work, use of sterile techniques, and the clinician's skill. It is the commonly preferred treatment with complex fractures of coronal structure. However, for permanent dentition, challenges involve uncertainty of condition of pulpal tissue during treatment, unforeseeable outcomes, absence of extended observations for definitive results, all of which affect its rate of success. Failures are often caused due to incomplete removal of pulpal remnants while performing procedure and inadequate sealing at time of the final restoration.

G.K. Lamia et al. (2024)[6] conducted research to analyze comparative effectiveness of formocresol versus ZnO- eugenol as agents for treating carious deciduous teeth with vital pulp exposure. Results demonstrated equal effectiveness in both treatments. Analysis indicated that formocresol serves as a viable option for RCT for managing exposure of pulp in deciduous dentition.

Saeed Asgary et al. (2024)[7] investigated 105 cases of failed VPT in mature dentition, all treatment carried out by one endodontist over the span of 2011-2022.The study found that most cases which underwent failure were molar teeth. Detailed discussion was provided on patient profile, clinical aspects, and therapeutic approaches. Notable findings included the frequent occurrence of pulpal inflammation with pain and a higher failure linked restorations done with resin, with improper seal being a major contributing factor. The therapeutic approaches included RCT and reattempting VPT, both of which led into outstanding success and survival percentages. The

study emphasized need for proper patient assessments and precise diagnostic processes in addressing instances of failed VPT.

El Kharroubi et al. (2023)[8] explored the successful management of a mature tooth with a complex crown fracture through partial pulpotomy. The study found that Biodentine proved to be an effective material for treating such fractures, achieving a 100% success rate over the course of one year. The research also underscored the significance of prompt treatment, with an optimal treatment window of 20 hours following trauma. Furthermore, Biodentine was highlighted as a suitable alternative to Mineral Trioxide Aggregate (MTA), offering better aesthetic results.

Camoni N et al. (2023)[9] conducted a comprehensive review that confirmed for VPT, pulpotomy is effective approach in severely compromised young mature dentition, showing similar success rates both clinically and radiographically. It highlighted that agents such as MTA, MTA with laser, Ca(OH)2, Biodentine all performed equally well. The authors recommended prioritizing conservative treatment options whenever possible.

A. Farzaneh et al. (2023)[10] examined the use of lasers in VPT, emphasizing the need for precise adjustment of laser parameters and tip selection to prevent thermal damage and coagulation. They highlighted the importance of further studies to determine the most effective laser techniques for VPT. The review concluded laser therapy can mitigate inflammatory process, hasten recovery while improving the formation of dentinal bridges. Specifically, lasers in range 600- 700 nanometers were found to promote cell growth. Properly set photobiomodulation parameters can also lead to a significant reduction in pulpal inflammatory reactions while encouraging development of dentin tissue bridge.

Kahler et al. (2023)[11] implemented a comprehensive analysis for examining effectiveness of VPT. Their findings indicated it could be a suitable substitute to RCT, particularly when using silicate cements. The study emphasized that successful results depend on factors like careful case selection, proper aseptic techniques, and a proper coronal seal. Additionally, the authors suggested that improved control of infectious agents & using biomarker-based diagnostics could enhance predictability of therapeutic results. With its cost-effectiveness, simplicity, and high success rates, the study concluded that pulpotomy should be considered a primary option for management.

Donnelly et al. (2022)[12] conducted a comprehensive analysis to assess the effectiveness of pulpotomy in treatment of fractures of coronal tooth structure in mature dentition. It found that this therapeutic approach yielded valuable results, with 75% - 96% success across the various studies included. The authors emphasized the value of prioritizing conservative treatments over more invasive options. Additionally, it highlighted that all tested agents for capping teeth similar levels of success.

Henry F. Duncan (2022)[13] discussed possibility of VPT as a valuable approach for treating vital teeth with carious pulpal exposure, while acknowledging the existing gaps in understanding and challenges in disseminating educational resources. Its effectiveness is influenced by factors such as pulpal status and accurate preoperative evaluations. When advanced protocols are applied, which include magnification, sodium hypochlorite lavage, and silicate cements, rates for successful outcomes have been reported to be above 80% in trials with single interventions. It was also stressed the need of better protocols with creation of evidence-based standards to improve the reliability and predictability of VPT outcomes.

Nebu et al. (2022)[14] conducted a narrative review examining the pathophysiology of the pulp, its defense mechanisms, and outcomes of treatments. They found that achieving proper outcomes of pulpotomy relies primarily on properly sealing the residual dental pulpal tissue with a bioactive medicament and ensuring a durable final coronal restoration. The type of restoration used significantly impacts the prognosis, with full coverage crowns showing higher success than fillings. They also concluded factors such as the patient's demographic details, prior fillings, the location of carious exposure, and the presence of preoperative periapical lesions were not significant predictors of success for pulpotomy in mature teeth.

RojaRamya KS et al. (2022)[15] investigated the therapeutic success of propolis as a medicament, comparing it to MTA. The study involved 60 teeth from children aged 4-8 years, with 30 in each group. Evaluations were conducted at 6, 12, and 24 months. After 2 years, the success rates were 80% for the propolis group and 93.1% for the MTA group, though no substantial differences were found in the two groups. The researchers concluded it showed an acceptable success rate and may serve as a more cost-effective substitute.

S. Madhumita et al. (2022)[16] reviewed partial pulpotomy as an effective conservative treatment for anterior dentition that underwent trauma &

involvement of pulpal tissue, emphasizing good findings and success. Study analyzed results from a one-year follow-up period, reporting results of treatment with different therapeutic agents. The success rates for various materials were as follows: 94% for CaOH2 81.5% for MTA, 91% for Biodentine, and 90.3% and 92.3% for iRoot BP Plus.

Baranwal HC et al. (2022)[17] evaluated and compared outcomes of partial versus complete pulpotomy in fully developed molars showing signs of symptomatic irreversible pulpitis, using Biodentine. Sixty-six healthy molars with irreversible pulpitis were randomly distributed into two groups: PP(n = 33) and CP. Biodentine was applied as the pulp capping material, which was then covered with resin-modified glass ionomer cement (RMGIC) and restored with a composite filling. No statistically significant difference was found and it was concluded that both therapeutic approaches can be used as a permanent therapeutic modality in symptomatic irreversible pulpitis cases.

Jha et al. (2021)[18] examined various agents for pulpotomy, including natural alternatives, for treating pulpal inflammation. Despite formocresol being the traditional standard, its safety concerns have led to the exploration of natural options like turmeric, garlic oil, and Aloe vera. Modern materials like silicate cements have shown similar/improved efficacy compared to formocresol. The authors emphasized the need for further investigations, especially controlled intervention experiments, to determine best pulpotomy agents for immature dentition.

B. Richada et al. (2021)[19] assessed the results of treating coronal fractures in dentition. Their findings indicated fillings used demonstrated high longevity and they recommended quarterly follow-ups for coronal fractures over a 2 year period. Study also revealed that direct fillings showed better results than fragment reattachment of broken tooth. Additionally, although MTA showed slightly higher success in clinical outcomes when compared with Ca(OH)2 in procedures. Furthermore, the occurrence of luxation in fractures considerably lowered the success rates related to the health of the pulp and the long-term viability of restorations.

Hooman et al. (2019)[20] reviewed the use of VPT, specifically comparing different pulpotomy agents and techniques. The study focused on comparing Biodentine with those of other medicaments such as MTA, formocresol, and ferric sulfate. The goal was to evaluate its ability to maintain healthy pulp tissue and support the structural integrity of the dental arch. The review examined the strengths and weaknesses of various

materials used in VPT and suggested areas for future research. The results indicated that MTA generally had a lower failure rate than Biodentine, particularly radiographically. The authors emphasized the need for larger, more reliable studies with reduced bias to better assess the efficacy of different pulpotomy agents.

Yuan Chen et al. (2019)[21] conducted a comprehensive review and statistical analysis to evaluate the effectiveness of different agents in treating immature dentition by pulpotomy as therapeutic approach. The review found that there were negligible differences in efficacy rates between MTA and CH after 6 and 12 months. Similarly, MTA and PRF, or between MTA and CEM showed outcomes which were similar. Nevertheless, Presence of limited evidence is there suggesting that MTA and TAP had higher success rates compared to abscess treatments. The authors concluded that although the efficacy of these materials were generally comparable, further rigorous randomized controlled trials are needed to establish more conclusive results.

Louis M et al. (2019)[22] investigated the diagnostic and therapeutic approaches for pulpal inflammation in dentition, focusing on how clinical indicators and pulp sensitivity evaluations, and the overall health of the pulp correlate. The study pointed out the difficulties in diagnosing and managing pulp diseases. It also highlighted the importance of preserved functional pulpal tissue in these cases, as doing so helps maintain the tooth's structural and immune functions, reducing both patient discomfort and cost of treatment. While RCT has traditionally been seen as conventional approach, recent findings suggest that VPT could be an effective alternative for treatment, offering better outcomes and preserving the tooth's vitality.

Asgary S et al. (2018)[23] conducted an interventional study to evaluate four VPT methods. The results indicated that all four techniques yielded favorable & comparable outcomes. Furthermore, study found that the condition of the pulp and surrounding tissues, as well as the type and location of pulp exposure, had little to no effect on success of the treatments. The authors concluded that various VPT techniques are effective for managing deeply decayed mature dentition with symptoms, and presence of pulpitis/periodontitis does not play a major role for determination of treatment outcomes.

Coll JA et al. (2017)[24] performed a comprehensive assessment and pooled data analysis to evaluate the effectiveness of various VPT approaches for treating dentition with deep carious lesions. The results indicated that IPT, MTA, and FC pulpotomy are all successful treatments, with varying

successful outcomes depending on the specific therapy applied. The study emphasized the importance of consistent and standardized reporting for pulp therapy outcomes. Treatment decisions should take into account factors such as the child's age and the extent of the caries. MTA and MTA Angelus were found to be effective materials for pulpotomy. MTA and Biodentine were also effective in pulpotomy, while FC and CH showed lower success rates. IPT and DPC were identified as effective treatments, with MTA and FC being the most reliable agents. Ultimately, the study concluded that IPT, DPC, and pulpotomy are all viable treatment options for VPT, with the choice depending on the amount of affected dentin that needs to be removed.

Najeeb et al. (2017)[25] reviewed the existing publications on the use of EMD, derivative of enamel matrix in VPT, comparing its effectiveness with other materials based on different outcomes. In animal studies, 4 out of 6 found that EMD yielded more favorable results, while the remaining two highlighted similar outcomes to other materials. In human experiments, EMD was evaluated against Ca(OH)2 , MTA, and formocresol in certain studies. This article suggested that EMD was as effective as other commonly used pulpal capping agents.

W.S. Aniket et al. (2014)[26] assessed the harmful potential of four VPT materials on L929 fibroblasts. The agents when prepared immediately before use, they all showed comparable levels of cellular toxicity. On the other hand, after setting, Super-Bond C&B displayed lesser cellular toxicity when compared to other agents. The study also noted that the cellular toxicity of pulpal agents is unlikely a reliable indicator of clinical effectiveness. Given its low cellular toxicity, Super-Bond C&B shows promise for future clinical research.

Yildiz E et al. (2014)[27] investigated research for investigating various pulpotomy agents. They assessed the efficacy of four agents, by analyzing their outcomes. While no variations were found among the materials, three teeth in the CH group necessitated removal due to the development of further clinical issues and radiographic complications over the 30-month observation period. In comparison, none of the teeth in the other groups required extraction during the same duration.

Asgary et al. (2014)[28] examined pulpal inflammation of ninety four teeth and were treated using VPT methods in combination with CEM cement. The approaches included IPC,DPC, PP, CP. All techniques showed favorable outcomes, CP achieving a 100% result after treatment. Research

investigation demonstrated efficacy of VPT by CEM as therapeutic agent suggesting it might serve as a feasible substitute to RCT for patients who may choose removal of tooth due to financial constraints.

S. Asgary et al. (2013)[29] conducted a comparison of VPT using CEM and RCT. The results indicated that, after 24 months, VPT/CEM had comparable clinical efficacy rates of around 98 percent to single-visit RCT. However, it was found to be significantly more affordable, with lower treatment costs. Research also recommended a 6-month follow-up period as sufficient to evaluate the outcomes. To conclude, the investigation suggested that it is a dependable, simple, and cost-effective alternative to RCT for managing pulpal inflammation of mature dentition.

P Anuroot Aguilar et al. (2011)[30] examined the effectiveness of different VPT techniques in mature dentition with exposure due to dental decay. The analysis found that efficacy of the therapeutic approaches ranged at 72.9 percent - 99.4 percent with one to ten years of subsequent assessments. PP and CP gave better therapeutic results when compared to DPC. It also proposed that it might be effective in pulpally inflamed teeth. However, the authors highlighted the need for more rigorous observational studies to better understand the factors affecting treatment outcomes.

Tabarsi et al. (2010)[31] conducted a comparative investigation to analyze response of pulpal tissue to different agents of pulpotomy. Research aimed for investigation of how three agents—CH, MTA and CEM cement—affected dog tissues. Histopathological evaluation was done to examine development of calcific barrier, sensibility testing with immunologically-triggered responses. The data revealed that MTA & CEM cement resulted in more favorable biological reactions in comparison with CH, producing equivalent outcomes observed between them. The study emphasized the significance of VPT and the importance of selecting appropriate agents to preserve pulp health. It also highlighted CEM cement as a promising alternative to MTA and CH, due to its beneficial properties and potential clinical applications.

References

1. Sangwan P, Ramani A, Mishra S, Durga K, Popat S, Sangwan A. Pulp sensibility responses following complete and partial pulpotomy in mature permanent molars with carious pulpal exposure and symptomatic irreversible pulpitis: Analysis of pooled data from three randomized clinical trials. Int Endod J. 2025;58(3):420–33.