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SYSTEMATIC REVIEW

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Hemostasis in vital pulp therapy for children and adolescents: does duration matter? A systematic review of randomized clinical trials

Saeed Asgary[1,*], Sayna Shamszadeh[1]

[1]Iranian Center for Endodontic Research, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, 1983963113 Tehran, Iran

***Correspondence**
saasgary@yahoo.com
(Saeed Asgary)

Abstract

Background: The relationship between the duration of hemostasis and the success of vital pulp therapy (VPT) in permanent teeth of children/adolescents with pulpitis has not been clearly established. This study aimed to evaluate the impact of hemostasis duration on VPT success. **Methods**: A comprehensive literature search was conducted across databases to identify randomized clinical trials (RCTs) reporting hemostasis duration in VPT up to August 2024. The inclusion criteria focused on studies involving children/adolescents that reported on various durations of hemostatic, along with their long-term success rates. Hemostasis durations were categorized into three groups ($\leq$2, 2–5 and $>$5 minutes). Additionally, various pulp capping agents (PPAs) were compared. A narrative synthesis was conducted using the Kruskal-Wallis test to assess the relationships between the maximum acceptable hemostasis duration and treatment outcomes ($p < 0.05$). **Results**: Thirteen RCTs were included (742 participants); they employed full pulpotomy, partial pulpotomy and direct pulp capping. The PPAs used included mineral trioxide aggregates (MTA), calcium hydroxide, Biodentine, platelet-rich fibrin, triple antibiotic, calcium-enriched mixture, MTA-laser, acemannan, abscess remedy, potassium nitrate in polycarboxylate cement and nano-hydroxyapatite. The pulp lavage solutions used were saline, sodium hypochlorite and saline/ferric sulfate gel. None of the included studies specifically evaluated hemostasis duration as primary outcome. Success rates across the various PPAs ranged from 50–100%. The narrative synthesis revealed no statistically significant differences in success rates among the different hemostasis durations ($p = 0.382$), indicating that the duration of hemostasis did not significantly influence the success of VPTs. **Conclusions**: This finding suggests that clinicians can adopt a more flexible approach to hemostasis timing during VPT procedures, and the choice of PPAs may not significantly affect treatment outcomes. However, due to the indirect nature of the evidence, current findings should be interpreted with caution. **The PROSPERO Registration**: The PROSPERO database under the number CRD42024601326.

Keywords

Mineral trioxide oxide; Endodontics; Vital pulp therapy; Hemostasis; Tooth pulp disease; Pulpotomy; Randomized clinical trials

1. Introduction

Vital pulp therapy (VPT) is a conservative dental treatment aimed at preserving the vitality and health of dental pulp in cases of reversible or irreversible pulpitis, particularly in children and adolescents [1, 2]. Techniques such as direct pulp capping (DPC) and miniature, partial or full pulpotomy (MP, PP, FP) have gained popularity due to their potential to maintain pulp vitality, promote healing and provide alternatives to traditional root canal therapy [3]. The use of calcium-silicate based biomaterials, such as mineral trioxide aggregate (MTA), Biodentine and calcium-enriched mixture (CEM), has further enhanced the success rates of these procedures, making VPT a preferred choice for managing pulp conditions in both immature and mature permanent teeth [4]. Achieving hemostasis during VPT is critical for the successful treatment outcomes, as it facilitates optimal healing of the pulp tissue. Excessive bleeding can compromise clinical outcomes by preventing proper sealing of the pulp chamber and exposing the pulp to reinfection. The time required to achieve hemostasis can vary widely, influenced by the techniques used and the clinical context. Despite its recognized importance, ongoing debates remain regarding the implications of prolonged bleeding times on the success rates of VPT [5].

Among VPT techniques, the *tampon* approach represents an innovative method designed to effectively manage pulpitis in cases of prolonged bleeding, especially in pediatric patients. In such instances, a biocompatible material, such as CEM cement, is applied with gentle mechanical pressure to the remaining pulp to control bleeding [6–8]. This pressure helps compress blood vessels, aiding in sealing the cavity, preventing bacterial reinvasion and promoting healing.

The time required for hemostasis is a critical indicator of the outcomes in VPT. According to the American Academy of Pediatric Dentistry (AAPD) guidelines, hemostasis should be achieved within a few minutes. However, the duration of hemostasis can vary across different studies. Recent research has set a cutoff time of 2 minutes for maintaining hemostasis [9], while other studies have reported a maximum duration ranging from 2 to 9 minutes [10, 11].

While existing studies have assessed various aspects of VPT, a comprehensive analysis focused specifically on the relationship between the duration of hemostasis and treatment outcomes is lacking. Current literature often excludes cases where hemostasis is not achieved [11], potentially skewing results and limiting our understanding of the impact of bleeding on VPT success. This systematic review aims to address this gap by analyzing randomized clinical trials (RCTs) to provide insights into whether the duration of hemostasis significantly influences VPT outcomes in pediatric patients.

To the best of our knowledge, there is no systematic review focusing on this topic By analyzing data from RCTs, the study seeks to clarify the relationship between bleeding duration and treatment outcomes. This will inform clinical practice and contribute to a better understanding of the factors influencing the efficacy of VPT in children and adolescents. The review aims to address the following PICOs question: "What is the effect of hemostasis duration (I/C) on the success rate (O) of VPT for treating pulpitis in vital permanent teeth of children and adolescents (P) in RCTs?". Here, (P) refers to the population of permanent teeth with pulpitis, (I = Intervention/C = Comparison) pertains to varying durations of hemostasis, (O = Outcome) indicates the clinical and radiographic success rates of VPT and (s = Study design) denotes RCTs.

2. Materials and methods

2.1 Protocol

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [11] and was registered in the PROSPERO database under the number CRD42024601326. The PRISMA checklist provides more details and is available as **Supplementary material**.

2.2 Search strategy

A comprehensive literature search was conducted to identify relevant RCTs that assessed the impact of hemostasis duration on VPT outcomes. The search was performed across electronic databases, including PubMed, Scopus and the Cochrane Library, up to August 2024, with no restrictions on publication date. The keywords and medical subject headings (MeSH) terms used for the search included "vital pulp therapy", "pulp capping", "pulpotomy", "children" and "randomized clinical trials".

2.3 Inclusion and exclusion criteria

The inclusion criteria for the systematic review were as follows:

1. Studies must be RCTs comparing VPT outcomes with documented hemostasis duration.
2. Participants must include children and adolescents undergoing VPT for reversible or irreversible pulpitis.
3. Studies must report success rates and specify the duration of hemostasis achieved.

The exclusion criteria included:

1. Non-randomized studies, observational studies, case-series, case reports and reviews.
2. Studies focusing on adult populations.
3. Research that does not specifically address hemostasis duration.
4. Trials without clear outcomes related to VPT success.

2.4 Data extraction process

Data extraction was performed independently by two reviewers (SA and SS) using a standardized form. Relevant information collected from each included study comprised the author, year of publication, sample size, participant demographics, pulp status, treatment type (pulp capping or pulpotomy), materials used, duration of hemostasis, follow-up period and success rates. Any discrepancies between reviewers (SA and SS) were resolved through discussion or by consulting a third reviewer.

Hemostasis duration was classified into three groups: brief ($\leq$2 minutes), moderate (2–5 minutes) and prolonged ($>$5 minutes). This classification was developed based on clinical relevance and pathophysiological considerations. The threshold of $\leq$2 minutes represents rapid hemostasis, typically indicating minimal pulpal inflammation and an optimal environment for pulp healing. This cut-off aligns with previous studies that associated shorter hemostasis durations with favorable outcomes in VPT. Conversely, a threshold of $>$5 minutes denotes prolonged hemostasis, which is linked to significant pulpal inflammation and may necessitate alternative strategies, such as pulpectomy. The intermediate range of 2–5 minutes reflects clinical scenarios where hemostasis is achieved within a slightly delayed timeframe, likely influenced by moderate inflammation. While this classification is innovative, it integrates timeframes addressed individually in previous studies, providing a cohesive evaluation framework.

2.5 Statistical analysis

Statistical analysis was conducted to evaluate the influence of hemostasis duration on the success rate of VPT. The three hemostasis duration time were predetermined rather than derived from the statistical distribution of data in the included studies, providing a clinically meaningful structure for subgroup analysis. This categorization enhances the interpretability of findings and supports evidence-based recommendations

for VPT protocols. The success rate was defined as the proportion of successful cases relative to the total cases for each study and treatment agent. As the data did not meet normality assumptions, the non-parametric Kruskal-Wallis test was used to compare success rates across different hemostasis durations (≤2 minutes, 2–5 minutes and >5 minutes). Statistical significance was set at $p < 0.05$.

2.6 Quality assessment of included studies

The quality of the included studies was assessed using the Cochrane Risk of Bias Tool [12], which evaluates the potential biases across several domains: selection bias, performance bias, detection bias, attrition bias, reporting bias and other biases. Each study was rated as low, unclear or high risk of bias. A study was considered "low risk" if all domains were rated as "low risk", "medium risk" if one or more domains were rated as "unclear risk" and "high risk" if one or more domains were rated as "high risk". Disagreements in assessments were resolved through discussion between the authors (SA and SS).

3. Results

3.1 Search results

Initially, 435 papers were retrieved from the mentioned databases. After screening the titles/abstracts and removing duplicates and irrelevant studies (n = 245 and 123, respectively), a total of 67 papers underwent full-text review based on the selection criteria (refer to the **Supplementary material** for excluded studies; n = 54). Ultimately, 13 RCTs were included in the final analysis (Fig. 1), with a combined sample size of 742 participants after accounting for loss to follow-up. The studies were published between 2013 and 2022, two conducted in turkey [13, 14], two in India [15, 16], two in Syria [17, 18], two in Thailand [19, 20], two in Egypt [21, 22], one in Iran [23], one in Chile [24] and one in Vietnam [25].

3.2 Main results

Meta-analysis was not possible due to heterogeneity across the studies. Thus, a narrative synthesis statistical analysis was conducted to evaluate the influence of hemostasis duration on the success rate of VPT. The Kruskal-Wallis test revealed no statistically significant differences in success rates among the various hemostasis durations ($p = 0.382$): Group 1 (n = 45; mean, 97.72; 95% confidence interval (CI), 68.81 to 126.63), Group 2 (n = 331; mean, 87.09; 95% CI, 74.41 to 99.76) and Group 3 (n = 258; mean, 96.54; 95% CI, 93.86 to 99.22). This finding suggests that varying the duration of hemostasis within the examined time intervals did not result in significant differences in clinical outcomes.

A sensitivity analysis was performed using success rate thresholds of >80%, >85%, >90% and >95%. At the >80% and >85% thresholds, minimal variation was observed among the categories, with success rates for the 2–5 minutes group and >5 minutes group showing confidence intervals of 96.63% (95% CI: 94.26%–99.01%) and 95.33% (95% CI: 91.51%–99.15%), respectively. At the primary cut-off of >90%, the Kruskal-Wallis statistic increased to 1.65 with a p-value of 0.20, and the success rates demonstrated greater separation between time categories: 98.44% (95% CI: 96.96%–99.92%) for 2–5 minutes and 96.42% (95% CI: 93.08%–99.76%) for >5 minutes. At the >95% threshold, success rates were exceedingly high with substantial overlap, showing 99.18% (95% CI: 97.95%–100.41%) and 99.09% (95% CI: 96.56%–101.62%), resulting in a Kruskal-Wallis statistic of 0.03 and a p-value of 0.87.

3.3 Study characteristics

Table 1 (Ref. [13–25]) presents the characteristics of the included studies. The review included children and adolescents (ages 6–14) with mature or immature teeth suffering from pulpitis. Patients received various types of VPT, including FP [15, 17, 18, 21–23, 25], PP [13, 14, 19, 20] and DPC [24]. The different pulp covering agents used in the included studies were MTA [13–25], calcium hydroxide (CH) [14, 19, 24], Biodentine [20, 22, 24], platelet-rich fibrin [15, 18], triple antibiotic paste [16], CEM cement [23], MTA-laser [13], Acemannan [25], Abscess Remedy [16], potassium nitrate in polycarboxylate cement [21] and nanohydroxyapatite [18]. The lavage solutions or hemostasis agents used included saline [14–18, 22–24], sodium hypochlorite (NaOCl) at concentrations of 2.5% [14, 19, 20, 25] or 5.25% [13] and a combination of saline and ferric sulfate gel [21]. Final restorations varied and included resin composite [13, 16, 18, 19, 21–23, 25], amalgam [15, 20, 24] and stainless-steel crowns [14, 17, 22, 25].

3.4 The outcome of the included studies

Table 2 (Ref. [13–25]) presents the overall success rates at last reported follow-ups, which were based on a comprehensive evaluation of clinical and radiographic outcomes. Separate success rates for clinical and radiographic evaluations were not analyzed due to insufficient data from some studies. In term of clinical outcomes, most studies (n = 11) defined success based on normal sensitivity test and the absence of pain, swelling, sinus tract or fistula and tooth mobility. However, two studies did not include tooth mobility as a criterion for success. For radiographic outcomes, all included studies considered the absence of periapical lesions as the measure of success. Additionally, other criteria such as the absence of root resorption (n = 11) [13–15, 17–21, 23–25], widening of periodontal ligament (n = 5) [13–15, 18, 24], loss of lamina dura (n = 2) [13, 25], continued root development (n = 9) [15, 16, 18–22, 24, 25] and the presence of apical closure (n = 2) [16, 23] were also used to access success. The success rates for various pulp capping agents ranged from 50% to 100%.

Despite generally favorable outcomes associated with varying durations of hemostasis, a common theme emerged regarding the management of excessive bleeding. Several studies excluded participants if hemostasis was not achieved, which may introduce bias and limit the generalizability of the results. Moreover, the assumption that excessive bleeding correlates with poor outcomes in VPT was challenged. While excessive bleeding can complicate treatment, the data suggest that it may not directly impede success if managed appropriately during the procedure.

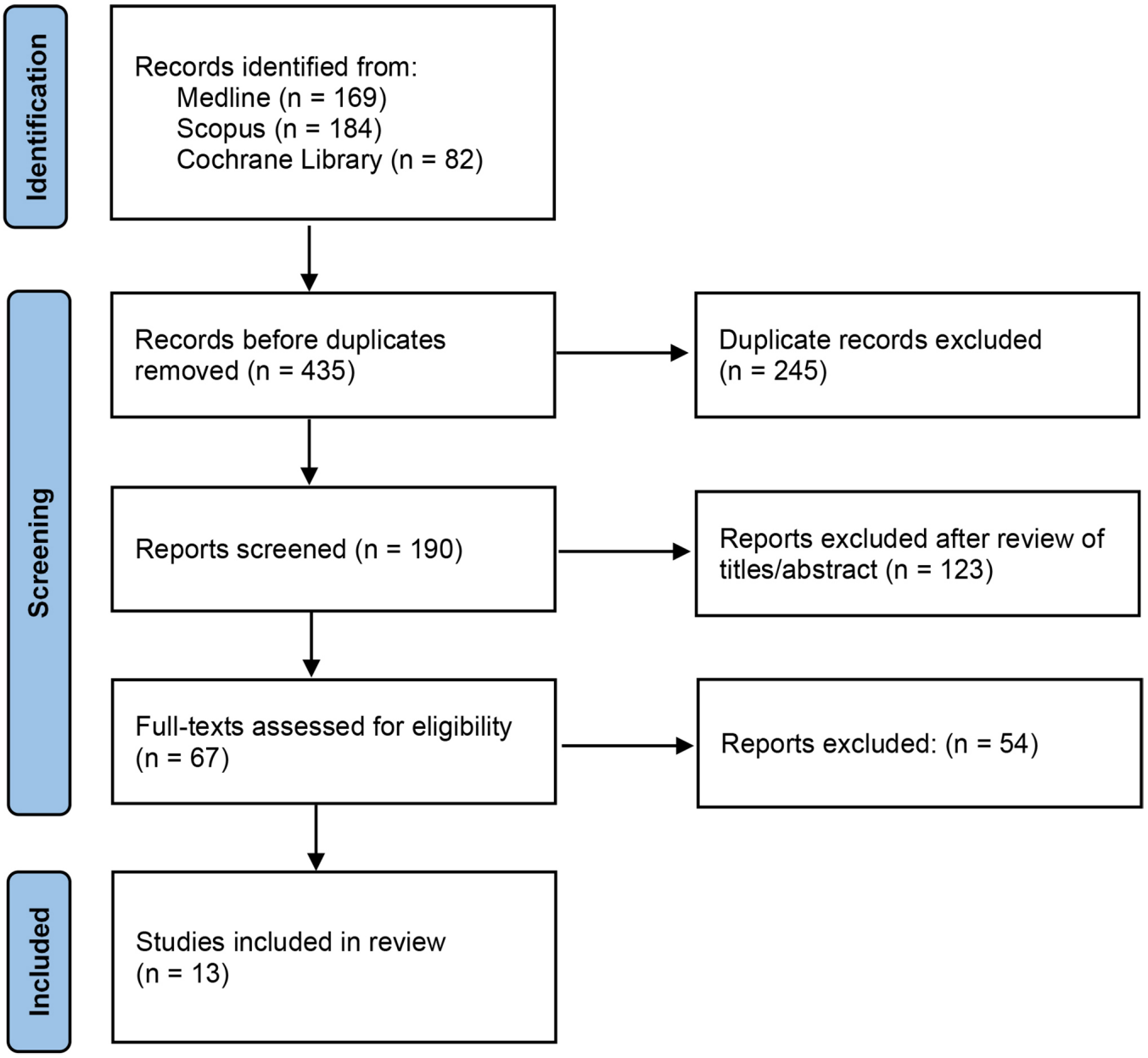

FIGURE 1. PRISMA flow diagram.

3.5 Quality assessment of included studies

Table 3 (Ref. [13–25]) presents the risk of bias assessment of the included studies. Five studies were rated as having a low risk of bias, four had a moderate risk and four had a high risk of bias. All studies reported on randomization procedures, blinding of investigator and outcome measurements. No studies reported selective reporting, but incomplete outcome data was reported in one study. Allocation concealment was described in nine studies, and patient blinding was reported in eight studies.

4. Discussion

The present systematic review aimed to evaluate the influence of hemostasis duration on the success of VPT in children and adolescents experiencing pulpitis. This review analyzed 13 RCTs involving 742 participants. Due to the variability in results among the included studies, a meta-analysis could not be performed. Instead, we categorized hemostasis duration into three groups based on time intervals: brief (1–2 minutes), moderate (2–5 minutes) and prolonged (>5 minutes), and performed a narrative synthesize. The primary finding indicates that the duration required to achieve hemostasis does not significantly affect VPT success rates.

The literature suggests that clinical signs, sensitivity tests, and radiographic findings often fail to reliably indicate the true pulpal status [26]. While some clinicians rely on the color and volume of blood, as well as the ability to achieve hemostasis as diagnostic tools, these criteria—apart from hemostasis—are largely subjective [27].

Despite these limitations, our systematic review provides reassuring evidence that extended bleeding management does not lead to poorer clinical outcomes in VPT. This finding contrasts with the AAPD's Guidelines on pulp therapy, which

TABLE 1. Characteristics of the included studies.

Author (Year)	Country	Aim	Age	Sex (F/M)	Teeth (type and location)	N	Pulp status	VPT type	Filling	Root status	Hemostasis Agent(s)	Hemostasis Max. Time (min)	Selection criteria' controlled bleeding
Chailertvanitkul (2014) [19]	Thailand	Comparison of MTA *vs.* CH	7–10	NS	Permanent Molar	84	RP	PP	AM	I	NaOCl 2.5%	2	NS
Vu (2020) [25]	Vietnam	Comparison of Acemnan *vs.* CH, MTA	9.2	NS	Permanent Molar	45	RP	FP	RC	I	NaOCl 2.5%	2	Up to 2 min.
Eid (2022) [18]	Syria	Comparison of MTA *vs.* nHAP, PRF	8.8	30:33	Permanent Molar	60	RP	FP	RC/SSC	I	Saline	3	Up to 5 min.
Keswani (2014) [15]	India	Comparison of MTA *vs.* PRF	7.8	21:32	Permanent Molar	53	RP	FP	SSC	I	Saline	3	Up to 5 min.
Abuelniel (2021) [22]	Egypt	Comparison of MTA *vs.* BD	7.15	17:13	Permanent Molar	54	RP	FP	RC	I	Saline	5	NS
Eppa (2018) [16]	India	Comparison of MTA *vs.* TAP, AR	6–14	NS	Permanent teeth	60	RP	FP	SSC	I	Saline	5	Up to 5 min.
Tozar (2020) [13]	Turkey	Comparison of MTA *vs.* MTA-laser	8.6	43:47	Permanent Mandibular Molar	90	RP	PP	RC	I	NaOCl 5.25%	5	Up to 5 min.
Özgür (2017) [14]	Turkey	Comparison of MTA *vs.* CH via different hemorrhage agents	8.4	36:23	Permanent 1st and 2nd Molar	38	RP	PP	RC	I	NaOCl 2.5%/Saline	5	Up to 5 min.
Nosrat (2013) [23]	Iran	Comparison of MTA *vs.* CEM	8.34	39:22	Permanent 1st Molar	48	RP	FP	AM	I	Saline	10	NS
Ahmed (2021) [21]	Egypt	Comparison of MTA *vs.* PC	7.7	33:15	Permanent Mandibular 1st Molar	50	RP	FP	RC	I	Saline then FSJ (15 s)	10	Uncontrolled bleeding
Uesrichai (2019) [20]	Thailand	Comparison of MTA *vs.* BD	10.0	45:22	Permanent 1st Molar	67	IP	PP	RC/SSC	I/M	NaOCl 2.5%	10	Up to 10 min.
Brizuela (2017) [24]	Chile	Comparison of MTA *vs.* CH	11.3	87:82	Permanent Molar	69	RP/NP	DPC	RC	NS	Saline	10	Up to 10 min.
Azawad (2020) [17]	Syria	Comparison of PRF *vs.* MTA	6.9	NS	Permanent 1st Molar	24	IP	FP	AM	I	Saline	15	NS

AR, Abscess Remedy; AM, Amalgam; BD, Biodentine; CEM, Calcium enriched mixture; CH, Chlorhexidine; DPC, Direct pulp cap; FP, full pulpotomy; FSJ, ferric sulfate gel; IP, Irreversible pulpitis; I, Immature; M, Mature; MTA, Mineral trioxide aggregates; NaOCl, Sodium hypochlorite; nHAP, Nanohydroxyapatite; NA, Not applicable; NS, not stated; NP, Normal pulp; RC, Resin composite; PP, Partial pulpotomy; PRF, Platelet-rich in fibrin; RP, Reversible pulpitis; SSC, Stainless-steel crown; TAP, Triple antibiotic paste; PC, Polycarboxylate; F/M, Female/Male; VTP, Vital Pulp Therapy.

TABLE 2. The outcomes of the included studies.

Author (Year)	Clinical success criteria	Radiographic success criteria	Operator	Pulpotomy agent(s)	Success cases/To cases	Success rate (%)	Last recall (mon)
Chailertvanitkul [19] (2014)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption); continued root development	NS	CH/MTA	NA	NA	24
Vu [25] (2020)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion, root resorption, loss lamina dura); continued root development	An endodontist	Acemnan	21/22	95.45	12
				MTA	23/23	100.00	
Eid [18] (2022)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion, root resorption, PDL widening); continued root development	A fully trained operator	MTA	20/20	100.00	12
				nHAP	20/20	100.00	
				PRF	20/20	100.00	
Keswani [15] (2014)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion, root resorption, PDL widening); continued root development	An operator	MTA	26/26	100.00	24
				PRF	27/27	100.00	
Abuelniel [22] (2021)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion); continued root development	A pediatric dentist	MTA	24/27	88.80	18
				BD	24/27	88.80	
Eppa [16] (2018)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion); continued root development and apical closure	NS	MTA	20/20	100.00	24
				TAP	20/20	100.00	
				AR	16/16	100.00	
Tozar [13] (2020)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion, root resorption, PDL widening, loss of lamina dura)	An experienced dentist	MTA	43/45	95.50	12
				MTA + Laser	40/45	88.80	
Özgür [14] (2017)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption, PDL widening, loss of lamina dura)	A pediatric dentist	MTA	17/18	94.40	24
				CH	19/20	94.40	
Nosrat [23] (2013)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption); apical closure	An endodontist	MTA	24/24	100.00	12
				CEM	24/24	100.00	
Ahmed [21] (2021)	Absence (pain, swelling, sinus tract); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption); continued root development	NS	PC	23/25	92.00	12
				MTA	23/25	92.00	
Uesrichai [20] (2019)	Absence (pain, swelling, sinus tract, tooth mobility); normal sensitivity test	Absence (periradicular lesion, root resorption); continued root development	Pediatric postgraduate students	MTA	34/37	91.89	34
				BD	26/30	86.60	
Brizuela [24] (2017)	Absence (pain, swelling, fistula); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption, PDL widening)	Endodontic postgraduate students	MTA	22/22	100.00	12
				CH	21/22	95.45	
				BD	25/25	100.00	
Azawad [17] (2020)	Absence (pain, swelling, fistula, tooth mobility); normal sensitivity test	Absence (periradicular/furcation lesion, root resorption)	Specialists	PRF	6/12	50.00	12
				BD	6/12	50.00	

AR, Abscess Remedy; BD, Biodentine; CEM, Calcium enriched mixture; CH, Chlorhexidine; MTA, Mineral trioxide aggregates; nHAP, Nanohydroxyapatite; NS, Not stated; PRF, Platelet-rich in fibrin; RP, Reversible pulpitis; TAP, Triple antibiotic paste; PC, Polycarboxylate cement; PDL, Periodontal ligament; NA, Not Applicable.

TABLE 3. The quality assessment of the included studies.

Author (year)	Randomizat	Allocation concealment	Blinding accessor	Blinding patient	Selective reporting	Incomplete outcome data	Overall ROB
Chailertvanitkul (2014) [19]	+	+	+	?	+	−	−
Vu (2020) [25]	+	?	+	+	+	+	?
Eid (2022) [18]	+	?	+	+	+	+	?
Keswani (2014) [15]	+	+	+	+	+	+	+
Abuelniel (2021) [22]	+	+	+	−	+	+	−
Eppa (2018) [16]	+	+	+	−	+	+	−
Tozar (2020) [13]	+	?	+	−	+	+	−
Özgür (2017) [14]	+	+	+	?	+	+	?
Nosrat (2013) [23]	+	+	+	+	+	+	+
Ahmed (2021) [21]	+	+	+	+	+	+	+
Uesrichai (2019) [20]	+	+	+	+	+	+	+
Brizuela (2017) [24]	+	+	+	+	+	+	+
Alawwad (2020) [17]	+	?	+	+	+	+	?

+, low risk of bias; ?, moderate risk of bias; −, high risk of bias.

recommend pulpectomy if bleeding cannot be controlled within a few minutes [28]. Our narrative analysis suggests that prolonged bleeding does not necessarily indicate an inability of the inflamed pulp to heal or the need for more invasive treatment, such as pulpectomy [7]. In general, inflammation is known to promote faster coagulation by activating coagulation pathways [29]. However, specific inflammatory responses within the dental pulp, particularly in teeth diagnosed with irreversible pulpitis, may paradoxically delay the clotting process. This delay is attributed to the hyperemic state and increased vascular permeability associated with inflammation, leading to elevated blood flow and prolonged bleeding [30]. Importantly, while prolonged bleeding may initially appear concerning, it should not necessarily be regarded as a negative prognostic indicator for pulp healing [31]. On the contrary, it may reflect a robust blood supply, which is critical for pulp repair and regeneration. Researchers have reported no significant differences in hemostasis times between inflamed and non-inflamed pulps, indicating that the range of pulp inflammation compatible with successful pulpotomy may be broader than previously assumed [32]. The current review indicates that, with proper management, even extended hemostasis times do not lead to poorer clinical results. This suggests that clinicians can adopt a more flexible approach to controlling bleeding during VPT without adversely affecting success rates, allowing them more time for complex cases where achieving hemostasis may be more challenging. The literature provides limited but encouraging evidence suggesting that, in cases of prolonged or excessive bleeding, utilizing a *tampon* approach can effectively halt bleeding while simultaneous enabling pulp capping with biocompatible materials such as CEM cement, alongside cavity filling and sealing [6–8, 33–35]. This strategy has been associated with favorable clinical outcomes in both reversible and irreversible pulpitis cases, particularly in pediatric patients [6]. Although our study did not specifically evaluate these cases or methods, these findings provide scientific support for the potential benefits of this approach and warrant further investigation in future research.

Another significant aspect of this review was the evaluation of different pulp capping agents. Success rates across various agents ranged from 50% to 100%. Calcium-silicate-based cements such as MTA, Biodentine and CEM cement—widely used in VPTs—demonstrated consistently high success rates, corroborating their established effectiveness in preserving pulp vitality [36]. The duration of hemostasis showed no significant impact on treatment outcomes, further supporting flexibility in clinical practice regarding hemostasis control. The findings of the current review reinforce the concept that success in VPT is multifactorial, involving several important factors, including patient selection, operator skill and the presence of pulp/periapical diseases, rather than solely depending on hemostasis duration or the choice of lavage solutions/hemostasis agents.

The risk of bias in the included studies was assessed using standard and validated risk of bias assessment tools. Some risks of bias were noted in our review. Allocation concealment was not evaluated in four studies, and inadequate allocation concealment can lead to exaggerated treatment effect estimates [37]. Additionally, blinding is important for ensuring comparability between groups and minimizing bias. In the current review, the risk of bias related to patient blinding was rated as high in three studies and moderate in two studies. This review is the first to focus on the correlation between the duration of hemostasis and the outcomes of VPT. A systematic review published in 2024 found that the use of NaOCl as a hemostatic agent resulted in a high success rate of FP [38]; however, in that review, the maximum time to achieve hemostasis varied widely, ranging from 2 to 25 minutes, making it difficult to draw any definitive conclusion.

The sensitivity analysis demonstrated the robustness of our findings across various success rate thresholds. At lower thresholds of >80% and >85%, success rates remained consistently high across all time categories, offering limited distinction between them. The >90% threshold was chosen as the primary analysis cut-off, balancing statistical power with clinical relevance. This threshold provided moderate separation of confidence intervals, revealing meaningful differences between time groups. In contrast, at the >95% threshold, the extremely high success rates hindered our ability to differentiate between categories, as shown by overlapping confidence intervals and a negligible Kruskal-Wallis statistic. These findings justify the selection of the >90% threshold, as it best captures clinically significant differences while maintaining statistical rigor.

However, our study has some limitations that should be considered. One limitations is that the included studies did not specifically evaluate hemostasis duration as the primary outcome. Although a meta-analysis was not possible, we calculated the correlation between hemostasis duration and success rate through narrative synthesis. Another limitation is the considerable heterogeneity across the included studies, which varied in term of the type of VPT, pulpotomy agents and hemostasis agents used. Additionally, cases excessively prolonged bleeding times were excluded from our review, preventing an evaluation of the actual upper limit of bleeding time within the population. The exclusion of gray literature due to resource constraints may also introduce selection bias, which should be acknowledged as a limitation of this review. Finally, the last limitation is the lack of detailed bleeding time data such as the mean, standard deviation, median and interquartile range.

5. Conclusions

This systematic review demonstrates that flexible approaches to hemostasis, including extended bleeding management, do not compromise the success of VPT for treating irreversible pulpitis in children and adolescents. Furthermore, the type of pulp capping agent used does not significantly influence treatment outcomes. These findings provide valuable insights for clinicians, reassuring them that adaptable techniques and a variety of capping materials can be employed without affecting success rates. This flexibility supports evidence-based decision-making in the clinical management of irreversible pulpitis. However, caution should be taken when generalising these findings due to the limitations of the included studies, particularly regarding the indirect nature of the evidence and the exclusion of cases with unachieved hemostasis. The direct effect of hemostasis duration on the treatment outcome in VPT for permanent teeth in young adults and the consequence of poorly managed bleeding remains areas for further research.

ABBREVIATIONS

AR, Abscess Remedy; AM, Amalgam; BD, Biodentine; CEM, Calcium enriched mixture; CH, Calcium hydroxide; DPC, Direct pulp capping; FP, full pulpotomy; F, Female; M, Male; FSJ, Ferric sulfate gel; IP, Irreversible pulpitis; I, Immature; M, Mature; MP, Miniature pulpotomy; MTA, Mineral trioxide aggregates; NaOCl, Sodium hypochlorite; nHAP, Nanohydroxyapatite; NA, Not applicable; NS, not stated; NP, Normal pulp; PDL, Periodontal ligament; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PRF, platelet-rich fibrin; PP, Partial pulpotomy; RC, Resin composite; RCT, Randomized clinical trials; RP, Reversible pulpitis; SSC, Stainless-steel crown; TAP, Triple antibiotic paste; PC, Polycarboxylate; VPT, Vital pulp therapy; AAPD, American Academy of Pediatric Dentistry; CI, Confidence Interval; MeSH, Medical Subject Headings; PICOs, Population, Intervention, Comparison, Outcome, study design.

AVAILABILITY OF DATA AND MATERIALS

Datasets supporting this manuscript are available upon request from corresponding author.

AUTHOR CONTRIBUTIONS

SA—designed the research study; analyzed the data. SS—performed the research. SA and SS—wrote the manuscript. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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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/1940452876672221184/attachment/Supplementary%20material.docx.

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