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Integrating Traditional Endodontics with Vital Pulp Therapy: A Contemporary Review of Concepts, Materials, and Clinical Decision-Making

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Abstract
Vital pulp therapy (VPT) and traditional root canal treatment (RCT) have historically been presented as opposing management pathways for the diseased dental pulp, with RCT regarded as the unconditional standard once carious or symptomatic pulp exposure occurs. Advances in the understanding of pulpal inflammation, together with the introduction of hydraulic calcium silicate cements such as mineral trioxide aggregate (MTA) and Biodentine, have repositioned VPT as a biologically driven, evidence-supported alternative even in mature teeth with signs suggestive of irreversible pulpitis. This review examines how traditional endodontic principles — meticulous case selection, disinfection, three-dimensional sealing, and long-term monitoring — can be integrated with contemporary VPT protocols to produce a combined, minimally invasive treatment philosophy. The biological rationale for pulp preservation, diagnostic tools for assessing pulp status, indications and techniques for indirect pulp capping, direct pulp capping, partial pulpotomy and full pulpotomy, and the properties of calcium hydroxide, MTA and Biodentine are discussed. Reported outcome data indicate that VPT performed with hydraulic calcium silicate cements achieves success rates broadly comparable to conventional RCT over one- to five-year follow-up periods, provided case selection and aseptic technique are rigorous. A decision framework is proposed in which VPT is attempted as a first-line, tooth-preserving option, with conversion to conventional RCT reserved for cases of uncontrolled haemorrhage, established necrosis, or treatment failure on review. Combining the biological philosophy of VPT with the technical discipline of traditional endodontics offers a pathway toward less invasive, more conservative pulp-preserving care without abandoning the safety net of definitive root canal treatment when biological healing is not achieved.

Keywords
Vital Pulp Therapy; Root Canal Treatment; Pulp Capping; Pulpotomy; Calcium Silicate Cements; Minimally Invasive Endodontics

1. Introduction

Root canal treatment has long been considered the conventional standard of care for permanent teeth with carious pulp exposure, particularly when the pulp is judged to be irreversibly inflamed or clinically symptomatic.[9] This treatment philosophy is rooted in the historical belief that once bacteria contaminate the coronal pulp, inflammation progresses irreversibly toward the radicular pulp and cannot be arrested by conservative means. Complete extirpation of the pulp, thorough disinfection of

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the root canal system and three-dimensional obturation have therefore been regarded as the only reliable route to a healthy periradicular tissue.

A substantial body of more recent histological and clinical evidence has challenged this assumption. Pulpal inflammation associated with deep caries is frequently localized to the coronal pulp tissue immediately beneath the exposure site, while the radicular pulp retains vascularity, cellularity and the capacity for repair.[2,8] This understanding, combined with the development of hydraulic calcium silicate cements that provide superior sealing, biocompatibility and bioactivity compared with calcium hydroxide, has renewed clinical and scientific interest in vital pulp therapy (VPT) as a legitimate alternative to root canal treatment (RCT), even in mature teeth with clinical signs of irreversible pulpitis.[1,2]

Both the American Association of Endodontists (AAE) and the European Society of Endodontology (ESE) have issued position statements recognising VPT — encompassing indirect pulp capping, direct pulp capping, partial pulpotomy and full pulpotomy — as evidence-supported treatment modalities for the management of deep caries and pulp exposure in permanent teeth.[3,5] The ESE has further incorporated vital pulp treatment into its S3-level clinical practice guideline for the management of pulpal and apical disease, reflecting the maturation of VPT from an adjunctive or paediatric-only procedure into a mainstream component of contemporary endodontic practice.[4]

Despite this evidence base, VPT and traditional RCT continue to be taught and practised in many settings as mutually exclusive treatment philosophies, with clinicians defaulting to RCT once pulp exposure occurs rather than considering a staged, biologically informed approach. The purpose of this review is to examine the biological rationale, diagnostic framework, materials and clinical techniques that allow VPT and traditional endodontics to be combined into a single, minimally invasive treatment continuum — one in which VPT is attempted as the first-line, tooth-preserving intervention, and conventional RCT is retained as the definitive fallback when biological healing does not occur or cannot reasonably be expected. The specific objectives of this review are to: (i) summarise the biological basis for pulp preservation; (ii) compare the properties and clinical performance of calcium hydroxide and calcium silicate–based capping materials; (iii) outline case selection criteria and clinical protocols for each level of VPT; and (iv) propose an integrated decision framework linking VPT to traditional endodontic management.

2. Materials and Methods

2.1 Review Design

This manuscript is a narrative review synthesising current clinical and biological literature on vital pulp therapy and traditional root canal treatment. As no original patient data, animal experimentation or identifiable clinical images were generated for this article, formal ethical committee approval and patient informed consent were not required. Where illustrative clinical scenarios are described, these are presented in generic terms and do not refer to identifiable individuals.

2.2 Literature Search Strategy

A structured, non-systematic literature search was conducted using PubMed/MEDLINE, Scopus and the Cochrane Library, supplemented by manual searching of the reference lists of key position statements and systematic reviews. Search terms included combinations of "vital pulp therapy", "pulp capping", "pulpotomy", "mineral trioxide aggregate", "Biodentine", "calcium silicate cement", "irreversible pulpitis", "deep caries", "regenerative endodontics" and "root canal treatment outcome". The search was restricted to English-language publications, with an emphasis on systematic reviews, meta-analyses, randomised controlled trials and position statements published by the AAE and ESE.

2.3 Inclusion and Exclusion Criteria

Publications were included if they addressed the biological rationale, diagnostic criteria, materials, clinical technique or reported outcomes of vital pulp therapy or traditional root canal treatment in permanent teeth. Case reports were included selectively where they illustrated a clinically relevant technique or long-term outcome not otherwise captured in higher-level evidence. Publications concerned exclusively with primary (deciduous) teeth, non-dental applications of calcium silicate cements, or non-English texts without an accessible translated abstract were excluded, except where cited as historical or foundational references.

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2.4 Synthesis Approach

Given the heterogeneity of study designs, follow-up periods and outcome definitions across the retrieved literature, a narrative rather than quantitative (meta-analytic) synthesis was undertaken. Findings are organised thematically around diagnosis, materials, clinical technique and long-term outcome, culminating in a proposed integrated clinical decision framework linking vital pulp therapy to conventional endodontic treatment.

3. Results and Discussion

3.1 Biological Rationale for Pulp Preservation

The dental pulp possesses an intrinsic capacity for repair that is disproportionate to its historical reputation as a fragile, easily and irreversibly compromised tissue. Deep carious lesions provoke a localized, compartmentalised inflammatory response in the coronal pulp, while the underlying radicular tissue frequently remains healthy or only mildly and reversibly inflamed.[2] Contemporary hydraulic calcium silicate cements are capable of inducing tertiary (reparative) dentinogenesis, forming a mineralised dentin bridge that seals the pulp wound and re-establishes a protective barrier against further bacterial ingress.[6,13] This biological capacity underpins the rationale for treating even symptomatic, cariously exposed pulps conservatively, provided haemorrhage can be controlled and the wound can be sealed predictably.

3.2 Diagnosis and Case Selection

Accurate pre-operative diagnosis remains the single most important determinant of VPT success, yet the traditional binary classification of "reversible" versus "irreversible" pulpitis correlates imperfectly with the true histological status of the pulp.[21] Clinical indicators traditionally used to support a diagnosis of reversible pulpitis — brief, elicited pain that resolves promptly on removal of a cold stimulus, absence of spontaneous pain, absence of percussion tenderness and absence of periapical radiolucency — remain relevant, but increasing evidence indicates that VPT may also succeed in teeth exhibiting some features historically associated with irreversible pulpitis, including prolonged pain to cold or intermittent spontaneous pain, provided intra-operative bleeding can be controlled within an acceptable time frame (generally under 5–10 minutes) and haemostasis is achieved with a clean, red, actively bleeding pulp stump.[1,2] Signs that should prompt conversion to conventional RCT rather than VPT include uncontrollable haemorrhage, purulent or necrotic-appearing pulp tissue, radiographic evidence of periapical pathology, spontaneous nocturnal pain of long duration, and clinical signs of a cracked tooth with an unfavourable fracture line.

3.3 Deep Caries Management and Indirect Pulp Therapy

Traditional endodontic teaching favoured complete, non-selective excavation of carious dentin regardless of proximity to the pulp, prioritising the elimination of infected tissue over pulp preservation. Randomised trial evidence has since demonstrated that stepwise or selective caries removal — deliberately leaving a thin layer of affected, but not frankly infected, dentin over the pulp — significantly reduces the risk of pulp exposure and improves the likelihood of maintained pulp vitality compared with direct complete excavation.[10] The ESE position statement on deep caries management endorses selective or stepwise removal, together with indirect pulp capping using a calcium silicate–based or calcium hydroxide liner beneath a well-sealed restoration, as the first-line strategy for deep lesions without frank pulp exposure.[3] Cochrane-level evidence similarly supports selective and stepwise excavation over complete caries removal for the preservation of pulp vitality in deep, non-symptomatic lesions.[22]

3.4 Direct Pulp Capping and Partial Pulpotomy

When frank pulp exposure occurs during excavation, trauma or mechanical preparation, the clinician must choose between direct pulp capping — sealing the exposure site itself — and partial (Cvek) pulpotomy, in which a small volume (typically 1–2 mm) of superficially inflamed coronal pulp tissue is removed before capping. Randomised clinical trial data comparing the two techniques in adults with deep-caries exposures found no statistically significant difference in the maintenance of pulp vitality between direct capping and partial pulpotomy at one-year follow-up, suggesting that both are viable options provided the capping material achieves a stable, bacteria-tight seal.[10] Partial

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pulpotomy is generally favoured when the exposure is larger, when bleeding does not arrest promptly at the exposure site, or when there is a wish to remove and histologically assess a small volume of the most inflamed superficial tissue before capping the deeper, healthier pulp.

3.5 Full Pulpotomy in Mature Teeth with Symptomatic Irreversible Pulpitis

The most substantial shift in contemporary VPT practice concerns the application of full (cervical) pulpotomy — removal of the entire coronal pulp to the level of the canal orifices — in mature permanent teeth with clinically diagnosed symptomatic irreversible pulpitis, a scenario traditionally regarded as an absolute indication for RCT. Systematic review evidence indicates that full and partial pulpotomy performed with hydraulic calcium silicate cements achieve success rates of approximately 78–90% at one to five years of follow-up in such teeth, with outcomes broadly comparable to those reported for conventional RCT over similar follow-up periods.[1] A meta-analysis comparing pulpotomy with RCT for the management of non-traumatic pulpitis associated with spontaneous pain likewise found comparable success between the two approaches, while a companion review addressing pulpitis without spontaneous pain reported favourable outcomes for VPT.[7,8] A further systematic review restricted specifically to pulpotomy for carious exposures reported pooled survival and success rates supportive of pulpotomy as a durable long-term treatment rather than a temporary or interim measure.[15]

3.6 Capping Materials: From Calcium Hydroxide to Calcium Silicate Cements

3.6.1 Calcium Hydroxide

Calcium hydroxide was, for several decades, the standard pulp-capping and pulpotomy agent, valued for its antibacterial alkalinity and its ability to stimulate a dentin bridge. However, the dentin bridge it induces is frequently porous, discontinuous and tunnel-defected, and the material itself is soluble and prone to dissolution over time, predisposing to microleakage and reinfection of the pulp.[6] These limitations, well documented across decades of clinical use, provided the impetus for the development of hydraulic calcium silicate cements as an alternative.

3.6.2 Mineral Trioxide Aggregate (MTA)

Mineral trioxide aggregate was introduced as a root-end filling material before its properties — favourable sealing ability, biocompatibility and the capacity to induce a continuous, well-organised dentin bridge — were recognised as advantageous for pulp capping, pulpotomy, apexification, perforation repair and regenerative procedures.[11,12] MTA sets in the presence of moisture and blood, an important practical advantage in the haemorrhagic environment of a freshly exposed or pulpotomised pulp, though its relatively long setting time, handling characteristics and potential for coronal discolouration have been recognised as limitations in anterior aesthetic zones.

3.6.3 Biodentine and Contemporary Bioceramics

Biodentine and related tricalcium silicate–based bioceramics were subsequently developed to address the handling and setting-time limitations of MTA while retaining its favourable biological profile. Biodentine sets considerably faster than MTA, does not contain bismuth oxide (avoiding one recognised mechanism of tooth discolouration), and releases higher levels of calcium ions, producing a thicker, denser and more continuous reparative dentin bridge in comparative studies.[13] A randomised trial comparing Biodentine with calcium hydroxide in pulpotomy reported significantly higher rates of favourable, continuous dentin bridge formation with Biodentine.[14] Across the wider literature, head-to-head comparisons of MTA and Biodentine for both direct pulp capping and pulpotomy have generally reported comparable clinical success rates between the two materials, with the choice between them in practice often guided by handling preference, setting time and aesthetic considerations rather than a clear superiority of one material over the other.

3.7 Regenerative Endodontic Procedures: Extending the Vital Pulp Philosophy

In immature permanent teeth with necrotic pulps and incompletely formed roots, regenerative endodontic procedures (REPs) extend the pulp-preservation philosophy beyond VPT itself, aiming to disinfect the root canal system and create conditions permitting the ingrowth of a vital tissue capable of continued root development and apical closure, rather than relying on an artificial apical barrier.[19]

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The AAE's published clinical considerations for regenerative procedures set out case selection criteria (a necrotic, immature tooth not required to support a post or core restoration, and a compliant patient without contraindicating allergies), informed consent requirements, and a staged clinical protocol combining thorough but gentle canal disinfection with intracanal medicaments, induction of a blood clot scaffold, and coronal sealing with a hydraulic calcium silicate cement.[20] Reported clinical success rates for REPs range from approximately 80% to 100%, with root development observed in a substantial proportion of treated cases, reinforcing the broader principle — shared with VPT in mature teeth — that biologically based, minimally invasive strategies can achieve outcomes that traditional apexification and RCT protocols cannot replicate, namely continued physiological development of the root.[19]

3.8 Long-Term Outcomes of Traditional Root Canal Treatment: The Comparator Standard

Any discussion of VPT as an alternative to RCT must be grounded in accurate knowledge of RCT's own long-term outcome data. Landmark systematic reviews of primary root canal treatment reported pooled success rates ranging from approximately 68% to 85% at one year or more of follow-up, with outcomes significantly influenced by pre-operative periapical status, technical quality of the root filling, and the presence of a satisfactory coronal restoration.[16,17] Secondary (retreatment) root canal therapy has generally been reported to achieve lower success rates than primary treatment, underscoring the clinical and biological cost of treatment failure and the value of avoiding unnecessary pulp extirpation where a conservative alternative is viable.[18] Recent comparative outcome reviews have found that root canal treatment performed on vital pulps achieves outcomes at least as favourable as, and in some analyses superior to, treatment of necrotic pulps with periapical disease, reinforcing the broader principle that preserving pulp vitality — whether by VPT or by timely, well-executed RCT — is associated with more predictable long-term outcomes than treating an already necrotic or infected pulp space.[9]

3.9 An Integrated Clinical Decision Framework

Combining traditional endodontics with VPT into a single coherent clinical pathway requires the clinician to retain the technical discipline of conventional RCT — rubber dam isolation, aseptic technique, magnification, and careful radiographic and clinical review — while adopting a staged, biologically informed decision sequence. In practice, this can be summarised as follows: (i) for deep caries without frank exposure, selective or stepwise excavation with indirect pulp capping is the default first-line management; (ii) for a mechanical or carious exposure in an otherwise asymptomatic or mildly symptomatic tooth, direct pulp capping or partial pulpotomy with a hydraulic calcium silicate cement is attempted, provided haemorrhage is controlled within an acceptable time frame; (iii) for a mature tooth with clinical signs suggestive of symptomatic irreversible pulpitis but without radiographic periapical pathology, full pulpotomy may reasonably be offered as a first-line, tooth-preserving alternative to RCT, with the patient counselled that conversion to RCT remains available should healing not occur; and (iv) conventional RCT is retained as the definitive treatment for teeth with necrotic pulps, established periapical pathology, uncontrollable intra-operative haemorrhage, or VPT that has failed clinically or radiographically on review. This framework does not discard traditional endodontics in favour of VPT, nor the reverse; rather, it positions VPT as an extension of minimally invasive endodontic philosophy, with traditional RCT retained as the essential and reliable definitive pathway when biological preservation of the pulp is not achievable or has failed.

3.10 Limitations of the Current Evidence Base

Several limitations temper the strength of current recommendations. Follow-up periods in most VPT outcome studies rarely extend beyond five years, whereas RCT outcome data extend to a decade or more in some cohorts, leaving genuine uncertainty about the very long-term durability of pulpotomised teeth.[1] Diagnostic criteria for irreversible pulpitis remain imprecise and do not reliably predict the true histological extent of pulpal inflammation, meaning that some proportion of VPT failures may reflect case selection error rather than a true limitation of the technique itself.[21] Finally, heterogeneity in study design, capping material, exposure size, and success criteria across the literature limits the precision with which pooled success rates can be interpreted or applied to an

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individual clinical scenario, reinforcing the need for individualised case selection rather than blanket protocols.

4. Conclusion

Vital pulp therapy and traditional root canal treatment need not be regarded as competing philosophies. The evidence reviewed here indicates that, with rigorous case selection, aseptic technique and the use of hydraulic calcium silicate cements such as MTA and Biodentine, VPT — spanning indirect pulp capping, direct pulp capping, partial pulpotomy and full pulpotomy — can achieve success rates broadly comparable to conventional RCT, including in mature teeth with clinical features of irreversible pulpitis. Traditional endodontic discipline remains indispensable: it supplies the diagnostic rigor, isolation standards, and definitive fallback pathway that make conservative pulp preservation a safe first-line strategy rather than a gamble. An integrated approach, in which VPT is attempted as the primary tooth-preserving intervention and conventional RCT is reserved for cases of failure, necrosis or established periapical pathology, offers patients a less invasive, biologically respectful pathway to long-term tooth retention without sacrificing the reliability that traditional endodontics has long provided. Further long-term, standardised outcome data will be required to refine case-selection criteria and to confirm the durability of this combined approach beyond the five-year horizon currently available in the literature.

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