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Original Article

Preserving pulp vitality for teeth with post-vital pulp therapy symptoms by retrying pulp-preserving procedures: A retrospective clinical study

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KEYWORDS
Minimized pulp resection;
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Abstract *Background/purpose:* The occurrence of post-vital pulp therapy (VPT) symptoms is perplexing for dentists, and root canal treatment (RCT) is preferred for such conditions. Furthermore, managing post-VPT symptoms, rather than performing RCT, would preserve pulp vitality and enhance VPT outcomes. This study aimed to evaluate the efficacy of VPT retrials in preserving pulp vitality and substituting RCT in teeth with post-VPT symptoms.
Materials and methods: VPT was performed on the exposed pulp during caries removal in symptomatic and asymptomatic teeth. VPTs were repeated in teeth with post-VPT symptoms. This study screened multi-time-practiced VPT cases from a VPT-performed data pool. The presence of vital pulp tissue after minimized pulp resection (MPR) was a prerequisite for substituting RCT with VPT retrials. A total of 22 cases from 19 patients were included in this study. MPR was introduced to maximize the preservation of the vital pulp.
Results: After performing VPT, post-VPT symptoms occurred in pre-VPT asymptomatic teeth, or pre-VPT symptoms were modified in teeth with pre-VPT symptoms. The rate of pre-VPT irreversible pulpitis (IP), comprising symptomatic/asymptomatic IP, was 81.68%. The most prevalent post-VPT symptom was heightened sensitivity to thermal stimuli (68.2%), followed by spontaneous pain (45.5%). The post-VPT IP was 63.6%. VPT retrials resolved 90.9% of cases with post-VPT symptoms.
Conclusion: VPT retrials using MPR could enhance VPT outcomes and be a viable alternative to RCT for teeth with post-VPT symptoms.

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Introduction

Clinical symptoms in teeth with deep caries lesions affect pulpal diagnosis and treatment modalities, such as root canal treatment (RCT) or vital pulp therapy (VPT).[1–3] Guidelines of the American Association of Endodontists recommend RCT for irreversible pulpitis (IP).[1] Furthermore, questionnaire studies have shown higher preference rates for RCT than for VPT in symptomatic teeth.[4,5] The presence of post-VPT symptoms is regarded as "VPT failure," and RCT is recommended for teeth with such cases.[6–8] However, clinical studies have shown enhanced outcomes of VPT in teeth with IP.[9–11] The current main pulpal diagnosis system, especially for IP that involves assessing the pulp's incapability to recover from inflamed conditions, conflicts with VPT outcomes.[12] Such inconsistencies have questioned the rationale behind performing RCT for the exposed pulp after caries removal in symptomatic/asymptomatic teeth.[13] Advancements in VPT have raised an issue of pulp vitality associated with clinical symptoms and pulpal diagnosis. Although not in all cases, performing RCT without considering pulp vitality in teeth with IP or post-VPT symptoms may imply unnecessary removal of the pulp that VPT could preserve.

VPT studies suggest that pulp vitality should be considered when selecting VPT or RCT.[13,14] Laser Doppler flowmetry and pulse oximetry may assess pulp vitality.[15,16] However, practical methods for estimating pulp vitality in clinical settings are lacking. Therefore, assessing the clinical factors, including conditions of exposed pulp, symptom alleviation after VPT, and relative analysis of numeric records of electric pulp test with adjacent normal teeth could be an indirect method for presuming pulp vitality.[13,17,18] Most of all, confirming the presence of vital pulp tissue seems critical when considering VPT, and in this study, VPT retrials were performed based on the presence of vital pulp to resolve post-VPT symptoms, even in cases of indicative IP.

Bacteria or bacterial products within carious lesions can induce immune responses or activate nociceptors in the pulp.[19,20] Dental pain or discomfort results from recognizing the transmitted information from peripheral nociceptors.[21] Post-VPT symptoms may imply remaining pulpal irritant after VPT. Additionally, the extent of pulp resection during VPT may include eliminating inflamed tissue, pathogenic irritants, and preventive tissue removal beyond the pathogen-affected portion. However, a consensus or evidence for selecting the pulpotomy type, such as partial or full pulpotomy, is lacking.[22] Full coronal pulp resection to eliminate potent irritants could be invasive and hinder securing maximum pulp vitality. In this study, minimized pulp resection (MPR) was introduced for suggesting the amount of pulp resection during VPT.

Post-VPT symptoms are complex negative factors during clinical assessment. However, despite the growing interest in VPT, few studies have focused on resolving post-VPT symptoms. In this study, we hypothesized that although VPT is performed, the irritants, which cause post-VPT symptoms, remain in the pulp, and the additional MPRs during VPT retrials would resolve the post-VPT symptoms by removing the residing pulpal irritants. This study aimed to demonstrate the efficacy of VPT retrials for resolving post-VPT symptoms and maintaining pulp vitality. VPT retrials suggest extending VPT indications and substituting RCT for teeth with post-VPT symptoms (Fig. 1).

Materials and methods

All procedures involving human participants were performed in accordance with the ethical standards of the institution and the Declaration of Helsinki. The Institutional Review Board of our institution approved this study and waived the requirement for informed consent from patients.

Inclusion criteria

This retrospective study screened clinical cases of multi-VPT-treated teeth in a VPT-treated data pool. VPT had been performed for patients with symptomatic/asymptomatic carious teeth. Post-VPT symptoms occurred, or pre-VPT symptoms were modified after VPT. VPT retrials were tried to resolve post-VPT symptoms (Fig. 2A—I). The following indications for VPT/VPT retrials were considered: (1) confirmation of the presence of vital pulp tissue after minimized pulp resection (MPR), (2) the resected pulpal surface conditions were within normal limits, (3) the

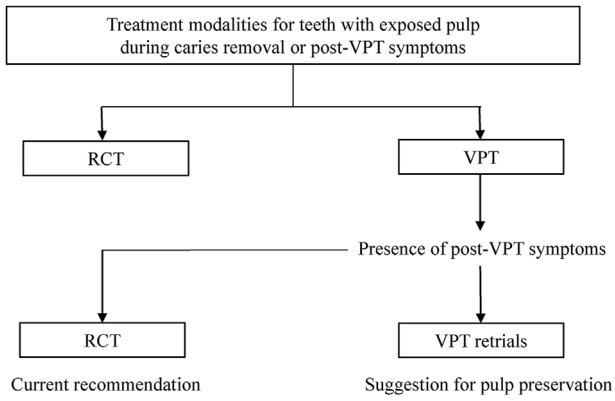

Figure 1 Suggestion of VPT retrials to resolve post-VPT symptoms. RCT, root canal treatment; VPT, vital pulp therapy.

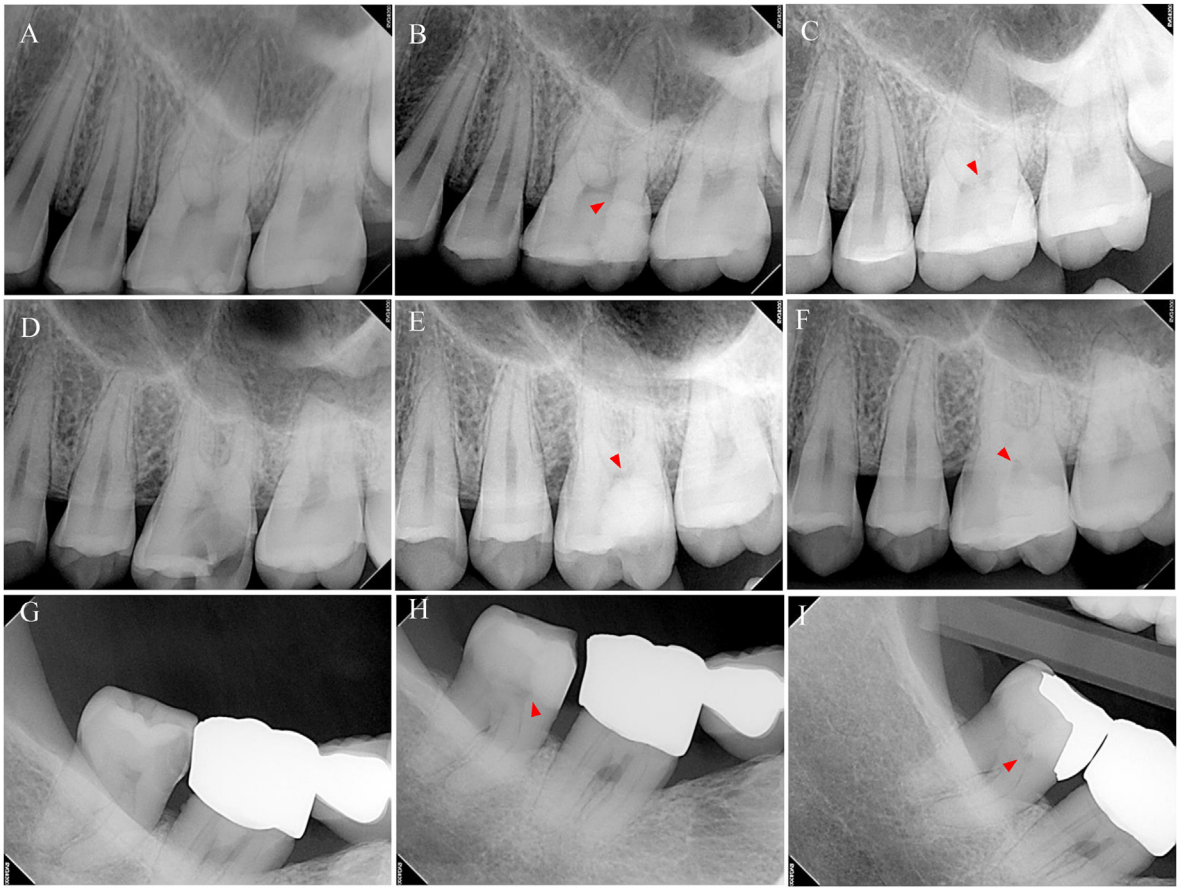

Figure 2 Treatment of deep/extremely deep caries and resolution of post-VPT symptoms through VPT-retrials in cases 5 (A–C), 17 (D–F), and 18 (G–I). **(A)** A deep carious lesion was present in the left maxillary first molar on the distal proximal region. **(B)** Pulpal exposure site around the distal pulpal horn area was capped with capping material. The amount of pulp resection resembled that done in direct pulp capping (red arrow). **(C)** The tooth was restored with resin inlay and showed favorable maintenance 29.9 months after VPT retrials. The extent of pulp resection after the VPT retrial was similar to what could be obtained with partial to full pulpotomy (red arrow). **(D)** An extremely deep caries was observed in the left maxillary first molar on the distal proximal area. **(E)** The amount of pulp resection resembled that done in full pulpotomy (red arrow). **(F)** Coronal pulp tissue remained after VPT retrials using MPR (red arrow). The tooth was restored with resin onlay and showed favorable maintenance 21.9 months after VPT retrials. **(G)** Deep caries existed in the right mandibular third molar on the mesial proximal surface. **(H)** Capping material covered the exposed pulpal surface (red arrow). **(I)** The extent of further pulp resection was located deeper than in H (red arrow). The tooth was restored with gold inlay, showing favorable maintenance 15.4 months after VPT retrials. MPR, minimized pulp resection; VPT, vital pulp therapy.

alleviation or no aggregation of symptoms after VPT, (4) post-VPT spontaneous pain was not severe, and (5) positive response to electric pulp test pre-VPT and post-VPT. Teeth with severe spontaneous pain or unalleviated persistent symptoms after VPT were considered for RCT. All the cases in this study were performed by the same endodontist to minimize operator-dependent deviations.

Pulp preservation procedures during vital pulp therapy/vital pulp therapy retrials

Advancements in pulp preservation procedures, including improved magnification, development of capping materials, and understanding of pulp biology, have enhanced VPT outcomes.[23] The term "pulp preservation procedures" has been introduced to emphasize the enhancements in VPT performance for exposed pulp.[18] Pulp preservation procedures include all procedures performed to treat the exposed pulp, including visual inspection, pulp resection, hemostasis, and pulp capping. In this study, MPR was introduced to enhance pulp preservation procedures with respect to the extent of pulp resection. MPR removes only unhealthy superficial layer of exposed pulp with meticulous peeling-like motion.

VPT was performed for carious symptomatic/asymptomatic teeth. After local anesthesia with 2% lidocaine (Huons, Seongnam-si, South Korea), the tooth was isolated with a rubber dam. Caries was removed using the "complete removing method" following the American Association of Endodontists guidelines.[6] A caries indicator, Seek™ (Ultradent, South Jordan, UT, USA), was used to identify the infected dentin, and the pulp was exposed (Fig. 3A). Pulp preservation procedures using MPR were performed as previously described.[18] An unhealthy layer of the exposed pulpal surface was removed through a minimized peeling-like motion. MPR was performed with sterilized long-

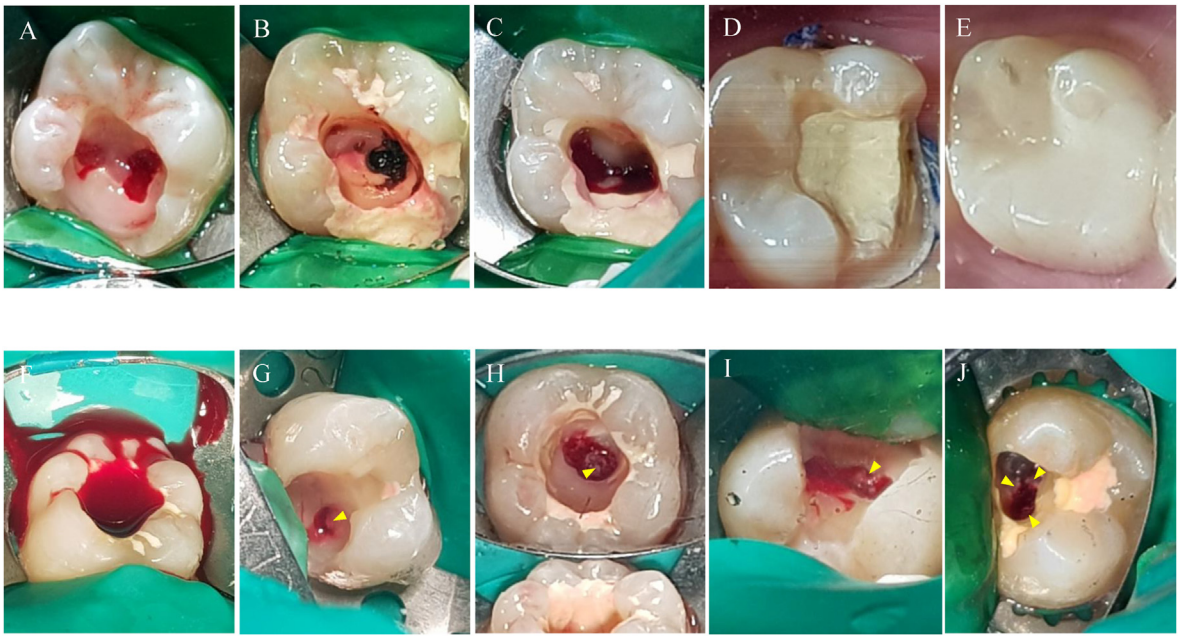

Figure 3 Procedures for retrying pulp preservation procedures (A to E) and conditions of re-exposed pulp sites at the second/third-trial VPT (F to J). **(A)** The pulp was exposed during the first-trial VPT, revealing bright red blood and the exposed pulp. **(B)** The exposure sites in the first-trial VPT were re-opened to inspect the pulpal surface. A black-colored avascular pulpal surface was observed. **(C)** Vital pulp tissues without inflammation, avascularity, necrosis, or inclusion of dentin chips were exposed after repeated MPRs. **(D)** The tooth was prepared for restoration. **(E)** The tooth was restored with a resin-onlay. **(F)** Heavy hemorrhage occurred at the re-opened pulpal exposure site. **(G)** Avascular flabby-appearing tissue was present on the re-exposed pulpal surface (yellow arrow). **(H)** Unclean tissue was limited to the superficial layer adhering to the normal pulp surface (yellow arrow). **(I)** Inflamed unhealthy tissue could be identified during visual inspection of the re-exposed pulp. **(J)** An abnormal portion of exposed pulp that should be removed by MPR was observed (yellow arrows). MPR, minimized pulp resection; VPT, vital pulp therapy.

shanked low-speed round burs (Komet, Lemgo, Germany) under water coolant. Further pulp preservation procedures were performed after confirming the presence of vital tissues at the pulpal exposure sites after MPR. Hemostasis was achieved using cotton pellets soaked in 2.5% sodium hypochlorite for a maximum of 10 min. The exposed pulp and entire cavity were filled with Biodentine (Septodont, Saint-Maur-des-Fossés, France), a calcium silicate cement, following the manufacturer's protocol. VPT retrials were considered to resolve post-VPT symptoms, substituting RCT. The pulp-capping material was removed to re-expose the pulp, referencing the locations of pulpal exposure sites that occurred during the preceding VPT (Fig. 3B). After inspecting the re-exposed pulpal surface, MPRs were repeated to remove the unhealthy superficial layer of the pulp until exposing vital pulp tissue (Fig. 3C). The capping material was re-applied to the exposed pulp and entire cavity after achieving hemostasis. After confirming the resolution of the post-VPT symptoms, the teeth were prepared for final restorations (Fig. 3D). The tooth was restored indirectly (Fig. 3E). All pulp preservation procedures were performed under magnification using EyeMag® Pro (Zeiss, Mainz, Germany).

Evaluation of exposed pulpal surface

Re-exposed pulpal surfaces showed altered conditions, including heavy hemorrhage, avascular flabby-appearing tissue, and avascular non-viable unclean tissue (Fig. 3F–J). The exposed pulpal surface should have no inflammation, avascularity, necrosis, or inclusion of dentin chips.[17] MPR and inspection were repeated to remove the unhealthy portion of pulp tissue.

Evaluation criteria for follow-up assessment

Multi-VPT-treated teeth were evaluated clinically and radiographically.[8] Clinical success criteria included the absence of pain or discomfort, no heightened sensitivity to thermal stimuli, no evidence of swelling or sinus tract, and a negative response to percussion tests. Radiographic success criteria included no evidence of radiographic changes in the apical area or root resorption (Fig. 2C, F and I). RCT-treated cases were regarded as failures of VPT retrials. Follow-up assessments using a phone call survey were performed in four cases that had no visiting examination. The phone call survey questions included clinical evaluation and experience with additional treatment after VPT, such as RCT.

Statistical analyses

Descriptive statistics were performed using the Statistical Package for the Social Sciences, version 28.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

A total of 22 multi-VPT-performed cases from 19 patients were screened from the VPT data pool. Pre-VPT clinical data are presented in Table 1. The clinical cases comprised 19 cases with two VPT-trials and 3 cases with three VPT-trials. The proportions of symptomatic and asymptomatic teeth at the initial examination were 59.1% and 40.9%, respectively. The most prevalent pre-VPT symptoms were heightened sensitivity or pain to stimuli, such as sweet and thermal stimuli (59.1%), followed by spontaneous pain (22.7%) and pain during mastication (22.7%). In five cases with pre-VPT spontaneous pain, three exhibited severe pain intensity. The spontaneous pain intensity of "severe" was estimated by considering the patient's chief complaint, "I had severe pain," combined with other descriptions, including aggravated pain at night, lasting pain for >4 min, and taking analgesics for pain relief. Pre-VPT diagnosis of symptomatic/asymptomatic IP showed the same rate (40.9%) and was higher than reversible pulpitis (18.2%). The diagnosis of asymptomatic pre-VPT IP was made based on the depth of caries. Regarding the depth of caries, teeth in 20 cases exhibited deep caries, whereas 2 cases had extremely deep caries following the European Society of Endodontology guidelines.[7]

Post-VPT clinical data are presented in Table 2. Heightened hypersensitivity to thermal stimuli was the most prevalent reason for VPT retrials (68.2%), followed by spontaneous pain (45.5%), pain during mastication (36.4%), and positive responses to percussion tests (18.2%). The intensity of post-VPT spontaneous pain was not severe. The proportion of post-VPT symptomatic IP (63.6 %) was higher than that of reversible pulpitis (31.8%). The overall success and failure rates of VPT retrials were 90.9% and 9.1%, respectively. RCT was performed for two cases (case 3, 21) and regarded as a "failure of VPT re-trials." In case 3, the history of RCT was identified through a phone call assessment, where the patient reported undergoing RCT for a "cracked tooth" at a local private clinic. In case 21, the alleviation of symptoms was

Table 1 Pre-vital pulp therapy clinical information of cases.

Case No.	Age/sex	Tooth No.[a]	Pre-vital pulp therapy symptoms				Depth of caries[b]		Pulpal diagnosis[c]		
			Asymptomatic (40.9%, 9/22)	Spontaneous pain (22.7%, 5/22)	Stimuli/HS or pain (59.1%, 13/22)	Pain during mastication (22.7%, 5/22)	Deep (90.9%, 20/22)	Extremely deep (9.1%, 2/22)	RP (18.2%, 4/22)	AIP (40.9%, 9/22)	SIP (40.9%, 9/22)
1	31/M	13	√				√			√	
2	39/F	31	√				√			√	
3	36/F	19	√				√			√	
4	21/F	4	√					√		√	
5	18/F	14			Sweet/pain		√		√		
6	14/F	5	√				√			√	
7	14/F	4	√				√			√	
8	16/M	15	√				√			√	
9	18/F	29			Cold, sweet/HS, pain		√		√		
10	18/F	19			Cold, hot/pain		√		√		
11	17/M	18		√	Cold/pain	Pain	√				√
12	14/M	31		√	Cold/HS		√				√
13	42/F	15			Cold/HS	Pain	√				√
14	28/M	15		√[d]	Cold/HS	Pain	√				√
15	25/M	13		√[d]	Sweet/pain		√				√
16	25/M	14		√[d]	Sweet/pain		√				√
17	28/M	14			Cold/HS	Pain		√			√
18	72/F	32	√				√			√	
19	24/F	18			Cold/HS		√		√		
20	51/M	12			Cold, hot/pain, last 3–4 min.		√				√
21	24/M	14	√				√			√	
22	33/M	2			Cold, hot/pain	Pain	√				√

Abbreviations: HS, heightened sensitivity; RP, reversible pulpitis; AIP, asymptomatic irreversible pulpitis; SIP, symptomatic irreversible pulpitis.

[a] Universal tooth numbering system.

[b] European Society of Endodontology (ESE) guidelines. Deep caries reaches the inner quarter of the dentine and have a zone of hard or firm dentine between the caries and the pulp. Extremely deep caries penetrates the entire thickness of the dentine.

[c] American Association of Endodontists (AAE) guidelines.

[d] Severe spontaneous pain.

Table 2 Post-vital pulp therapy clinical information of cases.

Case No.	Age/ sex	Tooth No.[a]	Post-vital pulp therapy symptoms and reasons for vital pulp therapy re-trials					Pulpal diagnosis[b]			Rest-oration	Re-trial number	EP: visiting/ phone (mon.)	RCT -practiced (9.1%, 2/22)	Success (90.9%, 20/22)
			Spontaneous pain (45.5%, 10/22)	Heightened sensitivity to thermal stimuli (68.2%, 15/22)	Pain during mastication (36.4%, 8/22)	Pain to percussion (18.2%, 4/22)	Others	NA (4.5%, 1/22)	RP (31.8%, 7/22)	SIP (63.6%, 14/22)					
1	31/M	13		√					√		G-In	2	55.8		√
2	39/F	31					Void[c]	√			R-In	2	22.3/53.6		√
3	36/F	19	√	√						√	G-Cr	3	14.0/14.0	√	
4	21/F	4	√	√						√	R-In	2	2.9/32.7		√
5	18/F	14		√	√					√	R-In	2	29.9		√
6	14/F	5	√		√					√	R-In	2	31.5		√
7	14/F	4	√		√					√	R-In	2	31.5		√
8	16/M	15			√	√				√	R-In	2	7.1		√
9	18/F	29	√			√				√	R-In	2	32.5		√
10	18/F	19	√	√						√	Un-R	3	27.0		√
11	17/M	18	√	√	√					√	R-In	2	29.3		√
12	14/M	31	√			√				√	R-In	3	22.2		√
13	42/F	15	√							√	R-In	2	30.7		√
14	28/M	15		√					√		R-In	2	1.9/19.5		√
15	25/M	13		√	√	√				√	R-In	2	17.5		√
16	25/M	14		√	√					√	R-In	2	17.5		√
17	28/M	14	√	√	√					√	R-On	2	21.9		√
18	72/F	32		√					√		G-In	2	15.4		√
19	24/F	18		√					√		R-In	2	13.8		√
20	51/M	12		√					√		Zi-Cr	2	13.3		√
21	24/M	14		√					√		NA	2	1.4	√	
22	33/M	2		√					√		R-In	2	7.8		√

Abbreviations: NA, non-available; RP, reversible pulpitis; SIP, symptomatic irreversible pulpitis; G-In, gold inlay; R-In, resin inlay; G-Cr, gold crown; Un-R, un-restored; R-On, resin onlay; Zi-Cr, zirconia crown; EP, evaluation period; RCT, root canal treatment.

[a] Universal tooth numbering system.

[b] American Association of Endodontists (AAE) guidelines.

[c] Void with bleeding trace in the base material.

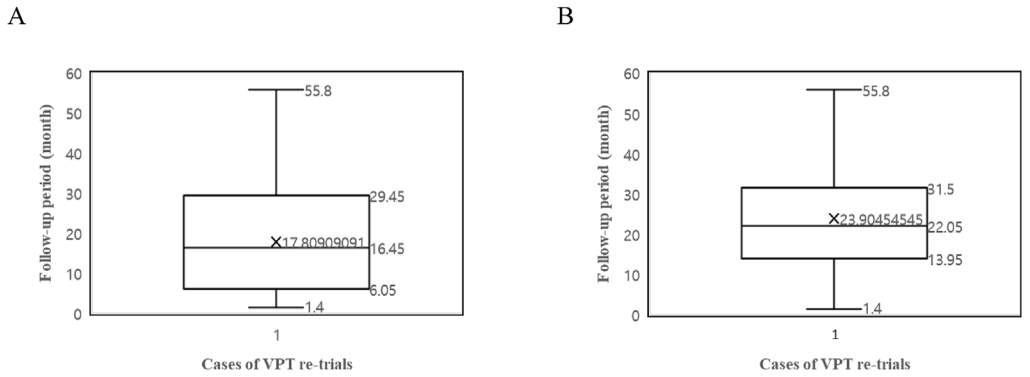

Figure 4 Periods of follow-up assessment after multiple VPT trials. **(A)** Follow-up periods excluding phone-call assessment data. The median follow-up period was 16.45 months. **(B)** Follow-up periods including phone-call assessment data. The median follow-up period was 22.05 months. The 75th percentile periods in A and B were 29.45 and 31.5 months, respectively. VPT, vital pulp therapy.

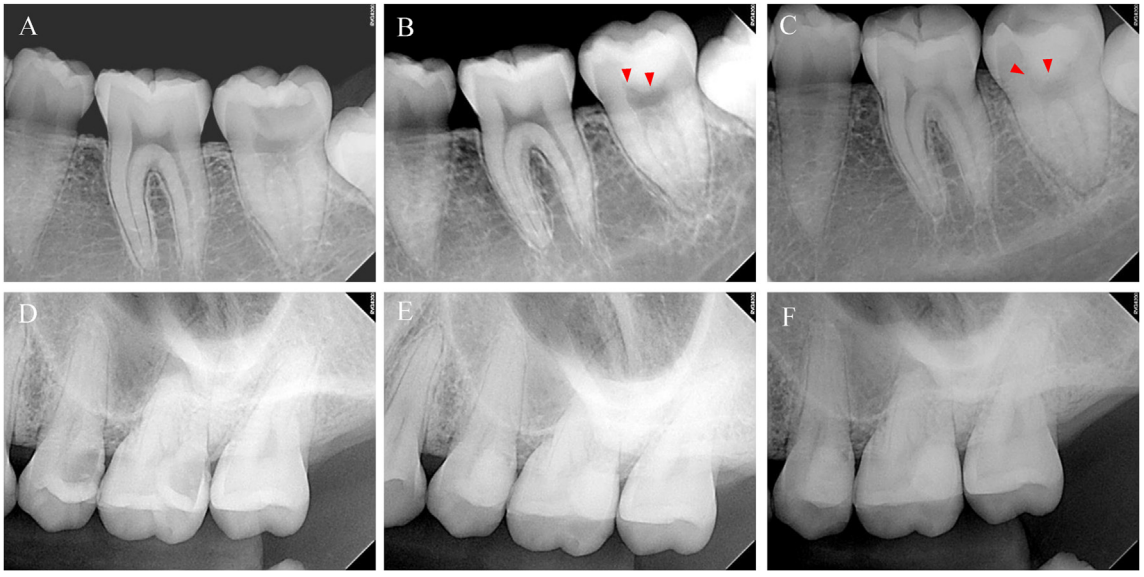

Figure 5 Varying extents of MPR in case 11 (A to C) and cases 15 and 16 (D to F). **(A)** A deep carious lesion was present in the left mandibular second molar. **(B)** Pulpal exposure sites were capped with capping material (red arrows). The amount of resected pulp was minimal and similar to that obtained with direct pulp capping. **(C)** The final extent of MPRs after the second VPT was deeper than that in B, resembling the resection amount in partial pulpotomy. **(D)** Deep carious lesions were present in the left maxillary second premolar and first molar in cases 15 and 16, respectively. Pulp chambers were restricted in both teeth. **(E)** The extent of MPR after the first VPT was similar to that of full pulpotomy. **(F)** No significant difference was observed in the amount of pulp resection after MPR between the first and second VPTs. MPR, minimized pulp resection; VPT, vital pulp therapy.

tenuous, and the tooth had a negative response to electric pulp test after a VPT retrial. RCT was performed for the tooth in case 21. Follow-up evaluations using phone-call assessments were performed in four cases (Table 2). The follow-up period analysis comprised data excluding and those including phone-call assessment periods. The median follow-up periods were 16.45 and 22.05 months excluding and including phone-call assessment periods, respectively. The 75th percentile periods were 29.45 and 31.5 months, respectively (Fig. 4A and B).

Discussion

RCT recommendations for teeth with IP conflict with the enhanced outcomes of VPT.[24] These contradictions may be due to the limited understanding of pulp vitality. In VPT, pulp vitality should be considered in association with the procedures, pulpal inflammation, and pulpal diagnosis. Pulp preservation procedures aimed at preserving pulp vitality, such as MPR, may enhance VPT outcomes. The severity of pulpal inflammation may be inversely proportional to pulp vitality and VPT outcomes. A pulpal diagnosis system that does not reflect pulp vitality may restrict the indications for VPT. In this study, VPT retrials were attempted even for teeth with post-VPT symptoms indicative of IP, based on the presence of vital pulp tissue where pulp vitality resides.

Clinical variables, such as heightened sensitivity to stimuli, depth of caries, and presence of spontaneous pain, may be associated with the degree of pulpal inflammation

and pulp vitality.[14,25] Heightened sensitivity to thermal stimuli might also indicate pulpal sensibility; however, it is not a quantitative marker for the degree of inflammation or pulp vitality.[26] Histological studies have shown induced pulpal inflammation in deep carious lesions.[27] However, inflammatory pulpal status does not always correlate with symptoms in teeth with progressed caries. Notably, all teeth in this study had deep to extremely deep caries, and the rate of pre-VPT asymptomatic teeth was 40.9%, consistent with a previous study showing progressive carious lesions without symptoms.[28] In this study, the pre-VPT pulpal diagnosis of asymptomatic IP was made by referring to the depth of caries according to guidelines (Table 1).[1,2] However, definite evidence supporting the irreversibility of pulp in association with deep to extremely deep caries is lacking. Regardless of symptomatic/asymptomatic IP, pulpal assessments of IP conflict with a 90.9% success rate of VPT retrials that suggests the ambiguity of evaluating "irreversible" regarding pulpal recovery potency. Spontaneous pain is a critical factor in diagnosing IP.[2] However, pulpal recovery is possible in teeth with spontaneous pain.[29,30] A histological study demonstrated severe pulpal inflammation in teeth with severe spontaneous pain, suggesting close correlations between pain intensity and histological pulpal diagnosis.[14] Therefore, pain intensity can be a factor for estimating the severity of pulpal inflammation and pulp vitality. In this study, VPT retrials using MPR resolved post-VPT spontaneous pain, and the spontaneous pain intensity was not severe. Collectively, these data imply that clinical factors, such as heightened sensitivity/pain to stimuli, spontaneous pain, and depth of caries, have limitations in reflecting pulp irreversibility. Until the advent of complementing pulpal diagnosis systems and guidelines for VPT indications, reasoning clinical variables, including comparative values of electric pulp test, evaluation of exposed pulpal conditions through visual inspection, and the intensity of pain or discomfort, could be the next best guidelines for considering VPT.[17,18] In this study, we demonstrated that the indications for VPT could be broadened to some extent in teeth with post-VPT symptoms, even when post-VPT symptoms indicate IP. VPT retrials using MPR can suggest strategies for resolving post-VPT symptoms, thereby enhancing VPT outcomes (Fig. 1).

Asymptomatic teeth with deep carious lesions do not suggest the absence of pulpal inflammation.[27] Therefore, efforts to maintain pulp vitality by eradicating pulpal irritants are required. Selecting the type of pulpotomy could be influenced by symptoms.[31] While full pulpotomy showed higher success rates than partial pulpotomy, the difference was not statistically significant.[9,24,30] Currently, definitive guidelines or evidence for selecting the type of pulpotomy are lacking.[22] Regarding the extent of pulp resection, a balance is required between the maximum preservation of vital pulp to secure pulp vitality and sufficient pulp resection to eliminate pulpal irritants. Immediate pulp resection reaching the canal orifice, such as full pulpotomy, can be invasive and eliminate the opportunity for pulp preservation by VPT or VPT retrials. Although repeating MPR during VPT may be more time-consuming than immediate partial or full pulpotomy, MPR is effective for pulp preservation. Furthermore, VPT retrials are possible by securing the maximum amount of pulp tissue using MPR. The amount of pulp resection with MPR was similar to that of direct pulp capping to full pulpotomy (Fig. 5A—F). By introducing MPR and considering pulp vitality in the context of VPT, this study provides insights for improving treatment guidelines. Selecting treatment modalities between VPT/VPT retrial and RCT should be based on confirming the presence of vital pulp tissue and evaluating the resected pulpal surface conditions. Performing RCT without considering pulp vitality may lead to unnecessary pulpal removal. Therefore, VPT/VPT retrials could be the first-line treatment for real "tooth saving" followed by RCT.

In this study, pulpal status was indirectly estimated by comparing the outcomes of electric pulp tests with adjacent normal teeth. However, the amount of pulp resection and the extent of coronal restoration had wide variations. Therefore, electric pulp test results were excluded from the success criteria. The pulpal status was also indirectly estimated through success criteria, including the absence of clinical symptoms and no periapical changes in intraoral radiographs. Collectively, in this study, pulpal status could be presumed to be within normal limits or at least not cause pathologic changes.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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