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REVIEW ARTICLE

Comparative Insights into Vital Pulp Therapy Techniques

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Abstract

Vital pulp therapy encompasses a spectrum of biologically based procedures aimed at preserving the vitality of dental pulp following exposure due to caries, trauma, or mechanical factors. This narrative review provides a comprehensive overview of six core VPT techniques—indirect pulp capping, direct pulp capping, miniature pulpotomy, partial pulpotomy, full pulpotomy, and deep pulpotomy—with an emphasis on their historical development, clinical protocols, and reported success rates. Indirect and direct pulp capping remain foundational techniques, particularly in minimally or non-exposed pulps, with recent studies supporting high clinical success when appropriate sealing and case selection are observed. Miniature pulpotomy has emerged as a promising modification of direct capping, offering favourable outcomes through minimal pulp removal and improved material-pulp interaction. Partial and full pulpotomies continue to gain clinical relevance in managing both immature and mature permanent teeth, with comparable outcomes to root canal therapy in selected cases of irreversible pulpitis. Deep pulpotomy, though conceptually aligned with full pulpotomy, remains an underexplored technique with limited evidence supporting its use. Despite favourable clinical performance across various VPT modalities, inconsistencies in case selection, terminology, and treatment protocols highlight the need for standardized guidelines and further long-term investigations. This review underscores the evolving scope of VPT as a conservative and biologically driven alternative to conventional endodontic therapy.

Keywords: Indirect pulp capping, Direct pulp capping, Endodontics, Irreversible Pulpitis, Miniature Pulpotomy, Partial Pulpotomy, vital pulp therapy

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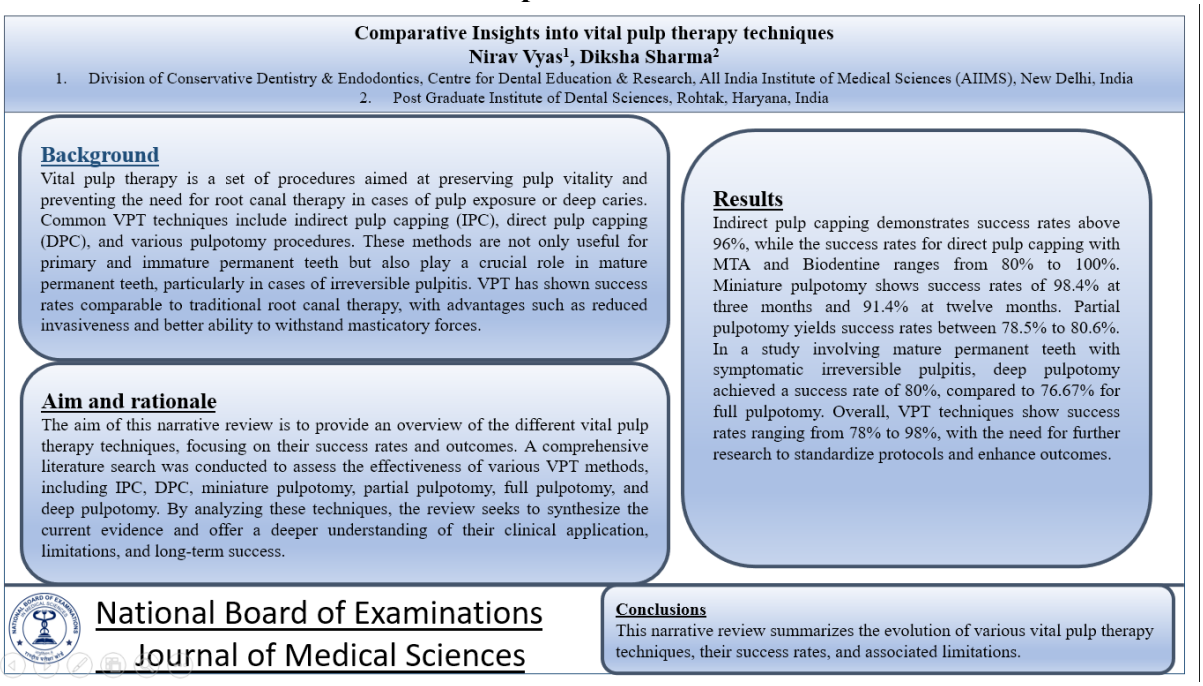
Graphical Abstract



Introduction

Vital pulp therapy (VPT) encompasses various approaches intended to protect pulpal vitality alongside maintaining tooth integrity in cases of pulp exposure/deep caries from mechanical factors/trauma [1]. VPT primarily includes direct pulp capping (DPC) and indirect pulp capping (IPC), along with various pulpotomy procedures. These procedures are routinely used in managing primary teeth for long-term retention and in immature permanent teeth to facilitate apexogenesis [2]. According to the AAE and ESE position statement over deep carious lesion management along with exposed pulp, VPT is considered a substitute method to traditional root canal therapy (RCT) aiming to maintain pulp vitality [3,4]. Another benefit of VPT over conventional RCT is its superior ability to withstand masticatory forces [5]. A study by Ghoddusi et al. (2014) highlighted vital pulp therapy's overall success rates in cariously exposed permanent teeth ranged between 87.5% and 95.4%, closely aligning with outcomes from iatrogenic exposures, which varied from 70% to 98% [6]. Therefore, the present study aimed to provide an overview of all 6 VPT technique and their respective success rate. A comprehensive literature search was conducted to identify all relevant studies on vital pulp therapy, from its inception up to April 2, 2025, utilizing the PubMed, Web of Science, and Scopus databases.

Vital Pulp Therapy techniques

Indirect Pulp capping

The concept of IPC had initially been presented by Hess in 1951 [7]. It was developed as a technique to maintain pulp vitality without exposing the pulp while treating carious dentine. IPC entails covering a thin layer of softened dentine close to the pulp with a protecting substance. It has been demonstrated that partial removal of carious dentine, followed by appropriate tooth sealing, will halt the progression of caries, suggesting that total caries removal is not necessarily required for efficient caries control. This technique

promotes the development of reparative dentine and pulp healing [8]. Three distinct IPC protocols— Dycal, TheraCal, and no liner—were examined in a recent randomized controlled experiment by Semprum-Clavier et al. (2024) in permanent teeth with deep carious lesions treated with resin composite. The findings demonstrated that all methods had effectiveness rates above 96%, and neither tooth sensitivity nor overall clinical outcomes revealed any significant variations [9].

Direct pulp capping

The term 'pulp capping' had initially been presented in literature by Barrett in 1877 [10]. The term DPC had been introduced by Hess in 1951, highlighting protective materials' use applied directly to exposed pulp tissue for facilitating healing as well as pulp function preservation [7]. Historically, DPC had been characterized as method employed for addressing pulp exposures caused by accidental trauma, in the absence of further signs of infection [11]. Nowadays, DPC is regarded as a Minimally invasive dentistry procedure that entails using a biocompatible substance to cover an exposed pulp directly, commonly trauma and carious lesions result [12]. Pinto et al.'s systematic review and meta-analysis from 2024 indicated that MTA had a greater success rate for DPC than calcium hydroxide. MTA and Biodentine showed similar success rate of 80-100% at 3 years follow-up. These findings suggest higher effectiveness of calcium silicate cement for DPC [13]. Even with improvements in materials and methods, DPC still has a lot of challenges that prevent it from being more widely used in clinical settings and from being as predictable.

Miniature pulpotomy

Asgary first used the VPT technique known as "miniature pulpotomy" (MP) in 2012. MP represents an advancement of the DPC technique by emphasizing effective debridement of the pulp wound, elimination of infected dentin and necrotic tissue, and improved interaction between capping materials and resident stem cells to enhance regenerative outcomes. MP is a conservative approach that involves careful removal of about 1mm inflamed superficial pulp tissue from exposure site while avoiding further enlargement of the wound. This method helps retain the vitality of the coronal pulp, supports effective bleeding control, and promotes better sealing of the capping material against the healthier underlying pulp, which contains mesenchymal stem cells capable of differentiating into odontoblast-like cells necessary for tissue regeneration [14]. A comparative study with 4 different pulpotomy techniques in mature permanent molar by Asgary et al. (2018) found that MP showed similar radiographical and clinical success compared to IPC, DPC and Full pulpotomy (FP). MP showed success rates of 98.4 and 91.4% at three- and twelve-month follow-up respectively which highlights its role as an alternative to conventional technique for VPT in permanent molars [15] Though there is a lack of large-scale studies and studies with prolonged follow-up.

Partial pulpotomy/Cvek pulpotomy

Cvek first introduced the term 'partial pulpotomy' (PP) in 1978 in permanent incisors for managing traumatic pulp exposures utilizing CH (calcium hydroxide) [16].

Bakland and Boyne later coined 'shallow pulpotomy' term as its synonym,

reinforcing its clinical relevance [17]. Cvek defined PP as elimination process of 1–2mm inflamed pulp in immature permanent teeth to preserve vitality. Fong and Davis later extended its application to carious exposures in vital teeth [18].

Lin et al. (2021) conducted a systematic review comparing PP and FP in cariously exposed mature molars. FP showed higher success (92.2%–99.4%) than PP (78.2%–80.6%). While the choice of capping agent didn't impact FP outcomes, it significantly influenced PP results [19]. Li et al. (2024) found that both PP and FP achieved outcomes comparable to RCT in mature teeth having irreversible pulpitis. At 24 months, PP had a radiographic success rate of 78.5% while 92.9% clinical success rate [20]. While FP marginally outperformed PP in one trial, Kumar et al. (2024) examined PP with FP in cases of irreversible pulpitis and found 0 significant difference in radiographic/clinical outcomes [21]. Umbrella review by Lin et al. (2022) analysed nine SRs on PP and FP published between 1970 and 2021. Success rates ranged from 88.5%–90.6%, though the effects of different medicaments and restorations were inconclusive [22].

Despite favourable outcomes, PP lacks a standardized definition, often described vaguely as ~2mm of inflamed pulp elimination. To validate PP as a reliable option, future studies must focus on well-designed clinical trials with standardized protocols, long-term outcomes, and better control of confounding variables.

Full/Coronal pulpotomy

The term FP was established by Aguilar and Linsuwanont in 2011 [23]. FP had 1st been utilized in treating non-inflamed pulp exposure, but it has demonstrated promising outcomes, even when treating irreversible pulpitis in primary as well as permanent teeth [24-26]. FP entails the coronal pulp being completely removed, with healthy radicular tissue preservation. Suitable bioactive material is then used to cover the pulp stump and seal the chamber. FP has been conservative and less invasive option than RCT to control exposure of carious pulp in permanent teeth. It offers comparable success rates while being more accessible, cost-effective, and simpler to perform [27]. Ather et al. (2022) showed 86% pooled success for FP in irreversible pulpitis, with Biodentine yielding better outcomes than MTA and CEM [28]. Li et al. (2024) further showed that mature teeth with irreversible pulpitis had combined radiographic as well as clinical success rates of 78.5% along with 92.9% over a 24-month period [20].

In a systematic review and meta-analysis by Wang et al. (2024), At 1- and 2-year follow-ups, FP employing CSCs and RCT achieved over 90% success, with no significant difference among 2 methods in mature teeth. Additionally, FP resulted in less postoperative pain during 1stweek, highlighting its advantage as a less invasive and more patient-friendly alternative [29]. Similarly, in a systematic review and meta-analysis by Li et al. (2024), which analysed 25 RCTs with ≥12 months follow-up, FP demonstrated an overall 86.7% success rate. In contrast to teeth having reversible/normal pulpitis, teeth with irreversible pulpitis demonstrated less success. The review also noted that MTA and Biodentine™ performed better than CH, with MTA exhibiting slightly superior results, although 0 significant difference had been found among MTA as well as other biomaterials [30]. While FP outcomes

were promising, standardization and higher-quality trials remain necessary to confirm long-term effectiveness.

Deep pulpotomy

Histologic research by Demant et al. (2021) observed that in teeth with extremely deep carious lesions, only 38% had unaffected radicular pulp tissue, while 62% showed inflammatory infiltrates in both the coronal and radicular pulps [31]. Another study by Ricucci et al. (2021) investigating invasion of pulp blood vessels by bacteria in teeth exhibiting symptoms of irreversible pulpitis reported that bacteria were present in the lumen of venules in one-third of cases, even in areas far from the necrotic focus in the root's coronal third [32]. The histological findings suggest that the success of partial or full pulpotomy procedures may be compromised by the presence of inflamed pulp tissue in the coronal third of the root in teeth with extremely deep caries and symptomatic irreversible pulpitis. Therefore, in such cases, it is advisable to remove 2–3 mm of the coronal radicular pulp to enhance the likelihood of successful outcomes [33]. Partial extirpation of the radicular pulp has been described in the literature using terms such as "high amputation," "radicular pulpotomy," or "deep pulpotomy" as a method for effectively managing teeth with traumatic or carious pulp exposure (Baume et al., 1971; Ingle et al., 2008; Tronstad, 2009). However, this approach is considered more invasive and technique-sensitive compared to FP [34-36]. A recent comparative study by Shah et al. (2025) on outcome of full vs deep pulpotomy in teeth with extremely deep carious lesions found that the success rate was 88.46% and 92.30% for per protocol analysis and 76.67 and 80% for ITT analysis for FP and deep pulpotomy, respectively [33]. Further long-term trials will require to evaluate the effectiveness of deep pulpotomy in extremely deep carious lesion.

Conclusion

VPT offers a conservative approach to preserving pulp vitality in cases of deep caries or pulp exposure, providing an effective alternative to more invasive treatment like root canal therapy. Techniques such as IPC and DPC, as well as MP, PP, and FP have demonstrated favourable success rates in both immature or primary teeth and mature permanent teeth. While VPT demonstrates promising clinical outcomes, the variability in treatment protocols and the need for more long-term, high-quality studies highlight areas for improvement. As VPT continues to evolve, further research is necessary to refine clinical techniques and establish standardized protocols for better long-term results.

Statements and Declarations

Conflicts of interest

The authors declare that they do not have conflict of interest.

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