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**VITAL PULP THERAPY VERSUS ENDODONTIC TREATMENT:
A NARRATIVE REVISION**

Universidade Fernando Pessoa

Faculdade Ciências da Saúde

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Vital Pulp Therapy versus Endodontic Treatment: A narrative revision

Trabalho apresentado à Universidade Fernando Pessoa
como parte dos requisitos para obtenção do grau
de Mestre em Medicina Dentária

(Ouardia Ouacher)

RESUMO

O principal objetivo de todos os procedimentos restauradores é manter a viabilidade da polpa dentária. Nas últimas décadas as técnicas minimamente invasivas têm sido amplamente adotadas.

O objetivo deste estudo é definir a opção terapêutica mais adequada em dentes maduros, terapia pulpar vital ou o convencional tratamento endodôntico radicular.

A pesquisa bibliográfica foi realizada na *Pubmed*, *Medline*, *Scielo* e no Google Acadêmico.

A evidência nesta revisão sugere que a proteção pulpar direta é um procedimento clinicamente efetivo para tratamento de dentes com cárie profunda e exposição pulpar. Embora sejam necessários mais estudos, as opções de tratamento apresentadas nesta revisão permitem mudar os protocolos e, dessa forma, melhorar a qualidade de vida dos pacientes.

Palavras-chave: “Terapia pulpar vital”; “Proteção pulpar”; “pulpotomia”; “tratamento endodôntico”; “tratamento do canal radicular”; “endodontia regenerativa”.

ABSTRACT

The major goal of all restorative procedures is to maintain the viability of the dental pulp. Over the last few decades, minimally invasive techniques have received wider acceptance.

The aim of this study is to define the most suitable therapeutic option for a mature tooth, the vital pulp therapies or the conventional root canal treatment.

The search for bibliographic material was done using *Pubmed*, *Medline*, *Scielo* and Academic Google.

The evidence in this review suggests that direct pulp capping is a clinically effective procedure for treating teeth with deep caries and pathologically exposed pulps. Although many more studies are required, the treatment options presented here will change endodontic therapies and improve quality of life in patients.

Key words: “vital pulp therapy”; “pulp capping; “pulpotomy”; “endodontic treatment”; “root canal treatment”; “regenerative endodontics”.

ACKNOWLEDGMENTS

I would like to thank my supervisor Tiago Reis for the precious advice, help, patience and availability during all these months of work. It was a grateful honour of being supervised by you.

I also want to thank all professors of Universidade Fernando Pessoa, for their assistance and teaching me how to be the best professional I can be.

Mom and Dad, thank you for always believing in me and for doing everything possible to make my dreams come true.

A big thank to my brother and sister, for your love, support, and encouragements.

And last but not the least, I would like to thank all my friends and colleagues, for making this experience fun and rewarding.

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ABBREVIATION INDEX

AAE – American Association of Endodontics

BD – Biodentine

Ca(OH)² - Calcium Hydroxide

CEM – calcium-enriched mixture cement

CHX – Chlorhexidine

CSC – Calcium Silicate-based Cement

DPC – Direct pulp capping

ESE – European Society of Endodontics

FP – Full Pulpotomy

MTA – Mineral Trioxide Aggregate

NaOCl – Sodium Hypochlorite

NSRCT – Non-surgical root canal treatment

VPT – Vital pulp therapy

WL – Working Length

I. INTRODUCTION

Direct exposure of the pulp to the oral environment breaks the integrity of the pulp-dentin complex and, if not properly treated, will lead to apical periodontitis, which eventually requires root canal treatment or extraction (ESE, 2006).

On the other hand, clinical experience indicates that inflamed pulps can recover if the majority of the antigens are removed early enough (Hahn and Liewehr, 2007).

Until recently, the pulp of a mature tooth exposed by caries has been considered a “doomed organ” because the induced inflammatory condition is often not reversible after intervention (typically direct pulp capping with calcium hydroxide). Pulp extirpation and root canal treatment have been the standard of care and have a very favourable outcome. However, inflammation is mostly confined to the coronal region immediately beneath the carious exposure, and the radicular pulp is essentially normal and uninflamed, with an intact odontoblast layer. Involvement of the entire coronal and radicular pulp occurs only at very late stages of the caries process. Therefore, it is possible that cariously exposed pulps could be preserved by resecting only the infected and diseased pulp tissue below the microbial front (Tan *et al.*, 2020).

The major goal of all restorative procedures is to maintain the viability of the dental pulp whenever possible, and over the last few decades minimally invasive techniques have received wider acceptance in teeth with carious exposure (Taha and Khazali, 2017).

The aims of vital pulp therapy (VPT) include the maintenance of vitality and preservation of the remaining pulp for adequate structural/functional healing of the pulp-dentin complex. The key point in the success of VPT is continued vitality of the tooth, especially the presence of sufficient blood supply to advance. Vital permanent teeth irrespective of their signs/symptoms of irreversible pulpitis and the presence of apical periodontitis may indeed be candidates for VPT (Asgary *et al.*, 2018).

Irreversible pulpitis is defined as an inflamed pulp that is no longer capable of healing and returning to normal status; however, this terminology is one of the existing dilemmas. Researchers suggested that, considering that infection is often the cause of inflammation, an inflamed pulp should be able to heal if the source of infection is eliminated, as is often the case in other body organs (Asgary *et al.*, 2018).

The aim of this study, based on scientific evidence, is to define the most suitable therapeutic option for a mature tooth affected by reversible or irreversible pulpitis, between vital pulp therapies and root canal treatment. For many years, the treatment of choice was root canal treatment while there are vital pulp therapies that are more conservative and allow dentin-pulp complex regeneration.

1. Materials and Methods

For this work, a search was carried out between October 2021 and April 2022, using the search engines *Pubmed*, *Medline*, *Scielo* and Academic Google through the access of the Library of the University Fernando Pessoa. The keywords used were “vital pulp therapy”, “pulp capping”, “pulpotomy”, “endodontic treatment”, “root canal treatment” and “regenerative endodontics”.

The inclusion criteria restricted the search to articles written in English and articles published in the last 16 years. Initially, the selection was based on the reading of the title and abstract, being rejected all of those that substantially diverged from the subject under study or whose availability was impossible. Subsequently, exclusion was determined by analyzing the full content of each article, culminating in a total of 24 articles. A reference book in the area was also consulted.

II. DEVELOPMENT

1. Vital pulp therapy

The VPT is an alternative to Non-Surgical Root Canal Treatment (NSRCT). VPT is consistent with contemporary concepts of minimally invasive dentistry, and has long been considered a definitive treatment for permanent immature teeth diagnosed as having reversible or irreversible pulpitis (Santos *et al.*, 2021).

VPT is defined as a dental procedure which aims to treat teeth with compromised dental pulps in order to maintain pulp tissue in a healthy state. Maintaining dental pulp vitality increases the long-term survival of teeth, a fact that makes VPT a treatment objective for teeth affected by caries, traumatic injury, or other causes. However, the most important issue in VPT is to accurately define the level of pulp disease. Underestimation of the levels of pulp inflammation may lead to clinical failure due to irreversible inflammation and pulp necrosis (Kodonas *et al.*, 2021).

Many recent works including some controlled studies have showed that mature permanent teeth clinically diagnosed with irreversible pulpitis without apical periodontitis could be successfully treated with VPT (Lin *et al.*, 2020).

i. Indirect Pulp Capping

Indirect pulp capping is a procedure in which a biocompatible material, is placed on a thin partition of remaining carious dentine that, that if removed, there is a risk of exposing the pulp (Edwards *et al.*, 2021). The purpose of leaving soft carious dentine in this first session is to avoid pulp exposure and to alter the microbial ecology of the caries biofilm, entombing and inactivating the remaining bacteria by virtue of the seal of the restoration, which denies further supply of fermentable sugars from diet to residual bacteria (Ricucci *et al.*, 2019). The capping material is expected to disinfect dentin close to the pulp, seal the pulp tissue and stimulate the formation of tertiary dentin. This tertiary dentin is also referred to as reactionary dentin, which by definition is formed by surviving postmitotic primary odontoblasts (Dammaschke *et al.*, 2019). A second visit should be performed to remove the restorative material and residual caries mass and for the final restoration (AAE, 2016).

For this procedure it's also mandatory to have pre-operative radiographs to exclude periapical lesions and no history of subjective symptoms (AAE, 2016; Edwards *et al.*, 2021). It should be also performed under controlled isolation using rubber dam. To avoid cross-contamination, it is also recommended to disinfect the clinical crown before excavation using sodium hypochlorite (NaOCl; 1–5 %) or chlorhexidine-gluconate (CHX; 2 %) (Dammaschke *et al.*, 2019).

ii. Direct Pulp Capping

Direct pulp capping (DPC) is a procedure in which the exposed pulp is covered with a radiopaque biocompatible material placed directly over the exposure site (ESE, 2006). The final restoration is placed over the base. The status of the pulp and periradicular tissues should be assessed through periodic recall examinations (AAE, 2016).

This treatment aims to maintain healthy pulp by sealing it against ingress of bacteria and inducing dentin bridge formation at the exposure site. Perhaps, this procedure is only recommended when pulp exposure is produced mechanically (i.e., accidentally) or traumatically and just in cases diagnosed with reversible pulpitis (Dammaschke *et al.*, 2019; AAE, 2020; Edwards *et al.*, 2021).

iii. Pulpotomy

Pulpotomy is a method to maintain vitality of the pulp after artificial exposure of the coronal pulp. The coronal pulp is partially amputated (partial pulpotomy) or amputated at the level of the root canal orifices (full pulpotomy) and treated similar to direct pulp capping after successful haemostasis (Dammaschke *et al.*, 2019). The European Society of Endodontology (ESE) position statement recommends using a Calcium Silicate-based Cement (CSCs) for complete or partial pulpotomies (Edwards *et al.*, 2021).

o Partial Pulpotomy (Cvek pulpotomy)

A partial pulpotomy is the removal of a small portion of the vital coronal pulp as a means of preserving the vitality of the remaining coronal and radicular pulp tissues (Ricucci *et al.*, 2019; AAE, 2020). This procedure is defined as a procedure that involves gentle/limited removal of the infected dentine chips/damaged pulp tissue at the most superficial part of the pulp. According to the proponents of the partial pulpotomy, this modality produces a clean surgical wound and improves the proximity/interaction of the pulp covering agent to undifferentiated mesenchymal stem cells (Ricucci *et al.*, 2019).

Similar to direct pulp capping, during partial pulpotomy the rinsing of the site of amputation with NaOCl is recommended until the bleeding is suspended. Provided that the formation of a blood clot is prevented, the same pulp repair mechanisms of direct pulp capping are to be expected. If the remaining pulp is healthy, the bleeding is expected to suspend within 5 minutes. If haemostasis has not taken place within this time, it may be concluded the pulp has not been reduced to a healthy level. In this case, the removal of the entire coronal pulp, a full pulpotomy, can be considered as the last possible measure to maintain vitality (Dammaschke *et al.*, 2019).

- Full Pulpotomy

A full pulpotomy (FP) is the removal of the coronal portion of a vital pulp as a means of preserving the vitality of the remaining radicular portion (Ricucci *et al.*, 2019). The most important issue is that current pulpotomy never leads to the regeneration of the dentin-pulp complex that was lost in the coronal portion (Morotomi *et al.*, 2019).

2. Pulpectomy/Non-surgical root canal treatment

The traditional treatment modality for permanent mature teeth diagnosed with irreversible pulpitis is pulpectomy, also known as NSRCT. The purpose of root canal treatment is either to maintain asepsis of the root canal system or to disinfect it adequately. This approach is not indicated on teeth that cannot be made functional nor restored, with insufficient periodontal support or with poor prognosis. To an uncooperative patients or patients where dental treatment procedures cannot be undertaken or patients with poor oral condition that cannot be improved within a reasonable period, NSRCT is also contra-indicated (ESE, 2006; AAE, 2020).

The major procedural steps and process goals of NSRCT are well established, including access cavity preparation into the pulp chamber of the tooth, extirpation of the pulp tissue, complete filling of the pulp space to establish an environment conducive to healing and to prevent future bacterial ingress, and definitive restoration of the endodontic cavity and coronal tooth structure. When NSRCT meeting the established process goals is performed in teeth diagnosed with irreversible pulpitis, 92 to 98% of the teeth are expected to remain healthy, based on radiographic and clinical criteria, several years after treatment (Dammaschke *et al.*, 2019; Ricucci *et al.*, 2019; Santos *et al.*, 2021).

In contrast, cross-sectional studies of root-filled teeth in general populations from many countries have reported high prevalence values of inadequate root fillings (56 to 86%) and apical periodontitis (34 to 68%), suggesting that often neither the accepted process goals nor the expected outcomes are achieved (Santos *et al.*, 2021).

Before starting a NSRCT is mandatory to have well-angulated radiographs, analyse the case difficulty. After place rubber dam is also important to assure a good isolation. The preparation of a conservative access cavity is crucial to reveal all root canal orifices. Start by scout canals with a #10 K-file and if the selected series of rotary instruments advances easily to the estimated WL, confirm patency and determine WL using an electronic apex locator. If the instruments meet resistance and the file does not progress gently to WL, use a dedicated Nickel Titanium (NiTi) instrument. It is prudent to modify the orifice to create a coronal receptacle for the subsequent rotaries. Negotiate, confirm patency, determine WL and create glide path to WL with appropriate instruments. Throughout the shaping procedure with selected series of rotatory instrument, it's important to irrigate with NaOCl. To allow an easy progression of instruments, repeat often #10 K-file and smaller instrument. At the end of shaping, determine the final foramen size with an appropriate hand file. Select irrigation solution for smear layer management and perform the final irrigation. Dry the canals and obturate with technics and material that allow three-dimensional fill. Finally restore the tooth in a timely manner (AAE, 2020; Berman and Hargreaves, 2020).

3. Decision-making flow chart

Based on Edwards *et al.* (2021), Ricucci *et al.* (2019), and Yong and Cathro (2021), this decision-making flow chart schematize guidelines of vital pulp therapy and suggest therapeutic decision based on history, clinical examinations, vitality testing, radiographic assessment and informed consent (Appendix 1). The reversible and irreversible pulpitis, are concerned to mature teeth with deep caries. After all treatments, clinical and radiographic follow-up at 6 months, 1 year and annual review up to four years is required to monitor the success of the treatment.

4. Litterature review

According to the literature, there are studies with different results in relation to vital pulp therapy.

The American Association of Endodontics's Special Committee on VPT, published in 2021 a position statement on vital pulp therapy who aims to addresses diagnostic considerations, caries management, pulp management, placement of biomaterials, and restoration. The aim was to broaden and make common the use of vital pulp therapy techniques in mature teeth. The authors wanted also encourage additional clinical trials to assess long-term outcomes of VPT and development of chairside techniques using biomarkers to assess pulpal viability (AAE, 2021).

Cushley *et al.* (2021) conducted a systematic review and meta-analysis to determine the outcome of DPC in mature permanent teeth with exposed pulp and a reversible pulpitis and determine whether the choice of the pulp capping material, influences the outcome of DPC in these teeth. Thirty-eighth articles were selected from MEDLINE Ovid-SP, Cochrane Central Register of Controlled Trials (CENTRAL), International Clinical Trials Registry Platform (ICTRP), ClinicalTrials.gov, Embase and Web of Science until April 2020. Only 14 studies met the inclusion criteria, 5 randomized trials, 5 non-randomized comparative studies and four single-arm prospective studies. The clinical and radiographical success at 12 months was defined by the absence of signs and symptoms of irreversible pulpitis, apical periodontics or loss of pulp vitality. It was proved that high success rate for DPC in teeth with exposed pulps with better long-term outcomes for MTA and BD compared with Ca(OH)_2 .

The study made by Ricucci *et al.* (2019) present a set of histo-pathology and histobacteriology based guidelines, refined by clinical findings from numerous cases, for VPT in teeth with deep caries and elucidate the indications for each modality of VPT approach. For the histopathological and histobacteriological examination, the authors analysed 264 carious, unrestored and VPT-treated human teeth, which were extracted for reasons not related with the study and included prosthetic or orthodontic treatment planning and the patient's desire to not maintaining the tooth. In this sample, 160 were untreated carious teeth, 59 were heavily restored with amalgam or resin composite, 18 had carious pulpal exposures that were managed by DPC, 19 were caries-free teeth that received experimental pulpotomy or capping with different biomaterials, and 8 were

carious teeth that received “partial” or “selective” caries excavation followed by adhesive restorations. They also analyzed 757 clinical cases that received different VPT procedures. 720 teeth, clinically diagnosed with “reversible pulpitis”, based on clinical and radiographic findings, were subjected to direct pulp capping procedures and 507 were followed-up for varying observation periods, ranging from a minimum of 3 to a maximum of 30 years. The size of pulp exposure was recorded, as well as the time needed to obtain haemostasis by applying a moderate pressure on the wound with a sterile cotton pellet. The cases were evaluated as success/ failure based on clinical signs and symptoms, radiographic findings showing presence/absence of periapical disturbances, and resorption or irregular calcifications in the root canals. At each follow-up, radiographs were taken and pulp vitality was determined with thermal and electric pulp tests. A vital pulp therapy following guidelines of mature teeth with deep caries is an alternative to pulpectomy, strict aseptic techniques are mandatory to be successful. Follow-up of the clinical cases indicated that DPC was successful in 73.2%, PP in 96.4% and FP in 77.8% of the cases. Histological and histobacteriological examination showed a localized inflammatory response that commonly occurred in the subjacent pulp tissue as soon as the enamel was penetrated by caries.

A prospective study published by Koli *et al.* (2021) evaluated the outcome of a combination of NSRCT and VPT for the management of mature permanent mandibular molar teeth with symptomatic irreversible pulpitis and apical periodontitis. 2 different groups, 30 teeth each, were created. In the NSRCT group, single-visit NSRCT was performed using a standardized operating protocol. In the NSET-VPT group, subsequent to full pulpotomy, at the root orifice where a vital pulp was observed (as determined by the arrest of pulpal bleed upon application of a 2.5% sodium hypochlorite pressure pack), an MTA radicular barrier was placed and covered with light-cured resin-modified glass ionomer cement. Teeth were followed up clinically and radiographically at 12 months and showed a success rate of 90% in the NSRCT group and 93.3% in the NSRCT-VPT group. The authors conclude that the combination of NSRCT and VPT can be a viable biologically based minimally invasive treatment option for mature permanent mandibular molar teeth.

Another randomized clinical trial from Asgary *et al.* (2018) published in 2018 aimed to evaluate and compare clinical and radiographic success of 4 different VPTs: indirect pulp capping (IPC), direct pulp capping (DPC), partial pulpotomy (PP), and full pulpotomy

(FP) using calcium enriched mixture cement for deep caries management of mature permanent molars including teeth with clinical signs of irreversible pulpitis and the presence of apical periodontitis. 302 patients were randomly distributed in the 4 different groups. Vital test results, pulpal/periapical status, and exposure type/location were recorded as also the pain score during the first week after the treatment. The 1-year success rates of the VPT techniques were comparable in the IPC (98.7% and 100%, respectively), DPC (98.4% and 94.7%, respectively), PP (98.4% and 91.4%, respectively), and FP (93.5% and 95.5%, respectively). After baseline pain adjustment, pain relief was continuous with similar patterns in all treatment groups. In deep caries management of mature permanent molars, the 4 VPTs were associated with favorable/comparable clinical and radiographic outcomes. The pulpal and periapical status as well as pulpal exposure type/location had no effect on treatment outcomes.

A randomized clinical trial made in 2019 by Suhag *et al.*, aimed to compare the success rate and postoperative pain of DPC using Ca(OH)_2 and MTA in teeth with carious pulp exposures and reversible pulpitis. 64 permanent teeth were randomly divided into 2 groups (32 teeth in each group) after caries excavation. Clinical and radiographic evaluations were performed at 3, 6 and 12 months. Pain was recorded using the visual analog scale every 24 hours for 7 days after intervention. After 12 month follow-up, only 56 patients were analyzed, 29 treated with Ca(OH)_2 and 27 with MTA. The success rate was 69% for CH and 93% for MTA at the 1 year follow-up outcome. No significant difference in pain incidence was found between the 2 groups although a significant pain reduction was found 6 hours after the procedure in both the groups. Significantly lower pain scores were reported in the MTA group after 18 hours. The authors conclude that teeth with carious pulp exposures and reversible pulpitis can be treated successfully with DPC (Suhag *et al.*, 2019).

Another systematic review assesses the outcome of VPT including partial and full pulpotomy performed with hydraulic calcium cements (HSCSs) in permanent mature posterior teeth diagnosed with symptomatic irreversible pulpitis. The outcome of treatment of VPT was evaluated clinically and radiographically and after compared to NSRCT outcomes. Based on PRISMA guidelines, the search strategy included PubMed®, EMBASE, Cochrane library and grey literature electronic databases, 142 articles were identified. After selection with inclusion criteria only 12 studies were selected for this review, 9 randomized controlled trials and 3 prospective cohort studies. All studies selected

reported favourable outcomes of the VPT performed with HCSCs. The 12 reviewed articles reported favourable outcomes of the VPT performed with HCSCs in permanent mature posterior teeth with symptomatic irreversible pulpitis, with success rate in the range of 81 to 90% (Santos *et al.*, 2021).

In 2015, Asgary *et al.* (2015) did a non-inferiority multicenter randomized clinical trial in which treatment outcome of VPT using calcium-enriched mixture cement (CEM) and RCT for mature molars with established irreversible pulpitis were compared. A total number of 407 patients aged from 9 to 65 years and of both genders were divided in two groups. The first group, VPT/CEM had 205 patients and the second group, RCT had 202 patients. The selection criteria were vital molar tooth with history of pain (spontaneous or exacerbated with hot and cold stimulus) indicative of irreversible pulpitis or vital molar teeth intended to extraction for pain relief. The results were based on clinical and radiographical evaluation. A total number of 271 patients (33% were lost) were available after 5-year to the follow-up. The results revealed no significant differences in the successes of both study arms. The patients' age or gender didn't affect the outcome. The presence of preoperative periapical lesion also didn't have a significant effect in both groups. VPT could be considered as a valid treatment for vital mature permanent molars clinically diagnosed with irreversible pulpitis and a successfully alternative to NSRCT.

A Randomized controlled Trial by Galani *et al.* (2017) compared the postoperative pain and the success rate after pulpotomy and NSRCT in mature permanent molars. The authors analysed 54 permanent teeth with carious exposures and this sample were randomly divided equally into 2 groups. In the experimental group, MTA pulpotomy was performed and in the control group a NSRCT was performed, using standardized protocols. The treated teeth were restored with base of glass ionomer cement followed by a composite restoration. Pain was recorded every 24 hours for 7 days after intervention and clinical and radiographic evaluations were done every 3 months for 18 months. Success rate at 18months was 85% in the pulpotomy group and 87.5% in the NSRCT group. Significant difference in pain incidence and pain reduction was found between the 2 groups ($P < .05$), with lower scores reported in the pulpotomy group. The authors suggested that pulpotomy can be as a suitable alternative treatment option for cariously exposed permanent teeth with no signs of apical periodontitis.

In a report published in Canada's Drug and Health Technology Agency, 6 publications were included to evaluate the clinical effectiveness and safety of vital pulp therapy compared with NSRCT, to evaluate cost effectiveness data to support reimbursement decision making and evidence-based guidelines for VPT. In VPT with CEM compared with NSRCT, there were no significant differences in clinical success at 6 months, 1 year, or 2 years. In cases with periapical lesions, outcomes were similar between VPT and NSRCT. The results for the outcome of post-operative pain were unclear and the radiographic results showed significantly different success rates in favour of VPT at 6 months and 1 year but no significant differences at 2 years follow-up. There were no significant differences in age, sex or tooth location. This report allowed to have a global visualization of results present in literature but limited by a low quality of evidence and high variety of techniques used (Wells *et al.*, 2018).

Based on position statement published by European Society of Endodontology (2019) and cases studies, Edwards *et al.* (2021) published a review who aim to examine current evidence surroundings vital pulp therapies and provides a rational approach to the management of exposed pulp. Success lies in accurate diagnosis and case selection, along with well-executed treatment and appropriate follow-up protocols. long-term outcome studies are required to provide robust evidence to support VPT in addition to the opinion and guidance of specialist societies (Edwards *et al.*, 2021).

A prospective longitudinal randomized controlled study of 68 vital permanent teeth with deep caries were used to evaluate the clinical performance of Biodentine (BD) and with MTA. Patients were randomly allocated into 2 groups: BD and MTA. In both groups, teeth were assessed clinically and radiographically before the procedure. After, caries was excavated under anaesthesia, haemostasis achieved after pulp exposure using sodium hypochlorite, and finally capped with BD or MTA according to the group they belong. Clinical and radiographical were performed in different period of follow-up, at 6 months, 1, 2 and 3 years. Some patients were lost for follow up; at 6 months 60 teeth were evaluated, at 1 year 53 teeth, at 2 year 51 teeth and at 3 year 49 teeth. BD and MTA had favourable and comparable success rates when used as direct pulp capping or pulpotomy material in permanent mature teeth with carious exposure (Awawdeh *et al.*, 2018).

III. DISCUSSION

Preservation of pulp vitality is a critical factor in long-term tooth survival. The vitality of the dental pulp can be compromised by the presence of a deep carious lesion and by its subsequent management; therefore, treatment options aimed at preserving pulp vitality are recommended (AAE, 2021; Cushley *et al.*, 2021).

There are several treatment options available for carious exposure, varying from conservative minimally invasive VPT, including DPC, partial and complete pulpotomies to the more invasive pulpectomy and root canal treatment (Ricucci *et al.*, 2019). Although root canal treatment is the traditional treatment of choice for the cariously exposed pulps, it is destructive and a technically demanding procedure (Cushley *et al.*, 2021). A promising prospective study published in 2021 proposed a minimally invasive treatment option, a combination of NSRCT and a pulpotomy on a same tooth to manage permanent molars with diagnose of irreversible pulpitis and apical periodontitis. Even the follow-up was just 1 year, this technique appears to have a high success rate and it could be considered as a suitable alternative to NSET (Koli *et al.*, 2021).

The DPC seems to be the most conservative and simplest approach to maintain the vitality of pulp, for pulp with reversible pulpitis that have been exposed mechanically or during the excavation of deep caries. With strategy based on the premise that a biologically active material placed in direct contact with the pulp wound can determine the pulpal response and result in the development of a reparative hard tissue bridge to preserve pulp vitality. When severe pulpal inflammation involving the radicular pulp, the dentist must opt for pulpotomy or pulpectomy rather than DPC. Pulpotomies are less invasive than root canal treatment and have high success rates in pathologically exposed pulps particularly when the clinical diagnosis was reversible pulpitis (Asgary *et al.*, 2018; Suhag *et al.*, 2019; Cushley *et al.*, 2021).

The “selective” caries removal approach, which recommends removal to soft or firm dentine, is based on the assumption that pulp exposure, like in a direct pulp capping, is a negative prognostic factor in teeth with deep carious lesions. It is beyond argument that a carious process is involved if an exposure is encountered during hand excavation. However, leaving soft carious dentine over the pulp is analogous to leaving bacteria or allowing bacteria to colonise the vicinity of a surgical wound, which may sustain

inflammation and lead to necrosis. In addition, partial caries excavation precludes the possibility of clinically evaluating the true extent of the carious process, the appearance of the exposed pulp tissue, the presence of necrosis, and the amount of pulp bleeding (Koli *et al.*, 2021; Ricucci *et al.*, 2019).

To practice VPT techniques it's important to have hemostatic control what is allowed by a wide range of hemostatic agents. These include different concentrations of NAOCL, 2% CHX, mixture of tetracycline, acid, and detergent, 30% H₂O₂, ferric sulphate, epinephrine, direct pressure with cotton pellets soaked in sterile water, or saline. The most common hemostatic agent is NAOCL no just because the fact of being an outstanding hemostatic agent but also because of our antibacterial properties, disinfects the contaminated dentinal chips and dentin adjacent to the exposure site, and avoid the formation of a fibrin clot (Asgary *et al.*, 2018; Santos *et al.*, 2021; Suhag *et al.*, 2019).

VPT in adult permanent teeth following carious exposure of the pulp is controversial; some authors state that VPT should be performed only in young patients because of the high healing capacity of the pulp compared to old ones. However, the results of the current studies proved that patient's age does not affect the success rate of VPT, neither does the patient's gender (Asgary *et al.*, 2015; Galani *et al.*, 2017; Wells *et al.*, 2019).

Nevertheless, the outcome of VPT depends on several procedural factors, such as the anaesthetics used, removal technique of carious tissue, strict disinfection and bleeding control, dressing materials, type of permanent restoration, and possibly the use of magnification, the reports from different geographical areas and clinical settings are required to validate the universal applicability of VPT for permanent mature teeth with symptomatic irreversible pulpitis (Santos *et al.*, 2021).

Overall, when comparing VPT and NSRC, short-term pain reduction was more pronounced in teeth receiving total pulpectomy compared with partial pulpectomy or pulpotomies. The highest proportions of failure in the comparison studies were 21.9% and 24.7% for VPT and RC respectively over five years. (Wells *et al.*, 2019) Furthermore probable treatment failure in VPT, there is still a chance of performing NSRCT (Asgary *et al.*, 2015; Galani *et al.*, 2017).

Given that the prevention of subsequent bacterial ingress is considered to be a key determinant in maintaining pulp vitality, dentine bridge formation, dentine bonding and solubility will all be important considerations in material selection for VPT.

Biocompatible materials that will promote pulpal healing are required. Calcium Hydroxide (Ca(OH)_2) and CSCs have been used with varying degrees of success. Ca(OH)_2 was initially established as the material of choice for DPCs because of its inhibition of bacterial growth and stimulation of reparative dentine. Clinical success with Ca(OH)_2 was found to vary between 13% and 97.8% after 10 years and 16 months, respectively in Suhag *et al.* (2019) study and has been reported to range from 21.3–80.1% at 1 to 13 years in Edwards *et al.* (2021) study for DPCs.

More recently, CSCs, like BD, have emerged as a more predictable alternative. A number of studies have found the dentine bridge in DPCs forms more quickly and is thicker with less tunnel defects where CSCs are used compared to Ca(OH)_2 . And have been shown to produce histologically superior dentine bridge formation and have improved long-term success rates. CSCs also induce less prolonged and lower levels of pulp inflammation and necrosis during healing compared to Ca(OH)_2 (Awawdeh *et al.*, 2018; Edwards *et al.*, 2021).

There are also some limitations in terms of this comparison because the outcomes were most commonly clinical successes and pain. Pain outcomes were generally short-term and “clinical success” was not defined or inconsistently defined across studies (Galani *et al.*, 2017; Wells *et al.*, 2019).

IV. CONCLUSION

Most current endodontic procedures are irreversible and sacrifice hard and soft tissue, making teeth vulnerable.

The evidence in this review suggests that direct pulp capping is generally a clinically effective procedure for treating teeth with deep caries and pathologically exposed pulps if the pulpal diagnosis is reversible pulpitis.

As emergency treatments for cases of irreversible pulpitis with or without periapical changes, pulpotomy, partial pulpectomy and total pulpectomy were similar with respect to pain relief, reduction in thermal and chewing sensitivity, and postoperative analgesic use.

It should also be noted that the experience of the practitioner, the ease of visualization of the field of work and the involvement of the patient are important to the success of vital pulp therapy.

Although many more studies are required, the treatment options presented here will change endodontic therapies and improve quality of life in patients. Future well designed and adequately powered randomized trials are required to determine whether these findings are correct in order to resolve ongoing uncertainties.

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APPENDIX

Appendix 1 - Illustration of decision-making flow chart, based on Ricucci *et al.* (2019), Edwards *et al.* (2021) and Yong and Cathro (2021).

