PULP CAPPING: IMPROVING THE PROGNOSIS

by Paul L. Child Jr., DMD, CDT, and Mark L. Cannon, DDS, MS

There are many clinical and research questions surrounding pulp capping. For example, what is the best way to treat a tooth that is asymptomatic with moderate to advanced caries, but excavation results in a small exposure? What are the best materials to use? What does the published, peer-reviewed literature inform us on these procedures? What extent of carious dentin should be removed to avoid exposing the pulp? Or, should all caries be removed regardless of pulp exposure? How is infected versus affected dentin identified? What materials should be used for hemostasis control if the pulp is perforated? The questions can continue indefinitely for such a small but vital procedure. It is not the intent of this article to answer every question surrounding pulp capping, but to briefly comment on the major points based on research, literature, and clinical experience.

Confounding factors

Pulp capping is an operative procedure that attempts to maintain the vitality of the tooth and facilitate the formation of reparative dentin. This topic has been researched for nearly a century and continues to evolve as we better understand the pulp, the dentin, and their biological reparative capacities. Despite new advances gained through research, this topic remains very controversial, as key opinion leaders, manufacturers, researchers, universities, associations and clinicians all seem to differ on what works best.

The literature can be useful for providing direction, yet can be confusing too, as it contains support or disagreement for most materials or techniques used by clinicians. Rarely do the everyday practices of a busy clinician reflect those of a researcher under a controlled environment. With all this confusion, many clinicians fall back onto old techniques or products out of frustration or ignorance, despite newer research, materials, or techniques that may provide a better option for their patients.

The prognosis of pulp capping (both direct and indirect) varies with success rates ranging from 13 percent to 100 percent. In the reported literature, the prognosis of direct pulp capping is unpredictable, with the lowest success rate in carious pulp exposures in the adult dentition. A recent Cochrane review of the literature (2012) stated, “If the tooth is asymptomatic but the caries is extensive, there is no consensus as to the best method of management.” It further stated, “There is no consensus as to whether the tooth should be indirectly pulp capped or directly pulp capped; whether a two-stage procedure should be carried out, nor as to which material is most effective.” It appears that this leaves clinicians without a reliable means to know whether to remove all the pulp or provide a direct pulp cap.

In clinical practice, mantras such as “hoping for the best, expecting the worst” are conveyed to patients as well as the often-heard statement, “you have a 50/50 chance of this tooth requiring root canal therapy.” As such, pulp capping seems to be a dichotomy at times. If the clinician provides the service as a conservative approach at saving the tooth and it descends into irreversible pulpitis, the patient may get frustrated that his or her previous asymptomatic tooth is now symptomatic and requires an endodontic root-canal therapy. On the other hand, if the tooth has minimal signs of pulpits with a small carious exposure and they are advised they need endodontic treatment, additional costs, efforts, appointments, and patient frustration ensues.

Unfortunately, many insurance providers do not reimburse for pulp capping if it is done in conjunction with the final restoration on the same day. In addition, some insurance providers simply do not allow for a separate fee to be charged to the patient, since the allowance for a final restoration includes pulp caps, cavity liners and bases. This practice has discouraged some clinicians to not provide the service if they cannot be reimbursed, which may not be in the patient’s best interest. The costs involved in a conservative pulp cap versus endodontic treatment is less expensive, takes less time, and is more likely to be accepted by the patient.

Diagnosis

There are many approaches to direct pulp capping, ranging from some that provide a direct pulp cap every time a pulp is exposed to those that provide endodontic therapy every time a pulp is exposed. There are clinicians, specialists, and associations who advocate providing endodontic treatment on every carious pulp exposure regardless of size or symptoms. However, clinical experience demonstrates that some carious exposures can be properly managed with a direct pulp cap. Proper diagnosis is the key to success.

It is often difficult to diagnose how inflamed the vital pulp is or to what degree the infection extends into the pulp. The pulp may be impaired and/or gravitating toward symptomatic or asymptomatic irreversible pulpsitis, pulpal necrosis, and/or symptomatic apical periodontitis (where occasionally no radiographic changes have taken place yet). According to the American Association of Endodontists (AAE) Endodontic Diagnosis criteria, asymptomatic irreversible pulpsitis is based on subjective and objective findings, have no clinical symptoms, and usually respond normally to thermal testing, resulting from trauma or deep caries. When these cases are identified, the clinician needs to make a judicious decision on whether to provide a direct/indirect pulp cap or root-canal therapy.

Presently the AAE recommends root-canal therapy for asymptomatic irreversible pulpsitis, but diagnosing the pulp as irreversible without any clinical or radiographic symptoms is difficult, and many
or two-appointment approach, where a provisional restoration is more successful due to its ultraconservative method, is a two-step plan as an indirect pulp cap. The second option, which appears to be at greater risk of failure, is to leave carious dentin and place a protective dressing, known as a protective restoration. This first option, where purposely avoiding a pulp exposure by excavating decay via comparative testing such as biting, percussion, palpation, stimulus to hot/cold/electric, periodontal probing, mobility, and radiographic examination for advanced to severe caries. A thorough medical history and dental history should be documented, along with the chief complaint, history of present problem (including inception, frequency, duration, intensity, location, provoking factors, spontaneity, and attenuating factors), and clinical examination.

Caries excavation

Knowing when to stop removing carious dentin can be difficult and seems to vary widely by each clinician and his or her experience. To date, most clinicians still rely upon tactile sensation or the hardness of the dentin. When near the pulp, it is advised to stop excavating and leave a layer of affected dentin, but some recommend commencing endodontic treatment. Both approaches need to be investigated further with randomized controlled clinical trials. However, a recent systematic review and meta-analysis of the literature by Schwendicke et al. (2013) concluded that incomplete caries removal seems advantageous compared with complete excavation, especially in proximity to the pulp. They also conclude “there is currently no evidence that incompletely excavated teeth are more prone to complications.”

There are two options for providing incomplete caries removal. The first option, which is most used by clinicians today is a one-step or one-appointment approach, but this option may carry a higher risk of failure. Despite this, recent clinical research has provided encouraging results for leaving carious dentin in a one-step approach. This first option, where purposely avoiding a pulp exposure by excavating decay via a comparative testing such as biting, percussion, palpation, stimulus to hot/cold/electric, periodontal probing, mobility, and radiographic examination for advanced to severe caries. A thorough medical history and dental history should be documented, along with the chief complaint, history of present problem (including inception, frequency, duration, intensity, location, provoking factors, spontaneity, and attenuating factors), and clinical examination.

Direct pulp exposures

There are three types of direct pulp exposures: carious, mechanical and traumatic. (See Figs. 1-3) The latter two generally have a higher success rate due to the pulp not being infected. Carious exposure appears greenish yellow and possibly purulent. Endodontic root-canal therapy is indicated. Large carious pulp exposure. Endodontic root canal therapy is indicated. Small combined mechanical, carious pulp exposure. Direct pulp capping was provided with no complications.

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pulp exposures, when small and properly diagnosed as mentioned above, can be successfully treated with a direct pulp cap (see Fig. 4).

When treating a carious exposure, excessive pulpal bleeding can be indicative of inflammation and a decreased ability to heal and form reparative dentin. Use of sterile saline, two percent chlorhexidine, sodium hypochlorite, ferric sulfate, hydrogen peroxide, aluminum chloride, local anesthetic with epinephrine, and many others, have been proposed for hemostasis of pulp exposures. A cotton pellet immersed in the hemostatic solution is placed against the pulp exposure for up to several minutes until hemorrhage is controlled. If it cannot be controlled after several attempts, endodontic root canal therapy should be considered.

Most clinicians use sodium hypochlorite due to its antibacterial effect and familiar use with endodontic procedures. However, it should be noted that it might affect bonding procedures due to oxygen free radicals. Interestingly enough, there have been a number of published studies demonstrating an increase in dentin bond strengths after sodium hypochlorite pre-treatment. Nevertheless, almost all hemostatic agents listed above may interfere with bonding protocols, except for sterile saline and two percent chlorhexidine. Further research is needed to better understand this. Unfortunately, most hemostatic agents are cytotoxic to some degree and decrease the pulp’s ability to heal. Despite this cytotoxicity and bonding impairment, sterile saline, sodium hypochlorite, or chlorhexidine seem to be the agents of choice for hemostasis control.

Materials

Knowing when to provide pulp capping may be more important than the material you use. Similarly, the reported literature has heavily emphasized that the peripheral seal of the restoration is more important than the material used for pulp capping. Does this mean that any material can be used? Not necessarily.

In the last 5-10 years, a plethora of new materials and products have been introduced for direct and indirect pulp capping. Unfortunately, most new products lack adequate laboratory, biological, and clinical studies. The increased cost of conducting clinical research while maintaining stricter ethical standards, along with fierce competition for grants, has contributed to the lack of clinical evidence necessary to use many of these new products, even if they are better. Many clinicians, associations, and groups do not recognize that it can cost well over one million U.S. dollars for a 1-2 year clinical trial. Even at that, the sample size may be lacking for sufficient power, or the results may not indicate if there is sufficient evidence to use a new product.

The development of practice-based research networks (PBRN) may help to alleviate some of these issues. These networks conduct clinical research on comparative products in many different clinical practices. Although not every variable can be controlled by this method, there is power in the number of practices that are using these products in a non-controlled environment, which actually may better represent how a product is going to perform.

A recent report of a PBRN clinical trial by Hilton et al. (2013) evaluated and compared the success of direct pulp capping in permanent teeth with MTA (mineral trioxide aggregate) or CaOH (calcium hydroxide), with significantly higher failure rates attributed to CaOH. They concluded that MTA was superior for direct pulp capping as compared to CaOH. This research is in agreement with previously published clinical studies finding MTA was either comparable or superior to CaOH. Unfortunately, these results come 15 years after the product was introduced.

Despite the recent success of MTA in the reported literature as a pulp-capping agent, it is still not the primary product used in most dental offices. This may be due to the higher cost, the 2-hour-and-45-minute setting time, or the delivery method. Improved versions have been introduced that may alleviate some of the limitations noted.

Most clinicians are using some form of CaOH based material with mixed success. Clinicians have reported removing restorative material that had CaOH placed under it, to find it completely gone, or crumbled with voids. Hilton (2009) reported that self-cure formulations of CaOH are highly soluble and subject to dissolution over time. In addition, he states there are no inherent adhesive properties and it provides a poor seal. In addition, the cytotoxicity of most CaOH based pastes is well documented in the literature. However, the material is inexpensive, easy to use, possesses a high pH causing release of bioactive molecules, and is antibacterial.

Other materials have been used and researched with varied success for direct pulp capping such as those that contain polyacrylic acid (i.e. RMI—resin-modified glass ionomer, GI—glass ionomer, and polycarboxylate cement). Although they are biocompatible and receive considerable attention from some KOLs, all of these materials are cytotoxic to the pulp and the polyacrylic acid contained within them inhibits apatite formation, questioning their value for direct pulp capping. As a liner or base over affected dentin or another direct pulp capping material, such as MTA based materials or CaOH, they have proven worthwhile and are recommended. Many clinicians believe the high initial fluoride release from these products make them a great candidate for a direct pulp capping material. However, it is reported in the literature that fluoride release from these materials correlates to cytotoxicity of dental pulp stem cells. Furthermore, the manufacturers of these types of products do not indicate them for direct pulp capping, most likely due to the high fluoride release being cytotoxic to pulp cells.

Adhesives were investigated and used for some time as a pulp capping material. This would save time and expenses; unfortunately adhesives are cytotoxic to pulpal cells, result in less healing, chronic inflammation, and a poor seal. Zinc oxide eugenol may seem like a logical choice for pulp capping as well since it has had some success in many other areas of dentistry, including provisional restorations. However, when used for direct pulp capping, it causes inflammation, poor dentin bridge formation, potential leakage, and reduced pulpal healing.

Bioactivity

Terms like bioactive, bioavailable and bioactivity are now loosely used in several manufacturers and KOLs’ claims for newer products, and appear to be buzzwords to attract customers and sales. From the research point of view, the term bioactivity was described over 25 years ago for research on glass-ceramics, as the formation of an apatite layer being a necessary and sufficient condition for bioactivity (Kukubo T et al. 1990). Further, bioactivity was defined in the ISO 23317:2014 in Implants for Surgery as, “a property that elicits a specific biological response at the interface of the material, which results in the formation of a bond between tissue and material.”

This document is applicable for implant surfaces that come into
direct bone contact, not necessarily restorative materials. Extracting the above definitions imprecisely means that bioactivity requires formation of an apatite layer and the formation of a bond between tissue and material, which assumingly comes from the deposition of apatite. To date, this has been demonstrated with several new bioactive materials but only in vitro. Further clinical research studies are needed to demonstrate that these materials do in fact form hydroxyapatite and a bond between the dentin and the pulp capping material.

In a recent review article by Niu, Pashley, Tay et al. (2014), they conclude that “universally acceptable criteria are lacking for objective appraisal of the relative in vivo bioactivity”, and that “the term “bioactivity” is used rather ambiguously.” They recommend that the ISO (International Organization for Standardization) or the ASTM (American Society for Testing and Materials) should develop appraisal criteria and to accurately define bioactivity for restorative and endodontic applications. This would better direct and define this growing segment of restorative and endodontic dentistry.

Despite the above shortcomings of accurately defining what is or what isn’t bioactive, there are several newer MTA-like materials that have improved on the limitations of MTA and are being accepted due to enhanced clinical outcomes. Theracal LC (BISCO) and Biodentine (Septodont) are two newer products that more closely resemble MTA, in that both are considered calcium silicate cements, similar to MTA. Both products contain calcium silicate fillers that releases calcium and hydroxide ions, which aid in stimulating apatite formation, promotes healing via an alkaline pH (and its antibacterial affect), aiding in the release of bioactive dentin matrix proteins, and formation of secondary dentin bridge.

Both products are being researched extensively, but more clinical research is necessary to confirm what many clinicians are finding successful for direct pulp capping. The differences between the two products are the handling, indications, and delivery systems. Theracal LC is a light-curable product indicated for direct and indirect pulp capping, whereas Biodentine can be used for endodontic applications as well, but must be mixed in a triturator and takes 12 minutes to set.

Calcimol LC (VOCO) and Activa (Pulpdent) are two materials that claim bioactivity due to release of various ions, including calcium (Activa also includes fluoride and phosphate ions). Calcimol LC is calcium dihydroxide in a resin carrier and is similar to other CaOH light curable resin-based pastes, as discussed above. Activa is a dual-curable base/liner that claims to have a bioactive resin matrix and bioactive fillers. In terms of their ability to form a bond between tissue and the material or form apatite, very little research is available. It should be noted that the above two products are not indicated for direct pulp capping. Activa specifically releases high amounts of fluoride, which would be cytotoxic to pulpal cells.

**Success versus failure**

Research reports that well-sealed margins determine the long-term success of adhesive restorations and can arrest progression of the carious lesion. Failure is determined by need for tooth extraction, endodontic treatment (root canal therapy), or diagnosis of pulpal necrosis, irreversible pulpitis, apical periodontitis, or apical abscess.

Successfully diagnosing the tooth, as described above, and providing a well-sealed restoration under rubber dam isolation can lead to three things:

1. Resolution of the tooth over a period of time including months and potentially some lingering sensitivity. Clinicians should monitor frequently for any radiographic changes indicative of apical periodontitis
2. Tooth progressively gets worse in a short amount of time requiring either emergency pulpectomy and/or non-surgical root canal therapy.
3. Tooth progressively gets worse over a longer period of time with the patient being able to tolerate the pain until one day he or she can no longer deal with the pain—leading to emergency pulpectomy or non-surgical root canal therapy.

Variables affecting success or failure include: size of exposure, amount of bleeding, type of exposure (carious, mechanical, or traumatic), rubber dam use, pulpal hemostatic agent, absence of symptoms, type of restoration provided (provisional or permanent), and class of restoration (I vs II).

**Case report**

A 14-year-old female presented for routine restorative dentistry on a maxillary molar with no complaints of pain or sensitivity. Radiographic and clinical examination revealed moderate to advanced occlusal decay. After anesthetic and rubber dam isolation, the tooth was accessed with a carbide bur. During caries excavation, the med- iast pulp was exposed resulting in mild hemorrhage (Fig 5). Upon examination, this was a carious/mechanical exposure. A cotton pellet soaked in 2 percent chlorhexidine was held against the exposure

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Subsequent follow-up appointments revealed no sensitivity or complications (Fig. 9). Routine radiographic and clinical examination has been provided for the last 3 years.

**Conclusion**

The prognosis of pulp capping a tooth in a busy practice can be improved greatly by following strict guidelines of diagnosing the tooth prior to excavation. Avoid exposing the pulp with great caution by removing only the infected dentin and providing an indirect pulp cap with a proven material that will assist the pulp in healing and arrest the caries process. For direct pulp capping, disinfect the cavity and control hemorrhage with 2 percent chlorhexidine, sterile saline, or sodium hypochlorite. Use MTA with a liner/base of RMGI/GI or a newer MTA-like material, which have many benefits over conventional CaOH. Lastly, provide a well-sealed restoration under rubber dam isolation.

**Author Bios**

Dr. Paul L. Child is a prosthodontist and a certified dental technician. He maintains a private practice in the greater Chicago area where he enjoys providing all aspects of dentistry, including prosthodontics, operative, aesthetics, implants, complex restorative, CAD/CAM, and all aspects of surgery. Dr. Child is the former executive vice president of BISCO Dental Products and the former CEO of CR Foundation (formerly CRA). He lectures nationally and internationally on dentistry with an emphasis on new and emerging technologies, prosthodontics, adhesives, cements, and surgery. He maintains membership in many professional associations and academies, and is on the editorial board of several journals.

Mark L. Cannon received his doctorate of dental surgery from the University of Nebraska and attended Northwestern University for his masters of pediatric dentistry. He completed his residency at Children’s Memorial Hospital and received his diplomat status by the American Board of Pediatric Dentistry. He is a professor of otolaryngology, Division of Dentistry at Northwestern University, Feinberg School of Medicine, and a member of the International Association of Pediatric Dentistry. In addition to maintaining a large private practice, he is the research coordinator of the residency program at Ann and Robert Lurie Children’s Hospital in Chicago.