CASE SERIES

Vital pulp therapy of permanent mature teeth

ABSTRACT

Aim: *Vital pulp therapy (VPT) has been recently suggested as an alternative clinical procedure to treat symptomatic mature permanent teeth presenting deep caries lesions, to maintain the pulp vitality over time and to avoid or post-pone root canal therapy. Therefore, the aim of the present study was to report cases of pulpotomy in mature permanent teeth with reversible pulpitis and to propose this technique as a viable alternative to traditional endodontic treatment.*

Summary: *The present case series was reported following Preferred Reporting items for Observational studies in Endodontics (PROBE) guidelines. Eight systemically healthy subjects presenting deep caries lesions approximating/involving the pulp of mature permanent teeth and with signs and symptoms of reversible pulpitis, underwent full pulpotomy using hydraulic calcium-silicate based cement. After final restorations, dental elements were clinically and radiographically followed-up for different time intervals (6 to 12 months). An overall clinical and radiographical success rate of 100% was reported up to 12 months.*

Key learning points:

- *Full pulpotomy should be considered as a valid non-invasive treatment in mature permanent teeth with signs and symptoms of pulpitis.*
- *VPT allows to maintain pulp vitality in the middle term.*
- *VPT may be regard as a viable alternative to traditional endodontic treatment.*
- *A larger sample size and a longer follow-up period are needed to confirm the preliminary obtained results.*

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KEYWORDS *Hydraulic cements, mature permanent teeth, pulp inflammation, root canal treatment, vital pulp therapy.*

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Vital pulp therapy (VPT) includes various treatment modalities aimed at preserving the integrity and vitality of dental pulp in cases of deep caries lesions approximating/involving the pulp tissue, or pulp exposure due to trauma or mechanical injury (1). VPT encompasses direct and indirect pulp capping procedures, as well as pulpotomy techniques - partial and complete pulpotomy - which are routinely applied in the management of primary teeth to enhance their longevity, and in immature permanent teeth to promote root development (2). Recently, the application of VPT may include symptomatic mature permanent teeth with deep caries lesions, providing an alternative approach to maintain pulp vitality and potentially avoid non-surgical root canal therapy (NSRCT) (3, 4).

This minimally invasive approach is supported by the reparative potential of dental pulp, that, as an inflamed tissue, has the possibility to heal. However, the effectiveness and success of VPT in permanent dental elements are closely associated with the severity of pulp inflammation and the extent of histopathological involvement of pulp tissue (5). In this light, it should be considered a lack of precise correlation between clinical symptoms and the histopathological state of the pulp, particularly evident in cases of irreversible pulpitis, which can lead to diagnostic inaccuracies (5-7); in addition, there is an absence of specific diagnostic tools able to provide a precise diagnosis based on histological status (8).

The chance to perform VPT on mature teeth not only has the advantage to preserve the tooth structure, tooth vitality and immune functions but also eases treatment procedures, decreasing economic and biological costs (9).

Therefore, the aim of the present study was to report cases of pulpotomy in mature permanent teeth with reversible pulpitis and to propose this technique as a viable alternative to traditional endodontic treatment.

Case Series

The present case series was reported following Preferred Reporting items for Observational studies in Endodontics (PROBE) guidelines (10) (Table 1). Eight systemically healthy subjects (M:F=3:5; aged between 9 and 32 years) referred to Dental Clinic of University of Naples Federico II, presenting deep carious lesions approximating/involving the pulp of mature permanent teeth.

Since data collection for observational analysis was not considered a clinical study, the study was notified to the ethical committee of the University of Naples Federico II. The study was conducted in accordance with the Declaration of Helsinki.

To provide a precise diagnosis of reversible pulpitis (8), clinical examination was performed recording the following symptoms: spontaneous pain, pain subsequent to cold or percussion, pain relief few seconds after stimulus removal, sensitiveness to ethyl chloride. In addition, intraoral radiographic examination was performed to verify the absence of periapical reaction (Table 2).

Before therapy, subjects were informed about the potential subsequent need of traditional endodontic therapy in case of pulp necrosis, irreversible pulpitis or untreatable suffering. Then, treatment procedures were explained to patients and signed informed consents were obtained.

All included teeth underwent full pulpotomy treatment following a standardized technique performed by a single operator (L.E.). Specifically, following local periapical anesthesia administration (mepivacaine without epinephrine), teeth were isolated using rubber dam, and cavities were cleaned using round burs at low speed under copious irrigation. After caries removal and exposure of pulp tissue, the roof of the pulp chamber was removed, and coronal pulp was amputated using a high-speed diamond bur under copious irrigation. Hemostasis was achieved using sterile cotton pellets moistened with saline solution up to 5 minutes.

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Table 1

PROBE 2023 Checklist

Section/ Topic	Item Number	Checklist items	Reported on page number
Title	1a	The specific area(s) of interest must be provided using words and phrases that identify the clinical problem(s) and focus of the study	1
	1b	The study design must be included in the Title, e.g., cross-sectional, cohort, case-control, case-series etc.	1
Keywords	2a	Keywords indicating the specific area(s) of interest using MeSH terms or other more applicable terms must be included	1
Abstract	3a	The Introduction/Background must briefly explain the rationale or justification for the study	1
	3b	The aim(s)/objective(s) of the study must be provided	1
	3c	The Methodology must provide (where relevant) essential information on the nature of the study design (retrospective, cross-sectional, prospective, etc.), setting, location(s), and relevant dates, including periods of recruitment, exposure, follow-up, outcome(s) assessed and statistical analysis	1
	3d	The Results must describe the number of subjects that were included and analysed as well as the most significant results for all experimental and control groups. The results of statistical analysis must be reported in terms of unadjusted and confounder-adjusted outcomes (if relevant). Adverse events or side-effects must also be reported if present or confirmed as absent	1
	3e	The Conclusion must interpret and summarise the primary aim/objective and main findings as well as emphasise the clinical implications	1
	3f	The source(s) of funding must be provided	N/A
Introduction	4a	The clinical problem/question, scientific background and rationale for the study must be provided, including the gap(s) or inconsistencies in the existing knowledge base	2
	4b	The primary and, if applicable, any additional/secondary aim(s) and objective(s) of the study must be provided, including any pre-specified hypotheses	2
Methods Ethics	5a	The details (name, reference number, date) of the approval or exemption granted by an ethics committee, such as an Institutional Review Board, must be provided	2
	5b	The process used for obtaining and storing informed consent must be provided	2
Study design	5c	The key elements of the study design must be described early in the Methods section	2
Setting	5d	The details of setting(s), location(s), socioeconomic status of participants (if available) and relevant dates, including periods of recruitment, exposure, follow-up, and data collection must be provided	N/A
Sample size	5e	Information on how the sample size was determined *a priori* must be provided as well as the rationale for sample size calculation, preferably with reference to the published literature or a pilot study with additional detail as to why the defined sample size makes the study worthwhile	N/A
Participants – unmatched studies	5f	All studies should include inclusion/exclusion criteria as well as the sources and methods of participant selection. Methods of follow-up must also be provided in cohort studies and the rationale for the choice of 'cases' and 'controls' in case-control studies	N/A
Participants – matched studies	5g	For matched studies (e.g., cohort, case-control) the matching criteria and the numbers of participants in each group must be provided	N/A
Variables	5h	All outcomes, exposures, predictors, potential confounders, and effect modifiers must be defined clearly	3
Data sources/ measurement	5i	Sources of data and details of the methods of assessment (measurement) for each variable of interest must be provided	3
Bias	5j	Efforts taken to identify and address potential sources of bias must be provided	N/A
Quantitative variables	5k	The handling of quantitative variables in the analyses must be explained. Decisions on how groupings were made and/or how category boundaries were defined for continuous variables must be described	N/A
Statistical methods	5l	All statistical methods, including those used to control of confounding factors in the study and in the analysis of the data, must be described	N/A
	5m	The methods used to examine subgroups and interactions must be described, if applicable	N/A
	5n	Missing data (e.g. drop-outs, data not reported) must be addressed and described	N/A
	5o	The analytical methods that take account of the sampling strategy (if applicable) in *Cross-sectional studies* must be described	N/A
	5p	Sensitivity analyses, must be described when used	N/A

Continued on the next page

Results *Participants*	6a	The number of participants in each stage of the study (i.e., eligibility, recruitment, available at follow-up and included in analyses for relevant outcome(s)) must be described	3
	6b	Reasons for non-participation (e.g., not eligible, losses/drop-outs) must be described	N/A
Dates	6c	Changes in baseline dates of recruitment, follow-up, and study duration reported in the Methodology must be described, if applicable	3
Descriptive data	6d	The baseline demographic and clinical characteristics of study participants as well as information on exposures and potential confounders must be provided	N/A
	6e	The number of participants with missing data must be provided for each variable. If relevant, follow-up times should be summarised clearly and accurately (e.g., average or total time)	N/A
Outcome data	6f	Information on number of outcomes or summary measures over time must be described	3
	6g	For multivariable analyses developing risk profiles or reducing the effect of confounders, the effect of all included independent variables may be reported, as well as their effects on the prediction model (if applicable)	N/A
Main results	6h	Unadjusted (or uncorrected or crude) estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence intervals) must be described. Which confounders were adjusted for and why they were included must also be described	N/A
	6i	Results in terms of relative risk should also be translated to absolute risk for a meaningful time period, if relevant	N/A
Additional analyses	6j	The results from any other analyses (e.g., sensitivity, subgroup analyses) must be described, if applicable, as well as adjusted analyses, distinguishing pre-specified from exploratory	N/A
Discussion *Key results*	7a	The main findings must be summarized with reference to the study aim(s)/objective(s)	3
Rationale	7b	The rationale for inclusion/exclusion criteria, exposure, and duration must be provided	3
Clinical relevance	7c	An explanation of the clinical relevance of the primary and any additional/secondary outcome(s) must be provided	3
Strength	7d	The strength(s) of the study must be provided	3
Limitations	7e	The limitations of the study must be provided - addressing the sources of potential bias, imprecision, study design, study size and potentially important but missing confounding variables. Both direction and magnitude of any potential bias must be discussed	3
Summary and validity	7f	The discussion of the strength and limitations should be summarized in an overall assessment of the internal validity of the study	3
Interpretation	7g	A detailed interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence must be provided	3
Generalisability	7h	The generalizability (external validity, applicability, real-world relevance etc.) of the study findings must be discussed	4
Future directions	7i	Implication for future research and clinical practice must be described	4
Conclusion(s)	8a	Explicit conclusion(s) from the study must be provided and address all the aims/objectives	4
Funding details	9a	All sources of funding and other support (such as supply of drugs, equipment etc.) as well as the role of funders must be acknowledged and described	N/A
Conflict of interest	10a	An explicit statement on conflicts of interest must be provided, together with full affiliations of every author(s)	1
Quality of images (if applicable)	11a	Details of the equipment, software and settings used to acquire the image(s) must be described in the text or legend (if applicable)	N/A
	11b	The reason why the image(s) was acquired and the rationale for its inclusion in the manuscript must be provided in the manuscript. A justification for all images that involve ionising radiation must be included	3
	11c	The circumstances (conditions) under which the image(s) were viewed and evaluated by the author(s) must be provided in the text	3
	11d	The resolution, any magnification of the image(s) or modifications/enhancements (e.g., adjustments for brightness, colour balance, magnification, image smoothing, staining, etc.) that were carried out must be described in the text or figure legend	N/A
	11e	Patient(s) identifiers (names, patient numbers) must be removed for General Data Protection Regulation (GDPR) and to ensure they are anonymized or de-identified in all images	3
	11f	An interpretation of the findings (meaning and implications) from the image(s) must be provided in the text	3
	11g	The figure legend associated with each image must describe clearly what the subject is and what specific feature(s) is illustrated. If cases are offered to illustrate descriptions of a cohort, then the age, gender, ethnicity, and other specific attributes that are relevant to the cohort should be provided	5
	11h	Markers/labels must be used to identify the key information in the image(s) and defined in the figure legend	N/A
	11i	The figure legend of each image must include an explanation on whether it is pre-, intra- or post-treatment and follow-up and, if relevant, how images were standardised over time	5

N/A: NOT APPLICABLE

Table 2

Clinical signs and symptoms reported by patients at baseline

	Spontaneous Pain	Pain - after application of cold or percussion stimulus	Pain - relief after few seconds following removal of stimulus	Periapical Reaction	Sensitivity test with ethyl chloride
Patient 1	NO	YES	YES	NO	+
Patient 2	NO	YES	YES	NO	+
Patient 3	NO	YES	YES	NO	+
Patient 4	NO	YES	YES	NO	+
Patient 5	NO	NO	YES	NO	+
Patient 6	NO	YES	YES	NO	+
Patient 7	NO	YES	YES	NO	+
Patient 8	NO	YES	YES	NO	+

Fossés, France) was used to seal the pulp chamber. The cement was prepared according to the manufacturer's instructions and placed on root pulp stumps with a thickness of 2-4 mm. Then, teeth were temporarily restored with polymer-reinforced zinc oxide-eugenol cement (IRM, Dentsply International Inc., Milford, DE, USA). Final composite resin restoration was performed after 3 days, following the clinical evaluation of cement hardness with a dental explorer. Treated teeth underwent clinical and radiographic evaluations by a single calibrated and blinded examiner at 7 days, 1 month, 3, 6 and 12 months.

All subjects referred slight sensitivity 1- or 2-days post-treatment, that was controlled by the administration of analgesic, if needed.

The clinical cases were followed for different time intervals (6 to 12 months); specifically, 5 subjects out 8 were followed up to 6 months (Figure 1), while the remaining 3 cases were evaluated up to 12 months (Figure 2). An overall clinical and radiographical success rate of 100% was reported.

Discussion

Permanent teeth with signs and symptoms of pulpitis routinely undergo root canal therapy in order to remove the inflamed tissue. However, if the removal would interest only the inflamed/infected pulp, the repair potential of the healthy tissue should be preserved and the tooth vitality is partially maintained (11). In this light, the present study observed mature permanent teeth presenting signs and symptoms of reversible pulpitis that were treated with full pulpotomy rather than conventional endodontic treatment. An overall 100% of clinical and radiographical success rate was reported within a follow-up period up to 12 months. Based on the obtained outcomes, the amputated pulp was subjected to a healing process - thanks to its reparative potential (11, 12) – that resulted in the resolution of clinical signs and symptoms.

To achieve and maintain the clinical success, the coronal sealing plays a fundamental role in preventing bacterial microleakage (13, 14). In the present study, Biodentine was used as hydraulic cements, thanks to its biocompatibility, bioactivity and sealing property (15, 16). In agreement to previous studies, the same materials showed 100% clinical and 98.4% radiographic success after one year (17) and 100% after two years of follow-up (18), when applied after VPT in permanent teeth with irreversible pulpitis and apical periodontitis. Accordingly, Taha et al. (19) reported comparable success rates (93%) between pulpotomy with Biodentine and root canal therapy; moreover, the pulpotomy group showed significantly lower pain levels 1 day after pulpotomy than traditional endodontic, as well as shorter pain

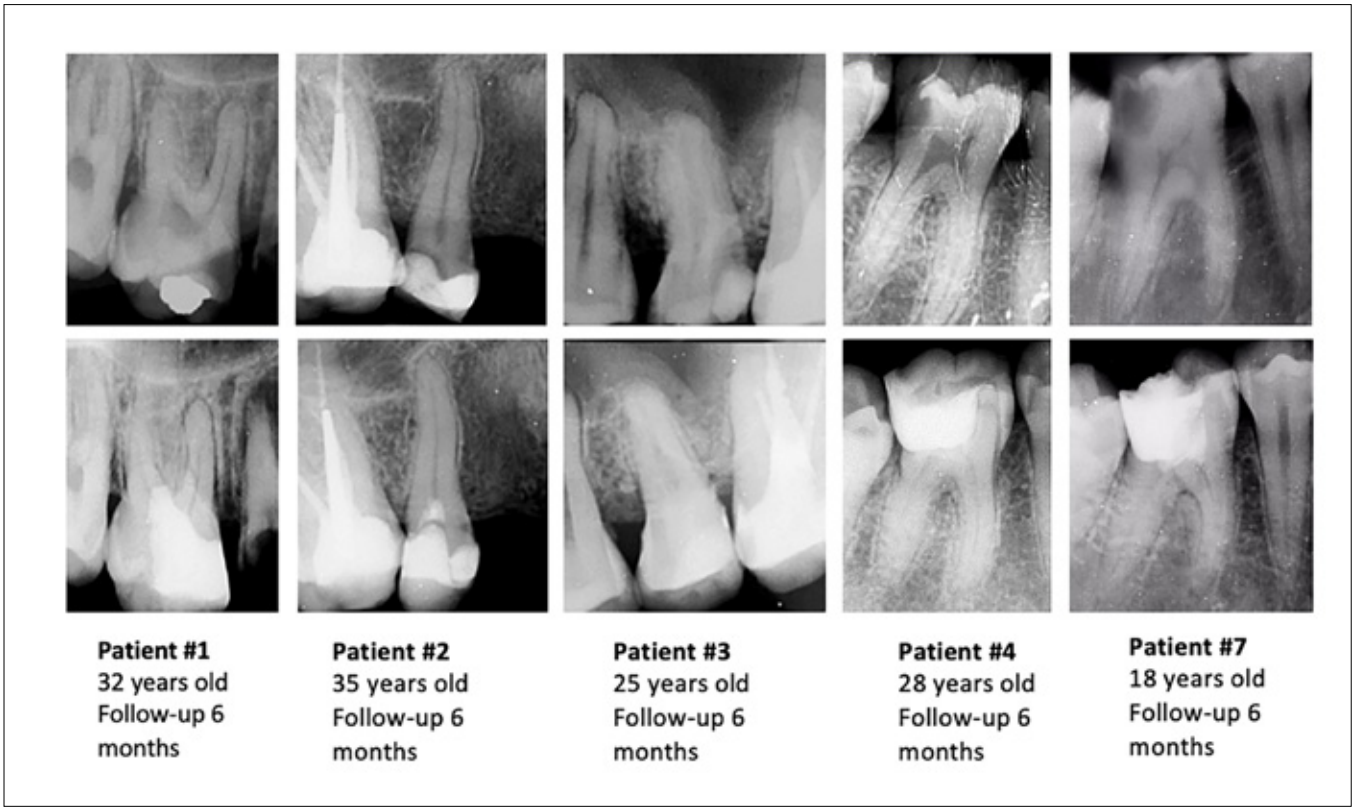

Figure 1
Periapical radiographs of baseline and 6 months follow-up of five patients.

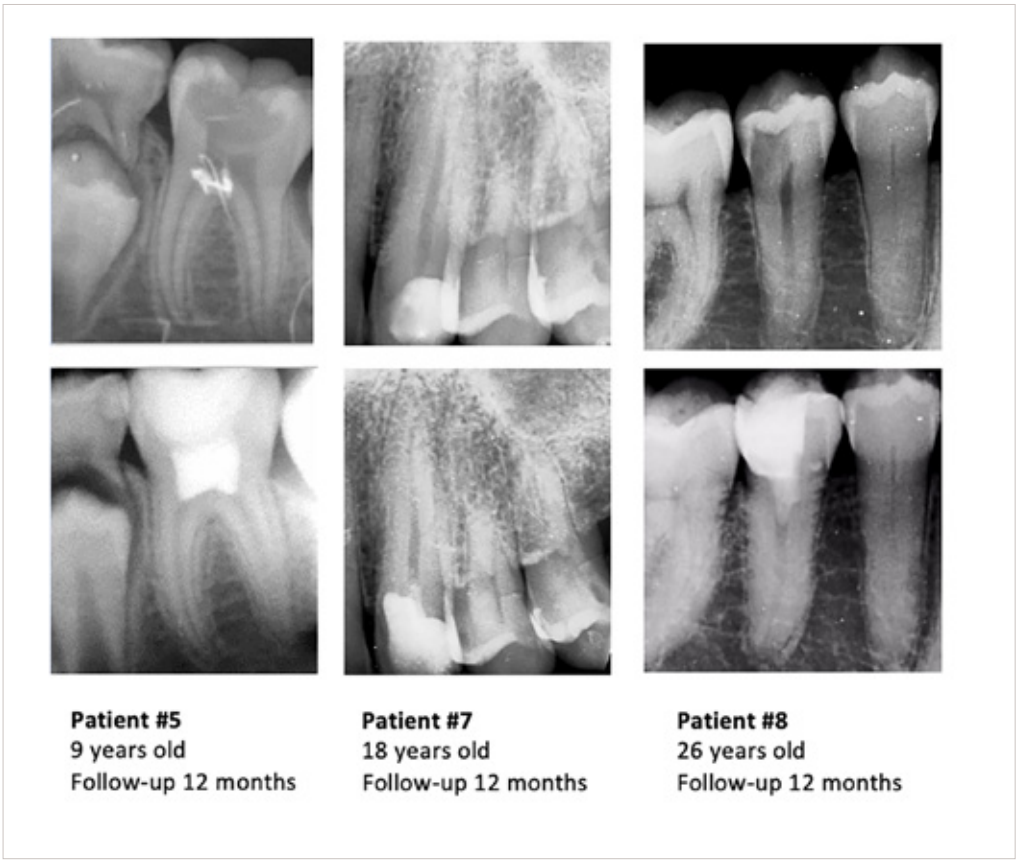

Figure 2
Periapical radiographs of baseline and 12 months follow-up of three patients.

relief and less requirement of analgesics (19). In this light, it should be stressed that, although the use of calcium silicate-based hydraulic cements in VPT has demonstrated promising outcomes in reducing pulp tissue inflammation and enhancing pulp healing, their role in reducing postoperative pain (8, 20, 21,) or benefit on pain management remains controversial and needs to be studied in depth.

Nowadays, VPT performed on mature symptomatic teeth is gaining a wide clinical interest and is becoming a valid alternative to traditional endodontic treatment (3,4, 22, 23). However, the major limitation of this technique is that current diagnosis of pulp diseases depends on various parameters such as subjective pain perception by the patient, objective/subjective clinical examination, and radiographic findings, without considering the histopathological state of the pulp tissue and its reparative potential (8). Indeed, during pulpotomy, tissue health is only appreciated by the time interval for hemostasis after pulp amputation (2-5 minutes), that is indicative of absence of acute inflammation. However, additional diagnostic criteria are needed to make this technique as predictable as possible.

Clinicians possess a wide range of therapeutic choices to individualize treatment based on patient symptoms, age, and dental element involvement, with the aim to preserve teeth function over time (24); nevertheless, the use of minimally invasive treatments is strictly related to several factors related to biology, subjects and clinical operator that might influence the prognosis (25, 26).

Therefore, these aspects should be prospectively evaluated with well-designed clinical trials supporting VPT as a strong clinical alternative to pulpectomy of vital dental elements.

Conclusions

Within the limitations of the present study, it can be concluded that a success rate of 100% was achieved, and appropriate diagnosis of pulp inflammation and use of proper materials, as hydraulic cements, are key factors in maintaining dental vitality over time. Therefore, VPT can be considered a valid minimally invasive treatment with medium success when applied to mature permanent teeth diagnosed with reversible pulpitis, ensuring greater reliability in terms of function, tooth weakening, and fracture risk compared to elements treated with traditional therapy. However, a larger sample size and longer follow-up period are necessary to confirm the obtained preliminary results, supporting VPT as a valid alternative to conventional endodontic treatment.

Clinical Relevance

VPT seems to be an alternative approach even in symptomatic mature permanent teeth with deep caries lesions to maintain pulp vitality over time and to post-pone or avoid non- surgical root canal therapy.

Conflict of Interest

None.

Acknowledgements

None.

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