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REVIEW

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Vital pulp therapy in permanent teeth: a comparative analysis of six contemporary international guidance documents with a unified clinical decision framework

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Abstract

Vital pulp therapy (VPT) refers to biologically based procedures that preserve pulp vitality in permanent teeth with deep or extremely deep caries, with or without pulp exposure. Between 2019 and 2026, six contemporary international guidance documents were issued, addressing VPT, deep caries management, or both, by the European Society of Endodontology (ESE; 2019 and 2023), the American Association of Endodontists (AAE; 2021), the American Academy of Pediatric Dentistry (AAPD; 2025), the International Association of Paediatric Dentistry (IAPD; 2026 Porto Forum), and, jointly, the European Federation of Conservative Dentistry, ESE, the European Organisation for Caries Research, and the German Society of Conservative Dentistry (EFCD-ESE-ORCA; 2026). This narrative review compares these documents across key clinical decision domains. Broad convergence emerged in five areas: first-line use of calcium silicate cements after pulp exposure; caries-removal method selection guided by lesion depth and pulpal status, generally favoring selective or stepwise removal for deep caries and non-selective removal when findings suggest irreversible pulpitis; rigorous isolation and an aseptic operative protocol; achievement of hemostasis as a pivotal intraoperative criterion; and placement of a durable, well-sealed coronal restoration. Divergence remained in indications for selective and non-selective caries-removal method, numerical hemostasis thresholds, and cavity-lining recommendations. Authorship and methodological overlap suggest four partially distinct guidance lineages, rather than six fully independent sources. Drawing on this convergence, this review proposes a unified chairside framework from pulpal and periapical diagnosis to follow-up. The framework complements the individual documents and may be especially relevant to children and adolescents, for whom loss of pulp vitality in a permanent tooth may have substantial long-term consequences.

Keywords

Calcium silicate cement; Clinical practice guideline; Deep caries; Direct pulp capping; Pediatric dentistry; Permanent tooth; Pulpotomy; Vital pulp therapy

1. Introduction

Vital pulp therapy (VPT) encompasses a spectrum of biologically based, minimally invasive procedures aimed at preserving pulp vitality and function in permanent teeth affected by deep or extremely deep caries, with or without pulp exposure [1, 2]. Depending on the clinical presentation and the terminology adopted by individual guidance documents, these procedures include indirect pulp treatment, indirect pulp capping (IPC), direct pulp capping (DPC), partial pulpotomy (PP), and full (coronal) pulpotomy (FP) [3–9]. Advances in the understanding of pulp biology over the past two decades have reframed pulpal inflammation as a potentially reversible dynamic process. Concurrently, the introduction of bioactive calcium silicate cements (CSCs) has provided more predictable clinical performance than previously common calcium hydroxide [1]. Together, these developments have broadened the clinical application of VPT to include mature permanent teeth and those with signs and symptoms suggestive of symptomatic irreversible pulpitis [1, 2].

Six contemporary international guidance documents now formalize this expanded scope to varying degrees: the American Association of Endodontists (AAE) Position Statement: Vital Pulp Therapy (2021) [3]; the European Society of Endodontology (ESE) position statement Management of Deep Caries and the Exposed Pulp (2019) [4] and its subsequent S3-level clinical practice guideline Treatment of Pulpal and Apical Disease (2023) [5]; the American Academy of Pediatric Dentistry (AAPD) Guideline for Use of Vital Pulp Therapy in Permanent Teeth (2025) [6]; and the International Association

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of Paediatric Dentistry (IAPD) Porto Forum, introduced in the related Porto Declaration (2026) [7] and resulting in a principal guidance document, Consensus-Based Recommendations on Pulp Therapies in Primary and Permanent Teeth (2026) [8]. The sixth document is the EFCD-ESE-ORCA S3-level clinical practice guideline Deep Caries Management (2026) [9], jointly developed by the European Federation of Conservative Dentistry (EFCD), the ESE, the European Organisation for Caries Research (ORCA), and the German Society of Conservative Dentistry (DGZ), hereafter referred to as EFCD-ESE-ORCA. The latter guideline was informed by four dedicated systematic reviews [10–13] addressing caries removal strategy, necessity and type of lining material, management of the exposed pulp, and materials for pulp capping and pulpotomy.

The proliferation of guidance creates both opportunities and challenges. Sachdeva *et al*. [14] (2025) appraised four VPT guidance documents published through 2021 using the Appraisal of Guidelines for Research and Evaluation II (AGREE II) and AGREE–Recommendation EXcellence (AGREE–REX) instruments. The ESE 2019 position statement [4] was the only document classified as high quality on the basis of its overall AGREE II score, followed by the AAE 2021 position statement [3] in the moderate-quality range; the remaining two documents, the German Society of Endodontology and Dental Traumatology (GSEDT) 2019 scientific communication [15] and the Yong and Cathro 2021 review published in the Australian Dental Journal [16], received lower overall scores, with the GSEDT communication scoring lowest of the four [14]. Across the four documents, the Rigour of Development and Applicability rubrics were among the lowest-scoring domains, indicating recurring limitations in the reporting of guideline-development methods and in the support for clinical implementation. On this basis, the authors recommended adherence to the ESE 2019 position statement and called for greater methodological coherence among endodontic associations. Their appraisal did not include the subsequently published AAPD 2025, IAPD 2026, or EFCD-ESE-ORCA 2026 documents.

To our knowledge, no review has compared the recommendations of all six contemporary guidance documents side by side, examined the extent to which they represent independent evidence streams given their authorship and methodological overlap, or synthesized how clinicians might reconcile divergent recommendations across the clinical pathway. This comparison spans the principal clinical decision points, from pulpal and periapical diagnosis through caries-removal strategy and management of the exposed pulp to hemostasis assessment; root maturity was included as a cross-cutting modifier that influences treatment goals, alternative options, and follow-up interpretation.

This narrative review, therefore, had two aims: first, to compare the six guidance documents across these decision points and identify areas of convergence and divergence; and second, to synthesize the convergent recommendations into a unified clinical decision framework that operationalizes their shared principles as a single chairside pathway from pulpal and periapical diagnosis through treatment selection and long-term follow-up. The framework is offered as a synthesis of contemporary guidance and as a complement to, rather than a substitute for, the individual documents. The review is intended for pediatric and general dental practitioners. A particular emphasis is given to children and adolescent patients, in whom loss of pulp vitality in an immature permanent tooth may compromise continued root development, with potential lifelong consequences. This review addresses VPT in the context of deep and extremely deep carious lesions. Traumatic and iatrogenic exposures are considered only where the guidance documents distinguish them from carious exposure; traumatic exposure occurs in a pulp that was uninflamed at the moment of injury and through dentin that is not carious, whereas a carious exposure occurs in tissue already subjected to a bacterial front.

2. Methods

2.1 Information sources and search strategy

Guidance documents addressing deep or extremely deep caries management, VPT, or both, in permanent teeth, published between January 2019 and February 2026, were identified through targeted searches of the official websites of the AAE, ESE, EFCD, ORCA, AAPD, and IAPD. The websites of the American Dental Association, the British Society of Paediatric Dentistry, and the DGZ were also screened. Where an organization issued more than one eligible document during this period, all were included. To contextualize and interpret these documents, supporting literature was identified through PubMed and Scopus using terms related to VPT, pulp capping, pulpotomy, permanent teeth, calcium silicate cements, deep caries, caries removal, hemostasis, restoration, and follow-up. Additional candidate documents were identified by hand-searching the reference lists of the included documents, of relevant systematic reviews, and of published appraisals of guidance documents on VPT; these were then screened against the same eligibility criteria. Guidance-document searches were last conducted on 25 February 2026, and searches for supporting literature were updated on 09 May 2026. No additional eligible guidance documents were identified in the updated search.

2.2 Document selection

One author (CM) conducted the searches and applied the eligibility criteria to all identified documents. The included documents and the reasons for exclusion were then verified independently by each of the two remaining authors (PC and NC), who reviewed the full text of each document and returned written comments. Any difference of interpretation was to be resolved by discussion until consensus was reached, with reference back to the original wording of the document concerned; in practice, no disagreement arose regarding the documents selected.

Documents were eligible if they (1) were published or formally endorsed by a major professional organization in endodontics, pediatric dentistry, conservative dentistry, or cariology; (2) provided explicit guidance on deep or extremely deep caries management, VPT, or both, in permanent teeth; (3) were published between January 2019 and February 2026; and (4) were available in English. Documents limited exclusively

to primary teeth, local institutional protocols, and publications that did not provide clinical recommendations were excluded.

Six documents met the eligibility criteria: the AAE 2021 position statement [3]; the ESE 2019 position statement [4]; the ESE 2023 S3-level clinical practice guideline [5]; the AAPD 2025 clinical practice guideline [6]; the IAPD 2026 Consensus-Based Recommendations [8]; and the EFCD-ESE-ORCA 2026 S3-level clinical practice guideline [9]. The IAPD Porto Declaration [7] was used as a related contextual publication, but was not counted as a separate guidance document. For the IAPD recommendations [8], only Working Group 3 recommendations concerning permanent teeth were included.

Two documents included in the AGREE II appraisal by Sachdeva *et al*. [14] were considered, but were not retained as primary comparison documents. The review by Yong and Cathro [16], although published in the Australian Dental Journal, is an individually authored narrative review rather than a document issued or formally endorsed by a professional organization, and therefore did not meet criterion (1). The GSEDT 2019 scientific communication [15] met all eligibility criteria; however, it was excluded as a separate comparison document by consensus of all three authors, as it is a national narrative summary that overlaps in scope and period with the ESE 2019 position statement and does not constitute an independent evidence stream.

2.3 Data extraction

Recommendations were extracted from each document by one author (CM) and recorded in a structured extraction table. Source wording was retained verbatim during extraction and was paraphrased only at the writing stage. The extracted content was then checked against the source documents by the two remaining authors (PC and NC), each working separately, and their written comments were returned. Discrepancies were resolved by discussion with reference to the original text. Consistent with the narrative design of this review, selection and extraction were each performed by a single author and then checked by the other two, rather than being carried out twice in parallel by independent reviewers with statistical measurement of agreement.

Recommendations were extracted across six principal clinical decision points: (1) pulpal and periapical diagnosis; (2) case selection for VPT; (3) caries-removal strategy according to lesion depth and pulpal presentation; (4) management when pulp exposure occurs; (5) procedure selection according to exposure characteristics and pulp status; and (6) hemostasis assessment. Root maturity was examined as a cross-cutting modifier of treatment goals, alternative options, and follow-up. Cavity lining, definitive restoration, and follow-up were examined as additional management domains.

For each document, relevant recommendations, qualifying conditions, supporting evidence, and reported grades of recommendation or consensus were tabulated. Where wording was unclear, explanatory text and supporting evidence cited within the document were consulted. The six documents differ in whether and how they grade their recommendations, drawing variously on the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach, the grading scheme of the German Association of the Scientific Medical Societies (AWMF), and Delphi consensus; each scheme was retained as reported in the source and is summarized in **Supplementary Table 1** (Ref. [3–6, 8, 9]), Panel A. Where recommendation grades and consensus categories are reported, the capitalization used in the source document is retained; AWMF consensus categories (Strong consensus, Consensus) are, therefore, capitalized when reported as formal labels, and lower case is used in running prose.

2.4 Data synthesis

Recommendations were compared to identify areas of convergence, divergence, and topics not addressed. Convergent recommendations were synthesized into a unified clinical decision framework extending from diagnosis to long-term follow-up. Areas of divergence were retained as alternative pathways or points requiring clinical judgment. The framework was constructed using five rules, according to how the documents relate at each decision point. (1) Where all six documents converged, the shared recommendation entered the algorithm as a single pathway. (2) Where documents differed only in terminology, terms were first mapped (Table 1, Ref. [3–6, 8, 9]) and a single node was used. (3) Where documents diverged substantively, no single document was privileged, and the available options were retained as parallel choices. When a choice would affect the pathway taken (*e.g.*, caries-removal strategy or hemostasis time thresholds), the divergence was marked in a clinical note; when it would not (*e.g.*, cavity lining; see Section 6), the step was presented as optional. (4) Where a default was required for the algorithm to be operable, a pragmatic default was adopted and identified by source, with advice to individualize (follow-up schedule, based on ESE 2019). (5) Where no document addressed a decision point, an author-derived operational convention was applied, expressed qualitatively and labeled as such (exposure-size categories for procedure selection). Cross-cutting considerations on which the documents converged, such as the influence of root maturity and the preoperative criteria for considering VPT in symptomatic irreversible pulpitis, are presented as clinical notes alongside the relevant decision points. The clinical algorithm is presented as Fig. 1. Overlap in authorship, methodological frameworks, and supporting evidence sources across the six guidance documents were also examined to assess whether apparent agreement reflected fully independent guideline-development processes.

3. Terminology and nomenclature

3.1 Overarching term

The AAE, AAPD, and IAPD use “vital pulp therapy” [3, 6, 8], whereas the ESE and EFCD-ESE-ORCA documents [4, 5, 9] generally use “vital pulp treatment”. Because these terms refer to the same overarching concept, “vital pulp therapy” (VPT) is used throughout this review.

TABLE 1. Cross-document terminology for caries-removal strategy and vital pulp therapy procedures.

Clinical context	Underlying procedure	Term used	Guidance document(s)
Deep caries; intended not to expose pulp	Selective one-stage caries removal to avoid pulp exposure, followed by sealing	Indirect pulp treatment (IPT)	AAPD 2025 [6]; IAPD 2026 [8]
Deep caries; intended not to expose pulp	Selective one-stage caries removal	Selective carious-tissue or selective caries removal	ESE 2023 [5]; EFCD-ESE-ORCA 2026 [9]
Deep caries; intended not to expose pulp	Staged caries removal with subsequent re-entry	Stepwise caries removal or stepwise caries excavation	ESE 2023 [5]; EFCD-ESE-ORCA 2026 [9]
No pulp exposure after non-selective removal	Biomaterial placed over the remaining hard dentin barrier	Indirect pulp capping (IPC)	ESE 2019 [4]
No pulp exposure; procedure not explicitly defined	Procedure not explicitly defined in the document	Indirect pulp capping[a]	AAE 2021 [3]
Pulp exposure	No pulp tissue removed	Direct pulp cap/capping (DPC)[b]	All six documents [3–6, 8, 9]
Pulp exposure	Superficial portion of the coronal pulp removed	Partial pulpotomy (PP)	All six documents [3–6, 8, 9]
Pulp exposure	Entire coronal pulp removed to the level of the canal orifices	Full pulpotomy (FP)	ESE 2019 [4]; ESE 2023 [5]; AAPD 2025 [6]; IAPD 2026 [8]; EFCD-ESE-ORCA 2026 [9]
Pulp exposure	Entire coronal pulp removed to the level of the canal orifices	Complete pulpotomy	AAE 2021 [3]

[a] *The AAE 2021 position statement lists "indirect or direct pulp capping" but does not provide glossary-level definitions of these procedures [3].*
[b] *The ESE 2019 position statement distinguishes Class I direct pulp capping following traumatic or iatrogenic exposure through sound dentin from Class II direct pulp capping following carious exposure through bacterially contaminated dentin, for which an enhanced aseptic protocol is recommended [4].*
This table compares nomenclature rather than clinical indications. Recommendations regarding when selective, stepwise, or non-selective caries removal should be performed are presented in Section 5.
Protective liner placement is not treated as a distinct VPT procedure in any of the six guidance documents; its terminology, indications, and relationship to cavity lining are discussed in Section 6.
AAPD, American Academy of Pediatric Dentistry; AAE, American Association of Endodontists; ESE, European Society of Endodontology; EFCD, European Federation of Conservative Dentistry; IAPD, International Association of Paediatric Dentistry; ORCA, European Organisation for Caries Research.

3.2 Procedural terminology

Differences in terminology are greatest in the management of deep caries without pulp exposure (Table 1). The terms "direct pulp capping" and "partial pulpotomy" are used across all six documents. For removal of the entire coronal pulp to the level of the canal orifices, five documents use "full pulpotomy" [4–6, 8, 9], whereas the AAE uses "complete pulpotomy"; these terms describe the same procedure [3]. Accordingly, "full pulpotomy" is used throughout this review, with "complete pulpotomy" retained when referring specifically to the AAE document. The distinction between indirect pulp treatment (IPT) and IPC is primarily procedural, rather than material-based. IPT is an exposure-avoidance strategy based on selective caries removal [6, 8], whereas IPC, as narrowly defined by the ESE 2019 [4], follows non-selective removal to a hard dentin barrier.

4. Clinical indications, diagnostic eligibility, and contraindications

The extension of VPT indications beyond reversible pulpitis and immature teeth to include symptomatic irreversible pulpitis in mature permanent teeth represents one of the most clinically significant developments in contemporary endodontic practice. All guidance documents acknowledge this extension, although the specificity and strength of their guidance differ. A critical appraisal of the underlying evidence for this indication is provided in Section 15.1.

4.1 Normal pulp and reversible pulpitis

All six guidance documents support pulp-preserving management for vital permanent teeth diagnosed with normal pulp or reversible pulpitis, whether or not pulp exposure occurs during treatment. For deep caries without symptoms suggestive of irreversible pulpitis, most documents favor selective or stepwise caries removal to avoid exposure [4–9], whereas the AAE 2021

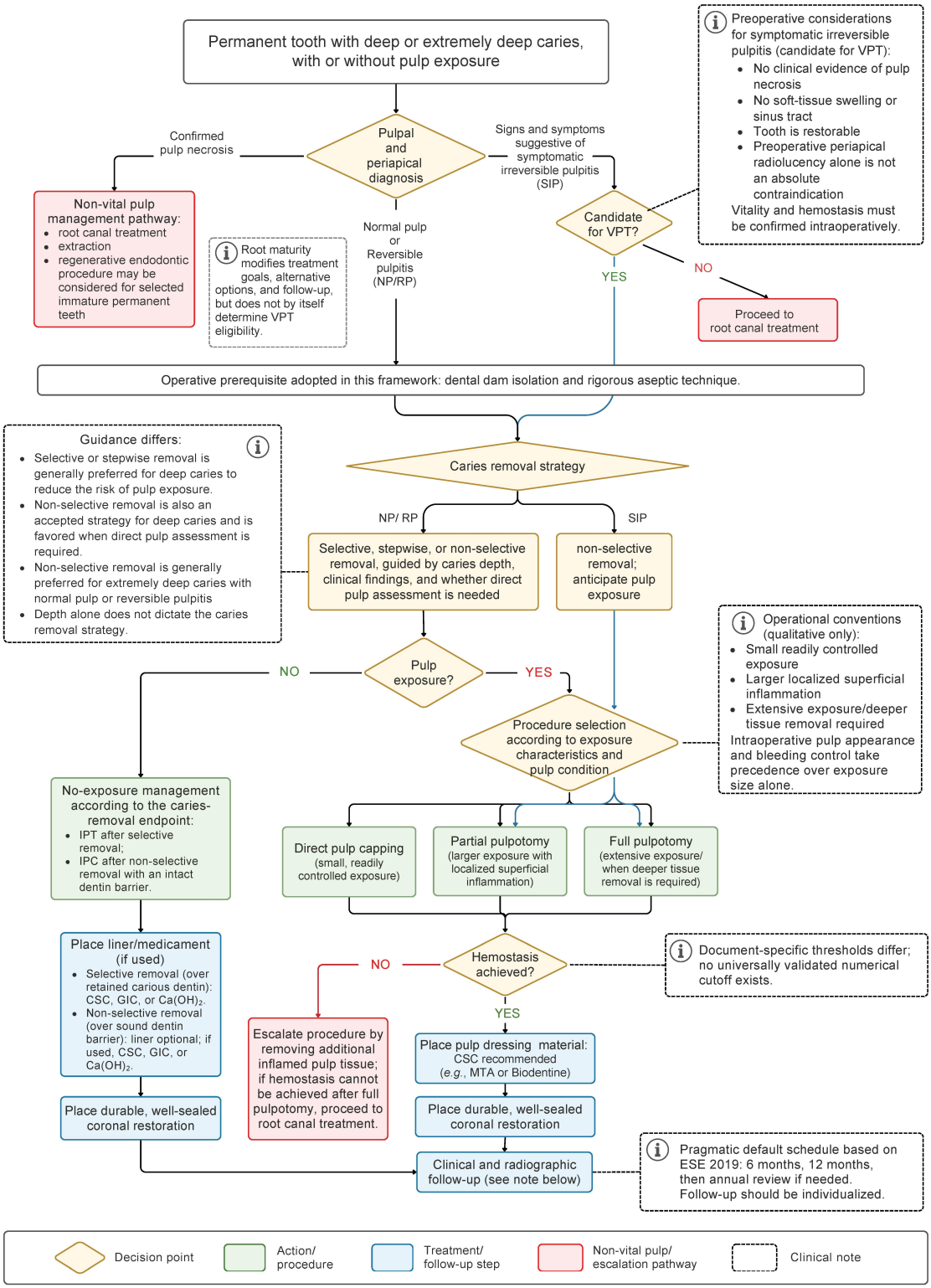


FIGURE 1. Unified clinical treatment algorithm (flowchart) for vital pulp therapy in deep and extremely deep carious permanent teeth. The framework synthesizes six contemporary guidance documents into a single chairside pathway from pulpal and periapical diagnosis to follow-up. Dashed callouts contain clinical notes of three kinds: points at which the guidance documents diverge and the available options are retained; conventions or defaults adopted by the authors where the documents differ or are silent; and cross-cutting considerations on which the documents converge. Author-derived conventions and defaults are identified as such within the note and are not graded recommendations. Box colors are defined in the figure key. $Ca(OH)_2$, calcium hydroxide; CSC, calcium silicate cement; GIC, glass ionomer cement; IPC, indirect pulp capping; IPT, indirect pulp treatment; MTA, mineral trioxide aggregate; NP, normal pulp; RP, reversible pulpitis; SIP, symptomatic irreversible pulpitis; VPT, vital pulp therapy; ESE, European Society of Endodontology.

position statement [3] emphasizes complete caries removal to permit direct visualization; these caries-removal strategies are detailed in Section 5. When carious or mechanical pulp exposure occurs, DPC, PP, or FP may be considered according to the clinical presentation, exposure characteristics, pulpal appearance, and ability to achieve hemostasis.

The ESE 2019 position statement is the only document to formalize the distinction between carious and traumatic exposure. It defines Class I DPC as that following traumatic or iatrogenic exposure through sound dentin, and Class II DPC as that following carious exposure through bacterially contaminated dentin, for which an enhanced aseptic protocol is recommended [4]. The other five documents do not adopt this classification, although the systematic review underpinning the AAPD 2025 guideline examines the reason for pulp exposure (caries or trauma) as an outcome moderator [6]. Because the evidence underlying most recommendations in these documents derives from carious exposure, the recommendations should not be assumed to transfer directly to traumatic exposure, where the surrounding dentin is sound and bacterial contamination is not established at the time of injury.

4.2 Symptomatic irreversible pulpitis

The AAE 2021 position statement describes pulpitis as a temporally and spatially graded disease. It notes that symptomatic pulps may be candidates for VPT when viability is confirmed through direct visualization. It cites 1- to 2-year success rates of 85–100% for VPT with CSCs in teeth diagnosed with irreversible pulpitis, but does not provide a graded recommendation [3].

The ESE 2019 position statement states that FP may be successful when irreversible inflammation is considered confined to the coronal pulp; however, it cautions that stronger long-term prospective randomized evidence is required before this can be regarded as the treatment of choice [4]. The ESE 2023 S3-level clinical practice guideline provides a weak recommendation, based on low-quality evidence and Consensus, that either root canal treatment or FP may be offered for permanent teeth with spontaneous pain; for this recommendation, 21.2% of panel members abstained because of conflicts of interest [5]. The recommendation presents FP as a treatment alternative to root canal treatment, but does not establish equivalence between the two interventions.

The EFCD-ESE-ORCA 2026 S3-level clinical practice guideline provides a Grade B recommendation, based on low-certainty evidence and Strong consensus, that either PP or FP for the exposed pulp may be performed after non-selective caries removal in permanent teeth with pulp exposure and signs and symptoms of irreversible pulpitis [9].

The AAPD 2025 guideline strongly recommends non-selective caries removal in teeth with extremely deep caries or deep caries accompanied by spontaneous, nocturnal, or lingering pain, provided that no radiographic signs of infection are present (moderate certainty); the purpose of this is to expose and assess the pulp. When pulpotomy is indicated, FP with a CSC is conditionally preferred over PP, based on low-certainty evidence [6].

The IAPD 2026 Porto Forum provides consensus-based recommendations, graded as strong on the basis of Delphi agreement above 70%. It supports FP with a CSC as an alternative to non-surgical root canal treatment for mature permanent teeth with carious pulp exposure and signs and symptoms of irreversible pulpitis, provided that no signs of pulp necrosis are present. It also recommends FP for immature permanent teeth with extremely deep caries and irreversible pulpitis without necrosis to preserve vitality and support continued root development [8].

4.3 Contraindications

The AAPD 2025 guideline is the only document to provide a discrete graded recommendation against pulpotomy. It strongly recommends, based on moderate-certainty evidence, that pulpotomy should not be performed in permanent teeth with irreversible pulpitis when pulpal bleeding cannot be controlled or in the presence of preoperative periapical involvement attributable to infection [6]. The other guidance documents generally express contraindications through eligibility criteria, procedural prerequisites, or treatment-escalation rules, rather than through formal contraindication lists.

Recurring findings that generally preclude VPT or require escalation of treatment include confirmed pulp necrosis, purulent exudate, a sinus tract or soft-tissue swelling, inability to achieve hemostasis after appropriate removal of inflamed pulp tissue, and a non-restorable tooth. Periapical radiolucency should not, however, be regarded as an automatic contraindication across all documents; its interpretation is dependent on the associated clinical findings and the diagnostic criteria applied.

The AAPD 2025 and IAPD 2026 documents also emphasize patient- and tooth-related factors and treatment-feasibility considerations. These include medical complexity or special healthcare needs, difficulty achieving local anesthesia, limited mouth opening, inability to cope with treatment, severe gag reflex, facial swelling, diagnostic uncertainty, complications from previous pulp therapy, periodontal conditions, patient or parent preferences, esthetic considerations, and financial cost [6, 8]. These factors may influence case selection or necessitate an alternative treatment approach, especially in pediatric patients. They are retained in the unified clinical decision framework presented in Section 14.

5. Caries removal protocols

Recommendations for caries removal are strongly stratified by lesion depth and pulpal presentation. The AAE 2021 position statement adopts the most uniform stance, advocating complete (non-selective) removal of demineralized enamel and infected dentin to permit direct visualization and assessment of the pulp under magnification. Caries-detection agents and laser fluorescence are described as potentially helpful adjuncts [3].

5.1 Normal pulp or reversible pulpitis

For deep caries in teeth with a pulpal diagnosis of normal pulp or reversible pulpitis, most guidance documents favor an exposure-avoidance strategy [4–6, 8, 9]. The ESE 2019 posi-

tion statement recommends either selective one-stage removal to soft or firm dentin or stepwise excavation, and states that non-selective removal is no longer the treatment of choice [4].

The ESE 2023 S3-level clinical practice guideline, whose primary scope is the treatment of pulpal and apical disease rather than caries removal, does not include an evidence-based recommendation on caries removal strategy due to a lack of identified eligible studies. Its linked expert consensus-based recommendation states that either selective or stepwise removal to avoid pulp exposure, or DPC or pulpotomy after non-selective removal and pulp exposure, may be considered (expert consensus-based recommendation; expert-based evidence; grade Strong; Consensus) [5]. The ESE 2023 guideline, therefore, does not establish a preference, and the ESE 2019 position statement remains the more detailed ESE source for caries-removal protocols.

The EFCD-ESE-ORCA 2026 guideline suggests both selective removal to soft dentin and stepwise removal over non-selective removal for deep caries associated with no symptoms or reversible pulpitis (both Grade B; Strong consensus; certainty very low to low across outcomes) [9, 10]. The guideline does not grade selective against stepwise removal; its accompanying text notes that this choice is not fully resolved, and is best guided by patient- and dentist-related factors (preferences, effort, and availability) together with caries penetration depth. Selective removal may be preferred for lesions radiographically extending into the inner third, but not the inner quarter of dentin, whereas stepwise removal may also be used for lesions reaching the inner quarter [9].

The AAPD 2025 guideline provides the strongest recommendation, favoring selective removal over both non-selective and stepwise removal (strong recommendation; high certainty; 60-month evidence) [6]. The IAPD 2026 Porto Forum similarly supports selective or stepwise removal for deep caries, but does not extend this to extremely deep lesions [8].

5.2 Extremely deep caries or findings suggestive of irreversible pulpitis

Recommendations diverge for extremely deep caries and those accompanied by signs or symptoms suggestive of irreversible pulpitis. The AAPD 2025 guideline aligns with the AAE approach, strongly recommending non-selective removal to allow assessment of the pulp in teeth with extremely deep caries or deep caries accompanied by spontaneous, nocturnal, or lingering pain (moderate certainty; 24- to 60-month evidence) [6].

The EFCD-ESE-ORCA 2026 guideline does not recommend non-selective removal solely on the basis of extremely deep caries. Instead, it notes that pulp exposure is highly likely and should be anticipated, while evidence remains insufficient to determine the roles of selective and stepwise removal in this subgroup [9]. The guideline further notes that the radiographic sign used to define extremely deep caries (the absence of a residual dentin band over the pulp) depends on radiographic projection and is, therefore, unreliable. Because of this diagnostic uncertainty, it applies the same caries-removal recommendation whether or not the band is visible. Clinicians are advised to prepare for possible pulp exposure and subsequent management [9]. Nevertheless, when pulp exposure occurs in teeth with signs and symptoms suggestive of irreversible pulpitis, the guideline suggests PP or FP after non-selective excavation [9].

Overall, for deep caries with normal pulp or reversible pulpitis, several documents prefer an exposure-avoidance strategy using selective or stepwise removal. The AAE 2021 favors non-selective removal throughout, and the ESE 2023 states no preference. For extremely deep caries or teeth with signs and symptoms suggestive of irreversible pulpitis, several documents affirmatively recommend non-selective removal to expose and assess the pulp. They differ, however, on the cases for which this is indicated: whether lesion depth alone is sufficient, or whether findings suggestive of irreversible pulpitis are also required. Divergence, therefore, persists across both scenarios rather than resolving into a single agreed strategy.

6. Cavity lining recommendations

The use of cavity liners following caries removal for deep carious lesions is addressed most directly by the EFCD-ESE-ORCA 2026 guideline [9]; the ESE 2019 position statement [4] offers a contrasting recommendation on placing material over deep unexposed dentin.

The systematic review by Kosan *et al.* [11] (2025) underpinning the EFCD-ESE-ORCA guideline included 12 randomized controlled trials involving 1184 teeth and encompassed heterogeneous caries-removal protocols, including selective (partial), stepwise, and non-selective (complete) removal. Across these approaches, no consistent clinical advantage of cavity liner placement was identified. The guideline, therefore, suggests that cavity liners should not be routinely applied in permanent teeth with deep caries and a diagnosis of normal pulp or reversible pulpitis (Grade B recommendation; very low- to low-certainty evidence; Strong consensus) [9]. The decision to place a liner may instead be guided by clinical judgment, individual patient circumstances, and economic considerations [9]. The guideline further notes that any decision to line based on the dentin remaining over the pulp is unsupported, with no available evidence for a residual-dentin-thickness threshold and no reliable method to measure that thickness. The impact of residual dentin thickness on the lining decision is identified as a priority for further research [9].

In contrast, the ESE 2019 position statement recommends that a hydraulic CSC or glass ionomer cement be placed over the residual deep dentin before the definitive restoration during procedures aimed at avoiding pulp exposure [4]. The stated rationale is that the thickness of remaining dentin over the pulp cannot be accurately assessed clinically, so a biologically based material is advised as a precaution [4]. The two documents, therefore, cite the same clinical uncertainty (the unmeasurable thickness of residual dentin), but reach opposite operational conclusions: ESE 2019 advises placing a material as a safeguard, whereas EFCD-ESE-ORCA finds no consistent benefit to routine lining and leaves the decision to clinical judgment. The divergence is partly one of terminology, since ESE 2019 frames the material as a biologically based pulp-protective measure, rather than as a routine cavity liner.

The remaining four documents address this question less directly. The AAPD 2025 guideline frames it as a choice of medicament for indirect pulp treatment rather than as cavity lining, and concludes, in a conditional recommendation, that 24-month success is not significantly altered by the material used, whether glass ionomer cement, calcium hydroxide, or CSC (moderate certainty) [6]. The IAPD 2026 Porto Forum issues no separate lining recommendation, but permits glass ionomer cement when the pulp remains unexposed (strong consensus-based recommendation) [8]. The ESE 2023 guideline does not address cavity lining, its scope being the treatment of pulpal and apical disease, and its material guidance concerns the pulp-dressing material placed on exposed pulp [5]. Similarly, the AAE 2021 position statement does not address lining over unexposed dentin. Its restorative guidance concerns the placement of a CSC as the primary sealing material over exposed pulp, followed immediately by a long-term restoration, without an intervening liner (see Section 9) [3]. This is consistent with its advocacy of non-selective removal and direct assessment of the pulp, an approach in which retained carious dentin requiring a liner does not arise.

The documents, therefore, differ not only in their conclusions, but in whether they treat cavity lining as a distinct clinical question at all: only the EFCD-ESE-ORCA 2026 guideline formulates it as a graded PICOTS (Population, Intervention, Comparison, Outcome, Time, Setting) question. These liner recommendations concern the management of unexposed dentin after caries removal, and do not bear on the CSCs placed directly on exposed pulp during VPT; the question of which material to place over residual dentin is compared across documents in Section 8.2. In the unified framework (Fig. 1), liner placement over unexposed dentin is presented as optional rather than mandatory, since the two positions lead to the same subsequent step (placement of a durable coronal restoration) and the choice does not alter the pathway taken.

7. Hemostasis criteria and techniques

The assessment and control of pulpal bleeding after pulp exposure or pulp-tissue removal together constitute a key intraoperative decision point in VPT. Achievement of hemostasis permits the assessment of the remaining pulp and supports continuation of a pulp-preserving procedure, whereas persistent or uncontrolled bleeding may indicate that additional inflamed tissue should be removed. If hemostasis cannot be achieved after FP, conversion to pulpectomy and root canal treatment may be required.

7.1 Hemostasis agents

Sodium hypochlorite (NaOCl) is the hemostatic and antimicrobial agent most frequently specified across the guidance documents, although the strength of recommendation and specified concentration vary. The AAPD 2025 guideline strongly recommends NaOCl irrigation or NaOCl-soaked cotton pellets over saline for DPC (moderate certainty; 36- to 42-month data) based on success rates of 83% with NaOCl and 67% with saline. For pulpotomy, NaOCl is conditionally suggested over saline, based on very-low-certainty evidence; no concentration is specified [6].

The AAE 2021 position statement describes NaOCl as suitable for direct contact with pulp tissue at concentrations ranging from dilute solutions to full-strength commercial preparations [3]. The ESE 2019 position statement recommends cotton pellets soaked with NaOCl (0.5–5%) or chlorhexidine (0.2–2%) for disinfection and hemostasis. Saline is noted to have limited disinfecting activity, while ferric sulfate, although hemostatically effective, may interfere with assessment of pulpal bleeding [4].

The IAPD 2026 Porto Forum emphasizes the importance of achieving hemostasis, but does not recommend a specific agent or concentration [8]. Likewise, the EFCD-ESE-ORCA 2026 guideline provides no graded recommendation for a specific hemostatic agent; its expert-based recommendation instead supports an enhanced VPT protocol incorporating dental dam isolation, intraoperative antimicrobial lavage, magnification, and a suitable pulp-dressing material [9].

7.2 Hemostasis time thresholds

The guidance documents differ in whether they specify a time threshold for achieving hemostasis. The AAPD 2025 guideline conditionally recommends PP or FP when hemostasis can be achieved within 6 minutes, based on low-certainty evidence from studies with 12- to 24-month follow-up. Its supporting systematic review reported a mean hemostasis time of 4.25 minutes for PP and a range of 4.25–5.78 minutes for FP [6, 17].

The ESE 2019 position statement specifies that, if hemostasis cannot be achieved within 5 minutes, additional pulp tissue should be removed, with escalation from DPC or PP to a deeper or FP. If bleeding remains uncontrolled after FP, pulpectomy and root canal treatment are indicated [4].

The AAE 2021 position statement indicates that NaOCl is typically applied to the resected pulp for 5–10 minutes, although durations may vary [3]. This represents the usual duration of NaOCl application rather than a defined threshold for determining VPT eligibility or treatment escalation.

The ESE 2023, EFCD-ESE-ORCA 2026, and IAPD 2026 documents do not specify a fixed numerical time threshold. Instead, they emphasize the ability to achieve hemostasis and the intraoperative appearance and condition of the remaining pulp. Evidence supporting any specific cutoff remains limited [8, 18]; this issue is considered further in Section 15.1.

8. Recommended materials and evidence basis

Material selection is one of the most extensively studied domains across the six guidance documents, and is an area of strong convergence. All six favor CSCs for placement in direct contact with exposed pulp during DPC or pulpotomy. The biological rationale for preferring CSCs includes their biocompatibility, ability to set in the presence of moisture, antimicrobial activity associated with an alkaline environment, and capacity to promote mineralized tissue formation and dentin-bridge development. Clinical evidence also generally favors CSCs over calcium hydroxide when the material is placed directly on exposed pulp [1, 2].

Throughout this review, CSC is used as the umbrella term for this material class. However, the source documents use different conventions. The ESE 2019, ESE 2023, and EFCD-ESE-ORCA 2026 documents use hydraulic calcium silicate cement (HCSC) [4, 5, 9], the AAE 2021 and IAPD 2026 documents use calcium silicate cement (CSC) [3, 8], and the AAPD 2025 guideline uses calcium silicate cement (CS) [6]. The qualifier "hydraulic" denotes setting through hydration and distinguishes these materials from resin-containing, light-cured calcium silicate materials. HCSC is retained when reporting recommendations specifically restricted to hydraulic materials; CSC is otherwise used as the general term.

8.1 Materials for exposed pulp

The EFCD-ESE-ORCA 2026 guideline suggests that DPC or pulpotomy should be performed using an HCSC rather than calcium hydroxide in permanent teeth with no symptoms or reversible pulpitis (Grade B; moderate certainty for absence of clinical symptoms and radiographic pathology; Strong consensus) [9]. Its supporting systematic review included five randomized controlled trials involving 552 teeth; HCSCs were associated with a higher probability of absence of pathology than calcium hydroxide (odds ratio (OR) 2.68, 95% confidence interval (CI) 1.70–4.22) [13].

The ESE 2023 guideline provides an expert consensus-based recommendation (grade Strong; Consensus) for an enhanced operative protocol incorporating an HCSC when DPC or pulpotomy is performed in immature or mature permanent teeth with no or non-spontaneous pain [5]. The ESE 2019 position statement similarly recommends placement of an HCSC directly on exposed pulp during DPC, PP, or FP and cautions against direct pulp contact with resin-based composites or dentin-bonding agents [4].

The AAPD 2025 guideline strongly recommends CSC over calcium hydroxide for DPC in teeth with normal pulp or reversible pulpitis (moderate certainty; 36-month success, 88% versus 70%) [6]. Following pulp exposure, DPC, PP, or FP may be performed using CSC regardless of root maturation (conditional recommendation; low certainty) [6]. For permanent teeth in esthetic areas, a non-staining CSC is strongly recommended (high certainty after 12 to 24 months); the supporting systematic review reported discoloration in 83% of teeth treated with bismuth oxide–containing mineral trioxide aggregate (MTA) and none of those treated with Biodentine [6, 17].

The IAPD 2026 Porto Forum recommends CSCs for VPT in permanent teeth with deep caries and for PP or FP in teeth with irreversible pulpitis without necrosis [8]. The AAE 2021 position statement identifies CSCs, including MTA and other tricalcium silicate–based materials, as contemporary VPT materials and reports 1- to 2-year success rates of 85–100% in teeth with symptomatic or asymptomatic irreversible pulpitis. Calcium hydroxide, glass ionomer cements, and resin-based materials are reported to have lower and more variable success rates of 43–92%; however, these ranges were derived from heterogeneous studies and clinical contexts and should not be interpreted as direct comparative estimates [3].

8.2 Materials when the pulp is not exposed

Material recommendations are less restrictive when caries removal does not result in pulp exposure. The choice of whether to place a liner over unexposed dentin was compared in Section 6; the question here is which material the documents permit when one is used. The AAPD 2025 guideline permits glass ionomer cement, calcium hydroxide, or CSC as the medicament for indirect pulp treatment, because material choice did not significantly affect 24-month success (conditional recommendation; moderate certainty) [6]. The ESE 2019 position statement permits either an HCSC or glass ionomer cement over residual or deep dentin following selective, stepwise, or non-selective caries removal [4]. The IAPD 2026 Porto Forum also permits glass ionomer cement when the pulp remains unexposed [8].

Overall, the six guidance documents consistently favor CSCs or HCSCs when a material is placed directly on exposed pulp. Calcium hydroxide and glass ionomer cement remain acceptable in selected non-exposure applications, but calcium hydroxide is no longer preferred for DPC or pulpotomy. In visible areas, non-staining CSC formulations should be selected to reduce the risk of tooth discoloration.

9. Restoration recommendations and prognostic impact

All six guidance documents emphasize the importance of a durable, well-sealed coronal restoration for long-term VPT success, with coronal leakage recognized as a major threat to treatment outcome.

The AAPD 2025 guideline concludes that the effects of restoration timing and type on VPT success could not be determined conclusively from the available evidence. It nevertheless recommends placement of a well-sealed restoration, preferably at the same visit as the VPT, but does not specify a preferred material or design for permanent teeth [6]. The IAPD 2026 Porto Forum similarly emphasizes that a well-sealed coronal restoration supports long-term success, without prescribing a specific restoration type [8].

The AAE 2021 position statement places particular emphasis on immediate restoration, identifying a minimal interval between VPT and the placement of a foundational long-term restoration as a predictor of successful outcome [3]. Immediate foundational restoration is not equated with mandatory cuspal coverage, but may provide a foundation for one if subsequently indicated. The AAE advises an appropriate waiting period before additional preparation for definitive cuspal coverage, with the decision based on the absence of signs and symptoms and the tooth's susceptibility to fracture [3].

The ESE 2019 position statement recommends immediate placement of a definitive restoration after application of the pulp-dressing material under dental dam isolation and magnification, but does not specify the restorative material or design [4]. The ESE 2023 guideline does not issue a separate restoration recommendation [5]. The EFCD-ESE-ORCA 2026 guideline incorporates restoration within its selective, stepwise, and non-selective caries-removal pathways, rather than issuing a separate recommendation on restoration type [9].

Overall, the documents converge on the need for prompt placement of a durable, well-sealed restoration, but do not mandate full cuspal coverage for all VPT-treated permanent teeth. Evidence is insufficient to determine when direct intracoronal restoration is adequate and when cuspal coverage provides additional benefit, particularly for posterior teeth. Given this important knowledge gap, restoration choices require individualized assessment of the remaining tooth structure, cusp integrity, functional loading, fracture susceptibility, esthetic requirements, and the feasibility of definitive restoration.

10. Success and failure criteria

The six guidance documents vary in the specificity with which they define VPT outcomes. The AAPD 2025 guideline provides the clearest explicit operational definition, defining success as the concurrent absence of pain, clinical signs or symptoms of infection, and postoperative radiographic pathology associated with the treated tooth [6].

The ESE 2023 and EFCD-ESE-ORCA 2026 guidelines frame outcomes through structured PICOTS questions rather than a single binary definition of success. In the ESE 2023 guideline, tooth survival is designated as the most critical outcome for VPT-related questions. Other outcomes rated critical include pain, tenderness, swelling, need for medication, emerging apical radiolucency, and response to pulp sensibility testing, where applicable; those rated important include tooth function, need for further intervention, adverse effects, oral health–related quality of life, and sinus tract formation [5]. The EFCD-ESE-ORCA guideline similarly prioritizes tooth survival or treatment failure according to the clinical question, and also considers loss of pulp vitality, symptoms, patient-reported outcomes, restoration longevity, adverse events, and treatment burden [9].

The ESE 2019 position statement presents follow-up criteria narratively rather than as a formal definition. These include absence of pain and other symptoms, absence of apical periodontitis and internal root resorption, and, in immature teeth, radiographic evidence of continued root development. A positive response to sensibility testing, within normal limits, may provide additional evidence of pulp vitality; however, teeth treated by FP and those with extensive restorations may not respond reliably [4].

The AAE 2021 position statement does not provide a discrete success-criteria list, instead emphases preservation of pulp vitality and function, reliable mineralized-tissue formation, and continued tooth function [3]. The IAPD 2026 Porto Forum likewise does not present a single consolidated definition of success for permanent teeth, but incorporates relevant outcomes across its recommendations [8].

For clinical application, successful VPT may, therefore, be summarized as maintenance of a functional tooth without pain or clinical signs of infection, absence of new or progressive radiographic pathology, and no need for further endodontic intervention. In immature teeth, continued root development is an additional desired outcome. Failure is indicated by persistent or recurrent symptoms, clinical infection, development or progression of radiographic pathology, loss of restorability, or the need for root canal treatment or extraction.

11. Follow-up protocols and duration

Only one of the six guidance documents provides a discrete clinical follow-up schedule for VPT. The ESE 2019 position statement recommends assessment at 6 and 12 months postoperatively, followed, if necessary, by annual reviews for a further 4 years [4]. Thus, follow-up may extend to approximately 5 years, depending on the clinical course.

The ESE 2023 S3-level clinical practice guideline provides a strong expert consensus-based recommendation that cases be monitored for a prolonged period and that follow-up be extended when healing remains uncertain, but does not prescribe fixed numerical intervals [5]. Its explanatory text refers to clinical assessment at 6 months, radiographic assessment at 1 year, and further review when symptoms persist or healing is uncertain. The follow-up periods specified in its PICOTS questions are eligibility criteria for the supporting systematic reviews rather than recommended clinical recall intervals.

Similarly, the EFCD-ESE-ORCA 2026 guideline specifies minimum follow-up periods for inclusion in its supporting systematic reviews, but does not provide a clinical recall schedule [9]. The AAE 2021, AAPD 2025, and IAPD 2026 documents likewise do not prescribe discrete follow-up intervals for VPT in permanent teeth. In the AAPD guideline, reported follow-up durations are associated with the evidence supporting individual recommendations, rather than representing a recommended recall schedule.

Accordingly, the unified clinical decision framework presented in Section 14 adopts the ESE 2019 schedule as a pragmatic default. Follow-up should nevertheless be individualized according to symptoms, radiographic findings, root maturity, restoration integrity, and uncertainty regarding pulpal or periapical healing.

12. Root maturity and age considerations

Collectively, the six guidance documents support the use of VPT in both immature and mature permanent teeth; root maturity alone does not determine eligibility. This represents a broadening from the historical emphasis on apexogenesis in immature teeth. The AAE 2021 position statement explicitly extends the scope of VPT to mature permanent teeth, including teeth previously considered to have irreversibly inflamed pulps [3]. None of the six documents specify a universal chronological age cutoff for VPT.

The ESE 2019 position statement applies its recommendations to both immature and mature permanent teeth, and includes radiographic evidence of continued root development among its success criteria for immature teeth [4]. The ESE 2023 S3-level clinical practice guideline presents separate treatment pathways for permanent teeth with immature and mature apices, and includes both stages of root development in its VPT recommendations [5]. The EFCD-ESE-ORCA 2026 guideline addresses immature and mature permanent teeth together. However, the supporting evidence did not consistently distinguish between the two stages when evaluating caries-removal strategies, cavity lining, VPT modality, or pulp-dressing materials. Consequently, whether root devel-

opment modifies treatment outcomes remains uncertain [9].

The AAPD 2025 guideline conditionally concludes, on the basis of low-certainty 24-month evidence, that root maturation does not significantly affect the success of PP or FP performed with CSC in permanent teeth with normal pulp or reversible pulpitis [6]. In contrast, the IAPD 2026 Porto Forum stratifies its recommendations by root maturity, providing distinct guidance for mature and immature permanent teeth with irreversible pulpitis without necrosis (Section 4.2), with continued root development an explicit goal in immature teeth [8].

In traumatic pulp exposure of immature permanent teeth, preservation of pulp vitality may support continued root development. A systematic review of VPT in traumatized permanent teeth with complicated crown or crown-root fractures (14 studies, 1081 teeth) reported PP as the main procedure, with overall success rates of 82.9–100%, and favorable outcomes for both calcium hydroxide and calcium silicate–based materials, although the evidence base was limited and of variable quality [19]. A clinical report by Dubey and Rathore described the use of MTA as an apexogenesis agent in a young permanent incisor with a complicated crown fracture, illustrating the clinical application of MTA-based pulp preservation in traumatic dental injury [20].

Overall, treatment selection should be guided by pulpal and periapical diagnosis, root development, restorability, and intraoperative findings rather than chronological age alone.

13. Interdependence of guideline development

The six guidance documents were not developed through entirely independent processes. The AAPD 2025 and IAPD 2026 documents share several contributors, whereas the ESE 2023 and EFCD-ESE-ORCA 2026 guidelines share contributors and related S3-level methodological approaches. The ESE 2019 and AAE 2021 position statements were developed through separate organizational processes and differ in scope and methodology from the later guidelines. For interpretive purposes, the documents may, therefore, be viewed as four partially distinct guidance lineages: ESE 2019; ESE 2023/EFCD-ESE-ORCA 2026; AAPD 2025/IAPD 2026; and AAE 2021. This grouping is descriptive rather than a formal assessment of evidence independence. Accordingly, agreement among the six documents should not be interpreted as six fully independent confirmations of the same recommendation.

14. Unified clinical decision framework

The six guidance documents converge on a coherent set of biological and procedural principles while differing in terminology, procedural thresholds, caries-removal strategies, and the level of detail provided for restoration and follow-up. A side-by-side comparison of guidance-document positions across all decision domains is provided in **Supplementary Table 1**. To translate shared principles of the six guidance documents into a clinically usable sequence, we developed a unified clinical decision algorithm that extends from pulpal and periapical diagnosis to treatment and long-term follow-up (Fig. 1). The framework represents one defensible interpretation of contemporary guidance and is intended to complement, rather than replace, the individual documents and clinical judgment.

Although the framework is applicable to permanent teeth across age groups, it has particular relevance to children and adolescents. In immature permanent teeth, loss of pulp vitality may interrupt root development and leave thin dentinal walls and an unfavorable crown-to-root relationship. In young mature permanent teeth, pulp loss may initiate decades of restorative and endodontic maintenance. Preservation of pulp vitality, therefore, has both immediate biological value and long-term implications for tooth retention. The IAPD 2026 Porto Forum makes an explicit recommendation for FP in immature teeth with irreversible pulpitis (Section 4.2). The framework's emphasis on conservative pulp management, CSCs, a durable coronal seal, and continued follow-up reflects this developmental priority. As noted in Section 4.3, patient-level and feasibility factors may also modify the pathway. The ability to complete the procedure safely should, therefore, be incorporated into case selection and shared decision-making.

15. Discussion

This comparative review identified broad agreement across six contemporary guidance documents on the principal biological and procedural foundations of VPT in permanent teeth. The pattern is itself informative: convergence is greatest where randomized evidence exists, notably on pulp-dressing materials; in contrast, divergence persists where recommendations rest on expert consensus or on evidence that does not distinguish clinical subgroups, notably on caries-removal strategy, hemostasis thresholds, cavity lining, restorative design, and follow-up intervals. The provided unified framework translates the areas of convergence into a sequential chairside pathway while retaining or explicitly acknowledging unresolved divergence.

15.1 Clinical implications and limitations of the evidence

The greatest uncertainty concerns VPT in permanent teeth with signs and symptoms suggestive of irreversible pulpitis. Conventional clinical diagnoses correlate imperfectly with histopathological pulp status [21, 22], and biologically oriented diagnostic systems (such as the Wolters classification [23]) were not used as enrollment criteria in the pivotal clinical trials supporting this indication [24–26]. Intraoperative assessment of pulp appearance and the ability to achieve hemostasis, therefore, remain important, although neither provides definitive histological confirmation. The documents also express different levels of confidence in pulpotomy for this indication (Section 4.2), and these are not directly comparable, since the documents grade evidence and consensus by different methods (**Supplementary Table 1**, Panel A).

The supporting trials generally have modest sample sizes, limited follow-up, and predominantly single-center designs [24–27]. Longer-term multicenter evidence remains limited, and the Pulpotomy for Irreversible Pulpitis feasibility trial has not yet been followed by a completed definitive trial [28]. Clinicians should, therefore, discuss both the potential benefits and the remaining uncertainty when obtaining

informed consent, particularly in cases where pulpotomy is considered as an alternative to root canal treatment. Apparent agreement should also be interpreted in light of the authorship and methodological overlap described in Section 13.

15.2 Strengths and limitations of the review

A strength of this review is the side-by-side comparison of all six contemporary guidance documents across a consistent set of clinical decision points. Recommendation wording, evidence grades, consensus levels, and important qualifying conditions were retained where available, and differences in terminology were mapped before developing the unified framework. The framework also distinguishes areas of broad convergence from author-derived operational choices.

Several limitations should be acknowledged. First, this was a narrative review based on targeted rather than fully systematic literature retrieval. Document selection and data extraction performed by a single reviewer and subsequently verified rather than duplicated independently; relevant publications may, therefore, have been missed. Second, no new formal methodological appraisal of the six documents was undertaken, and recommendation strength could not be standardized due to the different development and grading systems they use. Third, supporting literature was selected to contextualize recommendations rather than to generate independent pooled estimates. Finally, several elements of the framework, including the exposure-size categories and the operational handling of divergent caries-removal recommendations, represent the authors' clinical synthesis rather than uniformly graded recommendations. The framework should, therefore, be used alongside the source documents and updated as new evidence and guidance emerge.

15.3 Future directions for guideline harmonization

Future guideline development should prioritize reducing avoidable divergence among organizations by harmonizing terminology, clinical questions, outcome definitions, follow-up intervals, and evidence-grading methods. Cross-organizational collaboration is particularly needed for areas of persistent disagreement, including caries-removal strategy in deep and extremely deep lesions, VPT eligibility in symptomatic irreversible pulpitis, hemostasis thresholds, procedure selection, restorative management, and follow-up [29]. Shared evidence reviews, core outcome sets, and coordinated or living updates could improve consistency while preserving differences justified by specialty scope or patient population. Research should target these unresolved decision points using standardized diagnostic criteria, treatment protocols, and long-term outcomes, with adequate representation of children and adolescents.

16. Conclusions

The six contemporary international guidance documents demonstrate a maturing, but incomplete, consensus on VPT and deep caries management in permanent teeth. The strongest convergence concerns the use of CSCs when pulp tissue is exposed, preservation-oriented caries management in appropriately selected teeth, hemostasis-guided intraoperative decision-making, and placement of a durable, well-sealed coronal restoration.

The unified clinical decision framework proposed in this review translates these shared principles into a single chairside pathway from pulpal and periapical diagnosis to long-term follow-up. This is intended to complement, rather than replace, the individual guidance documents and clinical judgment. Confidence is greatest where recommendations converge across partially distinct guidance lineages; greater caution and transparent shared decision-making are required where evidence remains limited or recommendations diverge.

ABBREVIATIONS

AAE, American Association of Endodontists; AAPD, American Academy of Pediatric Dentistry; AGREE II, Appraisal of Guidelines for Research and Evaluation II; AGREE–REX, Appraisal of Guidelines for Research and Evaluation–Recommendation Excellence; AWMF, German Association of the Scientific Medical Societies; CI, confidence interval; CSC, calcium silicate cement; CS, calcium silicate; DGZ, German Society of Conservative Dentistry; DPC, direct pulp capping; EFCD, European Federation of Conservative Dentistry; ESE, European Society of Endodontology; FP, full pulpotomy; GRADE, Grading of Recommendations Assessment, Development and Evaluation; GSEDT, German Society of Endodontology and Dental Traumatology; HCSC, hydraulic calcium silicate cement; IAPD, International Association of Paediatric Dentistry; IPC, indirect pulp capping; IPT, indirect pulp treatment; MTA, mineral trioxide aggregate; NaOCl, sodium hypochlorite; OR, odds ratio; ORCA, European Organisation for Caries Research; PICOTS, Population, Intervention, Comparison, Outcome, Time, Setting; PP, partial pulpotomy; VPT, vital pulp therapy.

AVAILABILITY OF DATA AND MATERIALS

All data analyzed in this review are publicly available in the cited clinical practice guideline documents and the published studies referenced in the manuscript.

AUTHOR CONTRIBUTIONS

CM, PC and NC—conceptualization; methodology. CM—writing–original draft preparation; visualization. PC and NC—writing–review and editing. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/2117500163461136384/attachment/Supplementary%20material.docx.

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