Vital Pulp Therapy
in Permanent Teeth:
Sound Option or Pulp Fiction?

By Johnah C. Galicia, DMD, MS, PhD
ABSTRACT

With our increased understanding of pulpal biology and the advances in material biocompatibility, the potential to transform the fate of a compromised dental pulp from a condemned tissue to that of hope and recovery has never been more promising. In this article, several aspects of vital pulp therapy (VPT) in permanent teeth from diagnosis and indications to treatment outcomes will be discussed in detail.

EDUCATIONAL OBJECTIVES

Upon completing this article, the participant should be able to:
1. Define the latest endodontic diagnostic terminologies
2. Describe the ideal cases for vital pulp therapy
3. Compare the different vital pulp therapy materials, methods, and outcomes
4. Discuss several recommendations when performing vital pulp therapy.

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Dr. Galicia received the certificate and master’s degree in endodontics from the University of North Carolina at Chapel Hill in 2014 as an American Association of Endodontists Foundation Educator Fellow. Prior to that, Dr. Galicia was a Postdoctoral Fellow in oral microbiology and immunology with the School of Dentistry, University of Pennsylvania and the University of Louisville, KY. He received the PhD degree in oral biology from Niigata University, Japan, and a diploma in clinical dentistry from the University of Rennes 1, France. Before entering the PhD program, he was a general dentist and a faculty member of his dental school alma mater, the Manila Central University in the Philippines.

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In addition to clinical and academic pursuits, research also has been an integral part of Dr. Galicia’s career. He has coauthored several peer-reviewed articles in reputable international scientific journals and has presented his work in international forums. Dr. Galicia is a Diplomate of the American Board of Endodontics.
Introduction

Trivia: In a published article from 1883, Dr. F.A. Hunter pressed a mixture of sparrow droppings onto exposed dental pulps and reported achieving success fully equal to 98%.

Maintaining pulpal health is essential for the longevity of a tooth. It is, therefore, important that caries be controlled promptly and a well-sealing restoration be placed immediately. However, when performing deep caries removal in vital teeth, pulpal exposure can be a concern or an inevitability. For a near or an overt pulpal exposure, a decision has to be made whether vital pulp therapy (VPT) or pulpectomy then root canal therapy (RCT) would be the more appropriate treatment option. For a tooth with asymptomatic irreversible pulpitis that is confirmed after caries exposure, root canal therapy is the recommended treatment. The dilemma arises in asymptomatic teeth with normal pulp that becomes exposed after caries control. Should RCT be performed or is VPT acceptable?

With our increased understanding of pulp biology and the advances in material biocompatibility, an exposed dental pulp’s fate of being a condemned tissue can be raised to that of hope and recovery. In spite of this, vital pulp-capping principles and techniques are still subject to continuous scrutiny. One concern about procedures performed in a vital tooth that has received a considerable amount of irritation is pulpal degeneration. Another one is the possibility of pulpitis or periapical pathoses resulting from microbial and mechanical insults, which can lead to severe pain and emergency room visits. These scenarios add a significant burden to the patient who could have received RCT straightaway.

Published studies on VPT case selection, procedures, and outcomes are numerous. In this review, pulpal biology will be revisited and various aspects that influence VPT success and failure will be discussed. In addition, a series of cases will be presented to highlight case selection and techniques in VPT.

Spread of Pulpal Inflammation

Even in early caries when demineralization is limited to enamel, histological changes such as leukocytic infiltration and degeneration of odontoblasts have been observed in the dental pulp. These changes become widespread as caries spread apically into the dentin. The dental pulp, being an immunocompetent tissue, mounts an inflammatory response to the progressing microbial irritation. Its cellular elements like odontoblasts and fibroblasts express Toll-like receptors on their surfaces, which can trigger the production of cytokines and initiate histopathological alterations upon contact with microbial components. The resulting clinical manifestation of this host–pathogen interaction is commonly pain from inflammation; however, pulpitis can progress without symptoms.

The initial vascular response during the acute phase of inflammation causes a rise in tissue pressure due to increasing blood and interstitial fluid volume from vasodilation and increased vascular permeability. With an unyielding dentin wall encasing the dental pulp, a modest increase in tissue pressure may significantly impede blood circulation. In fact, some studies have shown that inflammatory mediators may cause a dramatic and persistent fall in blood flow in the pulp. These scenarios may have given rise to the self-strangulation theory that existed decades ago. However, in vivo studies on the pathophysiology of pulpal inflammation show that occlusion of veins at the apex due to a rapid transfer of high pressures from a site of pulpal inflammation, as suggested by the strangulation theory of pulpal necrosis, does not occur.

Tissue pressure is a local phenomenon that does not spread abruptly throughout the pulp tissue. If treatment is not rendered, a circumferential spread of necrosis and inflammation from the site of initial pulpal inflammation occurs incrementally until necrosis occurs. The fact that most dental pulps survive a lifetime of irritation from normal functioning of the tooth to various clinical procedures, together with their ability to revert back to health in several circumstances, support the debunking of the strangulation theory.
Endodontic Diagnosis Conundrum

The challenging aspect in endodontic diagnoses is that it is based on the patient’s subjective interpretation of nonstandardized endodontic clinical examination methods. The classical work by Seltzer et al. in the early 1960s and those by more recent authors revealed that the clinical diagnosis of reversible and irreversible pulpitis may not correlate with the gold standard of histological examination. Furthermore, these decades-old diagnostic methods do not stage endodontic disease, and considerable differences exist in the clinician’s interpretation of lingering pain or pain severity.

Diagnostic dilemmas have actual clinical repercussions and are often encountered in various clinical situations. The most common scenarios are when patients’ symptoms cannot be localized to a specific tooth, when deciding to proceed or forgo RCT in continuously symptomatic teeth with no lingering or spontaneous pain (i.e., tooth prepared for a crown, recent trauma) or in a root canal-treated tooth with a small, asymptomatic lesion for years, or when there is no clear distinction if the symptoms are odontogenic or nonodontogenic in nature. To this day, this diagnostic dilemma has remained to be a clear weakness of the specialty that needs to be addressed.

To come up with the most “accurate” diagnosis, a thorough and meticulous pain history and clinical examination are necessary. The patient’s description of pain such as: spontaneous, evoked, lingering, sharp, and others should be noted, compared to a control tooth and replicated on the suspected tooth upon clinical or objective examination by the clinician. In addition, combining diagnostic tests such as cold and electric pulp testing (EPT) increases both sensitivity and specificity of the results. The clinician is also expected to take time in educating the patient about the pulpal tests to be performed and what to expect with the tests. Chances are, the patients have little to no knowledge of what to feel and how to communicate the sensations triggered by the cold test or EPT, for example. A tooth with deep caries is expected to have inflammation. It is up to the clinician to diagnose whether the inflammation is reversible characterized by exaggerated, nonlingering pain to cold test, or irreversible that presents with both exaggerated and lingering response to cold test.

To better guide clinicians, the American Association of Endodontists (AAE) has a recommended list of pulpal and periapical diagnostic terminologies with the corresponding clinical description of each terminology (Table 1).

Pulpal Diagnosis and VPT

Performing diagnostic testing to assess pulpal status is needed for treatment planning. However, only 30% of general dentists (GDs), 17% of pediatric dentists (PDs), and 90% of endodontists (EDs) use diagnostic tests (e.g., cold test) when evaluating pulpal health. The status of the pulp and periapical tissues can have an impact on the prognosis of the tooth and the perception of patients to dental care; therefore, determining the pulpal periapical status of all teeth to be treated and restored is highly recommended.

The most reliable pulp-sensibility testing method is cold test using a refrigerant spray. A response to a cold stimulus leads to the assumption that the pulp is vital, which can be either normal or inflamed. A normal or baseline response is determined by the clinician interpreting the patient’s interpretation of the cold test on a control tooth first and then comparing that to the test tooth’s response. Sensibility to pulp thermal testing may indicate injury to the pulp where nociceptors have been sensitized by inflammatory mediators, but it cannot be used to predict the extent and severity of pulpal damage. In addition, thermal testing stimulates the nerves, which can persist even after the vasculature has disintegrated. It is, therefore, not uncommon for a dental pulp with no blood flow or an essentially necrotic pulp to respond to cold testing.

Determining whether or not the response of the test tooth is exaggerated or lingering, is left to the judgment of the clinician. A slight difference in intensity or lingering time can cause frustration and delay in treatment. Therefore, it is not
imperative to combine both the history of the present illness and the results of the sensibility tests to arrive at the most probable pulpal diagnosis. The critical part of the diagnostic terminology is delineating reversible from irreversible pulpitis because the treatment for each of these diagnoses is different. Irreversible pulpitis requires RCT, whereas reversible pulpitis does not. Clinically, the differences between the two can be stark or subtle.Descriptors such as lingering, spontaneous, or referred pain can be helpful, but these can be subject to interpretation biases.

When VPT is being considered, the current guidelines by both the AAE and the American Association of Pediatric Dentists (AAPD) limit VPT to definitive treatment (i.e., pulp capping) for teeth without symptoms of irreversible pulpitis (i.e., spontaneous pain) and without periapical pathosis. An exception is allowed in primary teeth where pulpotomy can be performed even in the presence of pulpitis. Pulpal debridement is recommended in teeth with clinical manifestation of irreversible pulpitis when RCT cannot be completed in one appointment.

Caries Removal: How Far to Go?

A paper in 2017 explored how U.S. dental schools teach removal of carious tissues during cavity preparations. Among the 43 cariology faculty members from dental schools across the U.S., hardness was the most common criterion used to assess sufficient removal of carious dentin in both shallow (100% of respondents) and deep (90.5% of respondents) lesions. Moisture and color were the other criteria. When asked about treatment recommendation for a vital, asymptomatic tooth with deep carious lesion, more than 57% would perform partial caries removal, then place a permanent restoration if there was a risk for pulpal exposure. The other 19.1% would attempt complete caries removal and leave carious dentin if there was a risk for pulpal exposure; then reassess the tooth weeks or even months later. Direct pulp cap (5%) and root canal treatment (1%) were also considered if there was a small pulpal exposure upon total caries removal.

It appears that dental schools in the U.S. teach students to preserve tooth structure and avoid pulpal exposure.
Clinicians, however, may have a similar or different approach depending on their specialty. A nationwide web-based survey of 175 GDs, 511 PDs, and 377 EDs showed that most EDs (68%) and GDs (47%) practiced complete caries removal. PDs (31%) were more likely than GDs (12%) and EDs (4%) to remove carious tissues partially. In other countries, such as Germany, complete caries excavation is practiced by approximately half of the GDs. If caries was to be removed incompletely, 77% considered two-step excavation.

From a biological perspective, invasion of dentinal tubules by microorganisms occurs immediately and is evident within a week of exposure. Consequently, the dental pulp starts to manifest histological changes and signs of inflammation even in incipient decay and shallow caries. As a protective mechanism, odontoblasts form reactive dentin, which blocks the dentinal tubules. A layer of hard, affected dentin then forms underneath the soft carious lesion. Complete removal of soft or infected dentin is necessary to eliminate most of the cariogenic microorganisms and allow the pulp to revert back to health. However, since microorganisms do not have to be in direct contact with the dental pulp to initiate inflammation, good diagnostic skills supersede the limits of caries removal.

VPT: Indications

According to the 2013 AAE Guide to Clinical Endodontics, the following are considered as VPT: apexogenesis, pulpotomy, pulp debridement, indirect pulp capping, and direct pulp capping. Because pulpal debridement is performed as an emergency procedure for teeth needing RCT, this procedure will not be discussed in this review.

The AAE Guidelines specify that except for pulpotomy, all VPT procedures on restorable permanent teeth with mature apices are to be performed only in teeth with no pretreatment symptoms and under strict asepsis. If caries was to be removed incompletely, 77% considered two-step excavation. Hemorrhage control was thought to be a critical step in achieving a favorable VPT outcome. However, from a biological perspective, control of bleeding at the exposure site or canal orifices did not provide an accurate assessment of inflammation and could be misleading for diagnosing and treating a vital pulp. In addition, the amount of bleeding was not associated with the outcome of VPT. From an actual clinical perspective though, it would be difficult to perform VPT if bleeding cannot be controlled within a reasonable amount of time. There are currently no clinical studies to support the length of time to achieve hemostasis before VPT can proceed; however, if bleeding does not stop after various hemostatic techniques have been employed for more than 10 minutes, RCT should be performed. Other VPT indications include mechanical pulp exposure during operative procedures or during carious excavation under rubber dam isolation and traumatic pulp exposure after removal of superficial pulp. The indications for VPT are summarized in Table 2.

Stepwise or Complete Caries Excavation?

Dr. I.B. Bender once stated that the dental pulp is “a small tissue with a big issue.” This statement reverberates in actual clinical practice on a daily basis. When presented with a permanent tooth with deep caries, the dental pulp becomes a concern. Pulpitis can be a progressive and devastating pain experience that is distressful both to the patient and to the dentist. The dentist decides whether to
avoid pulpal exposure by leaving caries or risk exposing the dental pulp by complete caries excavation (Figure 1).

In stepwise excavation, the first step involves removal of the superficial, necrotic, and demineralized dentin with complete excavation of the peripheral demineralized dentin, avoiding excavation close to the pulp. Once it is determined that a temporary restoration could be properly placed, no further excavation is carried out, leaving soft, wet, and discolored dentin centrally on the pulpal wall. A base material like calcium hydroxide is applied over the remaining carious dentin, then the cavity is temporarily sealed with glass ionomer cement. After four to eight weeks, the cavity is re-entered if the patient reports no symptoms associated with the tooth. The final excavation is performed

<table>
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<th>VPT Procedure</th>
<th>Indications</th>
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| Indirect pulp capping | • Deep carious lesion likely to result in pulpal exposure  
• No history of subjective pretreatment symptoms  
• Periapical radiographs should exclude periradicular pathosis  
• Patient has been fully informed that endodontic treatment may be indicated in the future |
| Direct pulp capping  | • Mechanical exposure of vital and asymptomatic pulp  
• Bleeding is controlled at exposure site  
• Exposure permits capping material direct contact with pulp  
• Exposure occurs when the tooth is under dental dam isolation  
• Adequate seal of coronal restoration can be maintained  
• Patient has been fully informed that endodontic treatment may be indicated in the future |
| Pulpotomy           | • Exposed vital pulps or irreversible pulpitis of primary teeth  
• Primary teeth with insufficient root structure, internal resorption, furcal perforation, or periradicular pathosis that may jeopardize the permanent successor are not indicated for pulpotomy procedures  
• As an emergency procedure in permanent teeth until root canal treatment can be accomplished  
• As an interim procedure for permanent teeth with immature root formation to allow continued root development |
| Pulpal debridement  | • Relief of acute pain prior to conventional root canal treatment when complete root canal treatment cannot be accomplished at this appointment |
| Apexogenesis         | Indicated on permanent teeth with immature apices if all the following conditions exist:  
• Tooth has a deep carious lesion that is considered likely to result in pulp exposure during excavation  
• No history of subjective pretreatment symptoms  
• Pretreatment radiographs should exclude periradicular pathosis  
• Mechanical exposure of a clinically vital and asymptomatic pulp occurs  
• Bleeding is controlled at the exposure site  
• Exposure occurs when the tooth is under dental dam isolation  
• Adequate seal of the coronal restoration can be maintained  
• Exposure permits the capping material to make direct contact with the vital pulp tissue  
• Patient has been fully informed that endodontic treatment may be indicated in the future |

Figure 1. A 7-year-old child presents with deep caries on #30. There were no reported symptoms and the clinical diagnostic testing points to a normal pulp. In this case, the clinician decides whether to perform a stepwise or complete caries excavation.
leaving the supposedly formed central yellowish or grayish hard dentin. A base is applied and the cavity is restored with a permanent restorative material.

One alternative to the stepwise method described above is the one-stage method wherein caries approximating the pulp is left behind and the tooth is restored with a permanent filling instead of a temporary one. The tooth is not re-entered but symptoms will be monitored. For both methods, RCT or extraction is carried out if the tooth causes symptoms consistent with irreversible pulpitis.

Complete caries removal is determined mostly by hardness of the underlying dentin. The risk involved with this method is pulpal exposure. If the pulp is not exposed, the tooth is either restored with a temporary material first and then monitored for symptoms, or with a permanent filling material right away. If no symptoms develop, the temporary material is replaced by a permanent restoration. RCT or extraction is recommended for teeth that produce symptoms of irreversible pulpitis.

In determining whether to use complete caries excavation or stepwise technique, the clinician should base the decision on the individual patient circumstances as the literature is inconclusive as to whether stepwise or complete caries excavation is the most successful over time. One study reported a significantly higher proportion of unexposed pulps with sustained vitality and without apical radiolucency in stepwise technique than those with direct complete excavation of deep caries lesions in adult teeth. However, in this study the complete-excavation patients had higher median pretreatment pain level, and rubber dam isolation was performed only after pulpal exposure. Another report that performed a systematic review of stepwise excavation concluded that the stepwise technique was effective in deep caries and in teeth without symptoms of irreversible pulpitis. The drawbacks of this systematic review are the inclusion of studies with either no control, no randomization, or no clear methods.

Pulp Capping or Pulpotomy?

When a normal or reversibly inflamed dental pulp is exposed during treatment, direct pulp capping, pulpotomy, or RCT can be recommended depending on the degree of inflammation, stage of root formation, patient considerations, and others. Maintaining strict asepsis using rubber dam isolation and control of bleeding are required for all types of VPT. Direct pulp capping consists of the application of a biomaterial directly over an uninfamed pulp tissue. In partial pulpotomy, a small portion of the coronal pulp is removed after exposure, while in full pulpotomy, the entire coronal pulp is amputated. For all these procedures, a biomaterial is applied over the uninfamed pulp prior to the placement of a permanent restoration. Indirect pulp capping involves the complete removal of caries and the application of a biomaterial on a thin layer of hard dentin covering an intact pulp tissue before placing a permanent restoration.

A systematic review demonstrated that direct pulp capping worked better in immature teeth. On the other hand, the success rate of partial or full pulpotomy in both mature and immature teeth showed no statistical difference. A meta-analysis study reported that full coronal pulpotomy had a favorable success rate at 92% (two-year recall) in treating carious vital pulp exposure of permanent mature teeth with closed root apices. In a report with a short follow-up of one year or less, no difference in success rate was seen between pulp capping and pulpotomy. The literature appears to support pulp capping in immature teeth. Partial or full pulpotomy would be the better option for permanent teeth with mature apices. Radiographic appearance of various VPT procedures are shown in Figure 2.

Calcium Hydroxide or Mineral Trioxide Aggregate?

Several products purported to be biocompatible are being marketed currently as endodontic materials. However, only two products have been extensively
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researched and utilized for decades: calcium hydroxide (CH) and mineral trioxide aggregate (MTA). CH has been used in pulp capping since the 1930s. It has good antimicrobial effect due to its high pH of 12.5 when in a slurry preparation. Extensive clinical documentation showed that CH initiates hard tissue repair of the exposed pulp, thus making it the material of choice for a long time.

The shortcomings of CH, like its tendency to dissolve over time, creates a pathway for microleakage to occur underneath restorations, especially with composite resins where polymerization shrinkage could pull the pulp cap away from tissue surface. Furthermore, the pH of CH drops rapidly when in contact with dentin, compromising its antimicrobial properties. For these reasons, the need for a biocompatible and well-sealing material gave birth to MTA in the mid-1990s. Since then, MTA has been widely utilized for various endodontic procedures that involve contact between a biomaterial and the surround tissues.

The largest clinical data comparing the long-term outcome of direct pulp capping between CH and MTA indicated that MTA provided better long-term results after direct pulp capping compared with CH. Placing a permanent restoration immediately after direct pulp capping was also recommended. In a study that compared the effectiveness of MTA and CH as pulp-capping materials in humans by means of a meta-analysis, MTA had a higher success rate and resulted in less pulpal inflammatory response and more predictable hard dentin bridge formation than CH. MTA is, therefore, a suitable replacement to overcome the shortcomings of CH.

MTA is not without its challenges, too. The presence of bismuth oxide in the aggregate causes discoloration in teeth treated with either the gray or white mixtures of MTA. In addition, MTA is not easy to manipulate and its setting time can last up to 24 hours. To address these shortcomings, newer materials have been introduced during the last few years. These new materials, predominantly calcium silicate (CSC) based cements, are being characterized as biocompatible, easy to manipulate, well-sealing, faster setting, and nonstaining. Randomized controlled trials comparing MTA to CSC materials have shown that CSCs have favorable and comparable success rates as MTA when used as pulp capping or pulpotomy material in permanent mature teeth with carious exposure while offering better and esthetic physical properties.

VPT or RCT?

Although the current endodontic diagnostic testing provides a specificity of over 90%, the actual level of inflammation cannot be staged by cold testing or EPT. An exaggerated response to cold testing is interpreted as the pulp being “vital,” but the severity and degree of inflammation cannot be reliably determined clinically. This predicament makes VPT a clinical decision wherein the operator judges whether all the inflamed tissues have been removed. Hemorrhage control and direct observation of the pulp tissue, preferably using magnification, are helpful methods in gauging whether necrotic or inflamed tissues are completely eradicated and normal pulp tissues are present for the VPT’s outcome to be more predictable.

Evidence suggests that pulpal inflammation progresses incrementally and normal tissues can be histologically identified around the inflamed ones (Figure 3A). It is,
therefore, theoretically feasible to amputate the inflamed tissues only so that a VPT biomaterial can be applied directly on normal tissues (Figure 3B). However, there are instances where the extent of the inflammation can be difficult to determine especially in an anxious, young patient where time is of the essence.

Pulpectomy circumvents the need to clinically determine the extent of inflammation, thus allowing the entire inflamed and infected pulp tissue to be removed. The long-term success rate (more than 10 years) of performing RCT in a vital case was reported to be much higher (over 90%) than that in pulpally necrotic cases or cases with periapical pathosis (~70%).\(^56,57\) Compared to RCT in vital cases, VPT specifically pulpotomy was shown to have initial success of 89% at one-year recall. However, the success rate drops to 63% at 10 years.\(^58\) The decision whether to perform VPT or pulpectomy then RCT should be determined based on individual patient circumstances, restorative goals, and the skill of the operator. Pulp tissues of young mature teeth tend to recover much better than those in older patients. A flow diagram illustrating the recommended course of treatment is presented in Figure 4.

**VPT in Mature Teeth with Irreversible Pulpitis**

Although the AAE guidelines recommend VPT to be performed only in cases with no pretreatment symptoms, recent studies have shown considerable success rates with VPT in teeth with symptomatic irreversible pulpitis. In a prospective report involving 64 mature molars with clinical signs and symptoms indicative of irreversible pulpitis among 19- to 69-year-old subjects, a 98.4% radiographically and 100% clinically normal outcomes were achieved at one-year follow-up.\(^59\) In 6% of the cases, a hard tissue layer was identified radiographically.

To push the treatment boundaries of VPT further, another study from the same group included cases with...
both symptomatic irreversible pulpitis and symptomatic apical periodontitis in young permanent teeth with carious pulpal exposure. At one-year recall, 95% of the cases were deemed radiographically and clinically normal. Similar studies with larger sample sizes and longer recall periods reported comparable success rates.

There appears to be an emerging evidence for a paradigm shift toward a more conservative approach in endodontic treatment. Preserving pulpal vitality is definitely beneficial for the tooth. Higher level studies with longer follow-ups are encouraged to replicate or increase the level of evidence concerning VPT in teeth with irreversible pulpitis.

**VPT in Immature Teeth**

When an immature tooth presents with reversible or irreversible pulpitis, VPT is recommended for apexogenesis to occur. Young, immature teeth have very high healing potential; thus, every attempt at preserving their vitality should be considered. Even in a clinical diagnosis of irreversible pulpitis, the reasonable first step would be complete caries excavation under strict asepsis followed by pulpotomy to remove inflamed pulp tissue. A biomaterial is then applied over the exposed pulp tissue before a permanent restoration is placed.

To illustrate VPT on immature teeth, an actual case is presented here of a 6-year-old female patient with a diagnosis of symptomatic irreversible pulpitis on #19. The preop bitewing (Figure 5A) and periapical radiographs (Figure 5B) show a large occlusal caries encroaching the pulp and the tooth’s immature apices, respectively. After complete caries removal, pulpotomy was performed. MTA was placed over the pulp tissue and the tooth was restored with composite resin (Figure 5C). At one-year follow-up, the tooth presented with clinical and radiographic normalcy. It did not respond to cold but had a positive response to EPT. The periapical radiograph shows normal apical tissues with closed apices (Figure 5D and 5E). With the successful outcome presented, the tooth is envisioned to be functional for as long as good oral hygiene is maintained. A discussion with the patient’s pediatric dentist about full cuspal coverage restoration on the tooth should be undertaken.

**What Factors Are Associated with VPT Success or Failure?**

In endodontics, asepsis is everything and seal is the deal. The success or failure of treatment relies heavily on strict elimination and control of microorganisms and the placement of a well-sealing coronal restoration. VPT is not an exception to these principles. In a long-term retrospective study, the risk factors influencing the success rates of pulpotomies in both young and adult populations were evaluated. Among the 273 evaluated cases, 172 (63%) were deemed successful at 10 years. The factors considered to have contributed to the longevity of these teeth were dentin bridge formation and placement of a full coverage crown. Teeth restored with composite resin had the worst outcome. Age, gender, smoking, systemic disease, and the number of appointments were equivocal factors to the outcome of VPT.

Dentin bridge formation is a sign of a healthy pulp with functioning odontoblasts, a hallmark of complete recovery after a pulp-capping procedure. It is, therefore,
not surprising that the formation of tertiary dentin bridges was associated with favorable outcome. Furthermore, the presence of full coverage crown has been linked to increased long-term survival of root canal-treated teeth in a large epidemiological study in the United States.\textsuperscript{46} Two cases of successful VPT are presented in Figure 6.

**Conclusion**

VPT is a conservative endodontic procedure that has a well-documented history of success. Correct diagnosis, case selection, microbial control, and the use of a well-sealing biocompatible material are essential factors that can dictate the outcome of this treatment. The current guidelines point to limiting VPT in mature teeth with no pretreatment symptoms of irreversible pulpitis and in immature teeth to permit apexogenesis to occur. However, there is emerging evidence of considerable VPT success in permanent mature teeth with clinical symptoms of irreversible pulpitis. VPT can also serve as an alternative option to extraction when root canal treatment cannot be performed for low-income and uninsured patients or in underserved areas.\textsuperscript{46}

**References**

1. The following are pulpal diagnostic terminologies formulated by the American Association of Endodontists (AAE) except one. Which one is the exception?
   a. Normal pulp
   b. Chronic pulpitis
   c. Symptomatic irreversible pulpitis
   d. Previously initiated therapy

2. Which of the following is not an indication for pulpotomy according to the AAE guidelines?
   a. Exposed vital pulps or irreversible pulpitis of primary teeth
   b. As an emergency procedure in permanent teeth until root canal treatment can be accomplished
   c. For apexification of immature teeth

3. Which one of the following pulpal diagnoses does not necessarily require root canal treatment?
   a. Asymptomatic irreversible pulpitis
   b. Symptomatic irreversible pulpitis
   c. Previously initiated therapy
   d. Previously treated

4. Tissue pressure is a local phenomenon that does not spread abruptly throughout the pulp tissue. This local phenomenon therefore debunks the strangulation theory of the pulp.
   a. Both statements are true
   b. Both statements are false
   c. The first statement is true, the second statement is false
   d. The first statement is false, the second statement is true

5. The following are recommended microbial reduction and control methods when performing vital pulp therapy (VPT) except one. Which one is the exception?
   a. Rubber dam isolation
   b. Sodium hypochlorite irrigation
   c. Asepsis
   d. Systemic antibiotic treatment

6. Which pulpal diagnostic testing has been reported to have the highest sensitivity and specificity, therefore providing a diagnosis that is more accurate than the other tests?
   a. Heat test
   b. Cold test
   c. Palpation
   d. Electric pulp testing

7. Transient and exaggerated pain to thermal stimulation is typical for a ________.
   a. normal pulp
   b. reversible pulpitis
   c. asymptomatic irreversible pulpitis
   d. symptomatic irreversible pulpitis

8. Clinical diagnostic testing results correlate almost perfectly with the actual histological status of the pulp.
   a. True
   b. False

9. Lingering pain to cold is a clinical symptom associated with ________.
   a. reversible pulpitis
   b. symptomatic irreversible pulpitis
   c. pulpal necrosis
   d. asymptomatic irreversible pulpitis

10. According to a 2017 survey, which one of the following criteria is used by most U.S. dental schools in assessing sufficient removal of carious dentin?
    a. Luck
    b. Color
    c. Hardness
    d. Moisture

11. The dental pulp begins to manifest histological signs of inflammation ________.
    a. in incipient decay
    b. when caries has reached the dentin
    c. 2 millimeters before pulpal exposure
    d. when the dental pulp is cariously exposed

12. This procedure is performed to allow the apices of immature teeth to naturally close.
    a. Apexification
    b. Apexogenesis
    c. Apicoectomy
    d. Apical preparation

13. Which of the following materials was shown to result in higher success rates in VPT?
    a. Calcium hydroxide
    b. Intermediate restorative material
    c. Glass ionomer cement
    d. Mineral trioxide aggregate (MTA)

14. Stepwise method was shown conclusively to be more successful over time than complete caries excavation.
    a. True
    b. False

15. A clinical diagnosis indicating the death of the dental pulp is ________.
    a. reversible pulpitis
    b. symptomatic irreversible pulpitis
    c. pulpal necrosis
    d. asymptomatic irreversible pulpitis
16. The following are essential factors to consider when performing VPT except one. Which one is the exception?
   a. Hemostasis
   b. Age
   c. Asepsis
   d. Biomaterial

17. In a long-term outcome study, which of the following contributed to pulpotomy success?
   a. Nonsmoking
   b. Single appointment
   c. Dentin bridge formation
   d. Absence of systemic disease

18. Which of the following will have a similar response as a normal pulp to cold testing using refrigerant spray?
   a. Reversible pulpitis
   b. Symptomatic irreversible pulpitis
   c. Asymptomatic irreversible pulpitis
   d. Previously initiated therapy

19. The literature appears to support pulp capping in immature teeth. Partial or full pulpotomy would be the better option for permanent teeth with mature apices.
   a. Both statements are true
   b. Both statements are false
   c. The first statement is true, the second statement is false
   d. The first statement is false, the second statement is true

20. Bacteria is the most common cause of pulpitis.
   a. True
   b. False

21. Transient pain to cold test using refrigerant spray is a clinical finding of ________.
   a. normal pulp
   b. reversible pulpitis
   c. symptomatic irreversible pulpitis
   d. pulp necrosis

22. All of the following diagnoses will give a sensation of pain to cold testing with a refrigerant spray except one. Which one is the exception?
   a. Reversible pulpitis
   b. Normal pulp
   c. Asymptomatic irreversible pulpitis
   d. Previously treated

23. Which of the following is not an indication for direct pulp capping?
   a. Mechanical exposure of vital and asymptomatic pulp
   b. Bleeding is controlled at exposure site
   c. Dental dam isolation is immediately placed after pulp exposure
   d. Exposure permits capping material direct contact with pulp

24. Maintaining pulpal health is essential to the longevity of the tooth.
   a. True
   b. False

25. Which of the following condition is contraindicated in performing apexogenesis?
   a. Controlled bleeding
   b. Adequate coronal seal can be obtained
   c. Capping material can be in direct contact with vital tissue
   d. Exposure occurs without dental dam isolation

26. A clinical diagnosis based on subjective and objective findings indicating that the inflammation should resolve and the pulp return to normal is ________.
   a. reversible pulpitis
   b. symptomatic irreversible pulpitis
   c. asymptomatic irreversible pulpitis
   d. previously initiated therapy

27. The following are indications for indirect pulp capping except one. Which one is the exception?
   a. Deep carious lesion likely to result in pulpal exposure
   b. Pulpal diagnosis of previously initiated therapy
   c. Absence of periapical pathosis
   d. Fully informed patient

28. Vital pulp is not present in which one the following diagnoses?
   a. Previously treated
   b. Reversible pulpitis
   c. Asymptomatic irreversible pulpitis
   d. Symptomatic irreversible pulpitis

29. In the largest clinical data comparing the long-term outcome of direct pulp capping between calcium hydroxide and MTA, placing a permanent restoration immediately after direct pulp capping was also recommended.
   a. True
   b. False

30. A tooth with pulp necrosis will ________.
   a. need root canal treatment
   b. lose its immunocompetence
   c. be a contraindication for pulpotomy
   d. all of the above
Vital Pulp Therapy in Permanent Teeth: Sound Option or Pulp Fiction?

CE ANSWER FORM (E-mail address required for processing)

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EDUCATIONAL OBJECTIVES
• Define the latest endodontic diagnostic terminologies
• Describe the ideal cases for vital pulp therapy
• Compare the different vital pulp therapy materials, methods, and outcomes
• Discuss several recommendations when performing vital pulp therapy.

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