One-Visit Apexification: Technique for Inducing Root-End Barrier Formation in Apical Closures

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Numerous procedures and materials have been utilized to induce root-end barrier formation. Mineral trioxide aggregate (MTA) was introduced to dentistry as a root-end filling material. It has been advocated for filling root canals, repairing perforations, pulp capping, and root-end induction. Mineral trioxide aggregate reacts with tissue fluids to form a hard tissue apical barrier. As a result, MTA shows promise as a valuable material for use in one-visit apexification treatment, primarily for treating immature teeth with necrotic pulps.

Key Words: apexification, MTA, one-visit, tooth trauma

Dental caries and trauma are the most common challenges to the integrity of a tooth as it matures. Both insults can render the dental pulp nonvital. If this occurs prior to complete root formation and apical closure, normal root development is halted (Figures 1 and 2). Clinically, there are several conditions associated with treating teeth that have a widened or open apical foramen. For one, the apical diameter of the canal is often larger than the coronal diameter, so debridement is difficult. In addition, the lack of an apical stop makes obturation in all dimensions virtually impossible. Finally, the thin walls of the root canal are prone to fracture, so that surgica treatment is generally not a viable option.[1] To avoid these complications, apexogenesis (ie, vital pulp therapy) is indicated to encourage continued physiological development and formation of the root end (Figure 3). When the insult to the tooth has caused pulpal necrosis, alternative treatment must be considered (Figure 4). The alternative is apexification, which is defined by the AAE Glossary as "a method of inducing a calcified barrier in a root with an open apex or the continued apical development of an incompletely formed root in teeth with necrotic pulp."

Immature teeth rendered nonvital (pulpal necrosis) require apexfication prior to nonsurgical root canal treatment. Numerous procedures utilizing various materials have been recommended to induce root-end barrier formation. These include: no treatment,[2] infection control,[3] induction of a blood clot in the periradicular tissues,[4] antibiotic pastes,[5] and calcium hydroxide ($Ca[OH]_2$) mixed

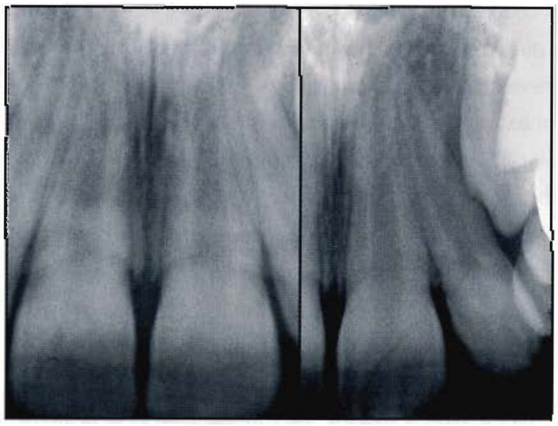

Figure 1. Preoperative radiographs of tooth #9(21) diagnosed with pulpal necrosis and acute periradicular periodontitis.

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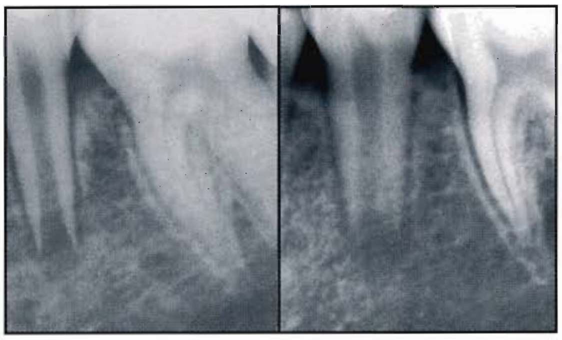

Figure 2. Preoperative radiographs of tooth #20(35) diagnosed with pulpal necrosis and acute periradicular periodontitis.

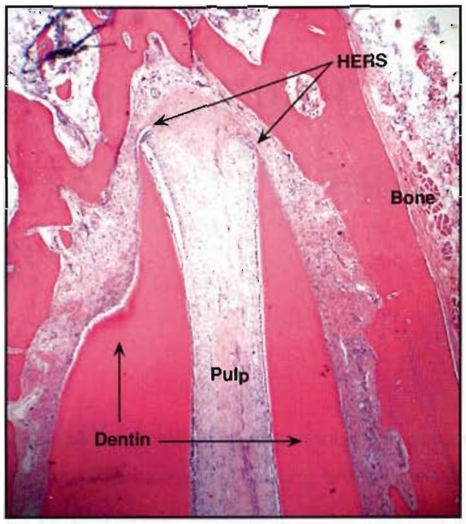

Figure 3. Histological image shows normal development of a tooth. Note location of dentin, pulp, and HERS.

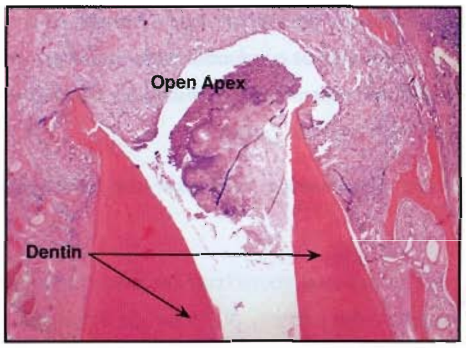

Figure 4. Histological stain demonstrates periradicular pathology in an open apex tooth.

with various materials.[6] Most commonly, the apexification procedure has been performed utilizing $Ca(OH)_2$. In 1959, Granath was the first to describe the use of $Ca(OH)_2$ for apical closure.[7] Prior to this, nonvital immature teeth were often extracted.[8] Frank popularized the technique in which the canals are debrided, $Ca(OH)_2$ is mixed with camphorated *p*-chlorophenol to make a paste that is then placed into the canals, and the access opening is subsequently filled.[6] In this procedure, the $Ca(OH)_2$ dressing is replaced every three months until a barrier is formed, which may require up to 24 months. When this procedure is performed today, the $Ca(OH)_2$ is most commonly mixed with sterile water or an anesthetic, but the time for barrier formation remains the same.[9]

Unfortunately, the Frank technique sometimes provides inconsistent results: 1) The periapex closes with a definite (though minimal) recession of the root canal. The apical aspect continues to develop with a seemingly obliterated apex. 2) The obliterated apex develops without any change in the root canal space. 3) A thin, calcific bridge that is not radiographically discernable develops. 4) A calcific bridge forms just coronal to the apex and can be determined radiographically. Other inconsistencies relating to the use of $Ca(OH)_2$ for apexification include the time for root apices to close, the number of dressings necessary to complete closure, and the role of infection. Depending on the study, the speed of barrier formation varies from 3 to 24 months.[6,10] There are also variations in the recommended number of reapplications of $Ca(OH)_2$.[13-14] Reapplication at 1 month then 3 months, or 1 month then 6 to 8 months has been suggested until apical barrier formation occurs.[12] Finally, some studies have reported an increase in the time for apexification when infection is present,[15,16] while others have demonstrated no statistically significant differences.[13,14,17]

These conflicting reports aside, the procedure for treating teeth with open apices is a difficult one. The root walls are thin and fragile, which render the tooth more susceptible to fracture during compaction of the obturation material.[1] Since patients are generally young, surgery is not a desirable course of treatment because immature teeth have large, patent dentinal tubules and a root-end filling may not provide an optimal seal. Compaction of a root-end filling may also cause fracture of the thin dentinal walls. Another factor that may compromise long-term apexification is the difficulty in maintaining a temporary filling that adequately seals the access opening. A temporary filling 4 mm in thickness is required to

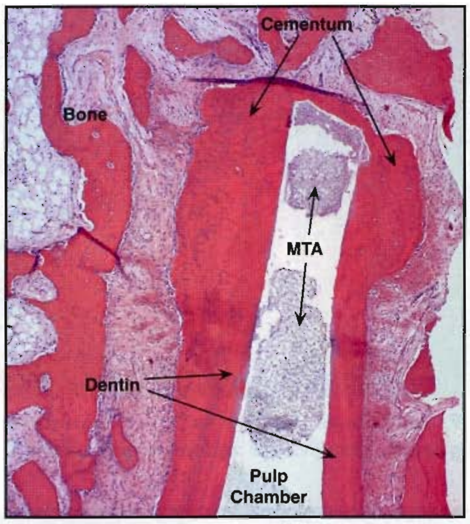

Figure 5. Histological image showing periradicular healing of an open apex tooth treated with MTA. Note the thin walls and the hard tissue formed at the apex of the tooth.

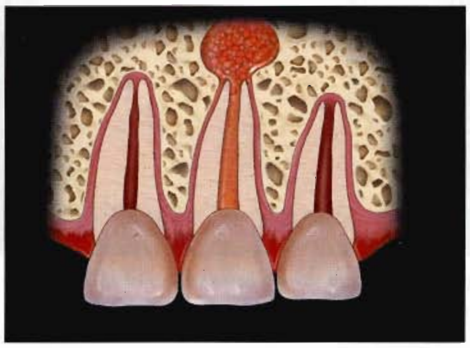

Figure 6. Illustration of pulpal necrosis with associated periradicular periodontitis in a central incisor with an open apex.

create a suitable seal. If there is dilution and/or contamination of the paste during the apexification treatment, with exposure of the healing tissues to bacteria, then acute exacerbation and a delayed healing response may occur.[6]

Requisites for Apexification

Mineral trioxide aggregate or MTA (Proroot, Tulsa Dental, Tulsa, OK) was introduced to dentistry in 1993 primarily as a root-end filling material.[18] Since then, MTA has been utilized in several additional endodontic procedures.[9,19,20] Mineral trioxide aggregate is a promising material due to its sealing property, ability to set up in the presence of blood, bactericidal effects, and biocompatibility.[21-23] Numerous clinical studies have demonstrated the efficacy of MTA as a root-end filling material, and its attributes could also provide benefits for apexification.

Marginal adaptation using MTA has demonstrated increased efficacy when compared to amalgam, intermediate restorative material (IRM), and ethoxy benzoic acid (Super-EBA, Bosworth, Skokie, IL).[24]

Blood contamination of the root-end site during barrier formation is also a relevant concern. In a similar comparative study, investigators noted that the presence of blood did not affect MTA's ability to maintain a seal.[21] Holland et al theorized that the tricalcium oxide in MTA reacts with tissue fluids to form $Ca(OH)_2$, resulting in an apical barrier.[25] In addition, apexification implies the presence of a necrotic pulp, so a material with antibacterial properties is also desired. Several studies have evaluated the ability of MTA to kill bacteria. In a comparison study of root-end filling materials and their effects on nine facultative bacteria and seven strict anaerobic species, MTA had an antibacterial effect on some of the former, but no effect on the latter.[22] Finally, due to its proximity to the periradicular tissues, an apexification material needs to be biocompatible. In a recent osteoblast biocompatibility study, MTA demonstrated promise in this area, allowing good cell growth in vitro.[23] As a result, MTA shows promise as a material for one-visit apexification (Figure 5).

Single-Visit Apical Closure: Technique

The inherent difficulties of inducing barrier formation over a period of months are avoided when treatment is

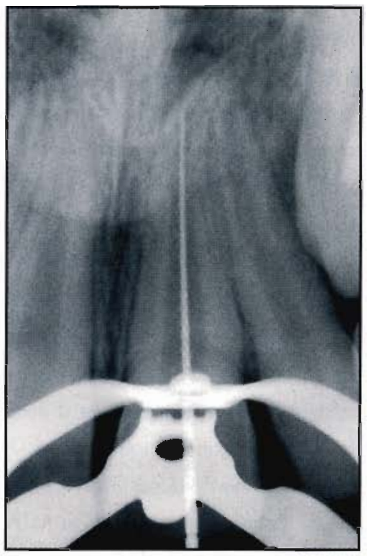

Figure 7. Working length radiograph of a maxillary central incisor.

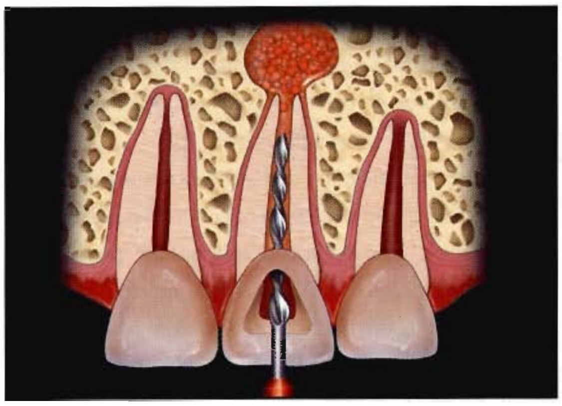

Figure 8. Diagram demonstrates cleaning and shaping of the canal system with nickel-titanium rotary instruments.

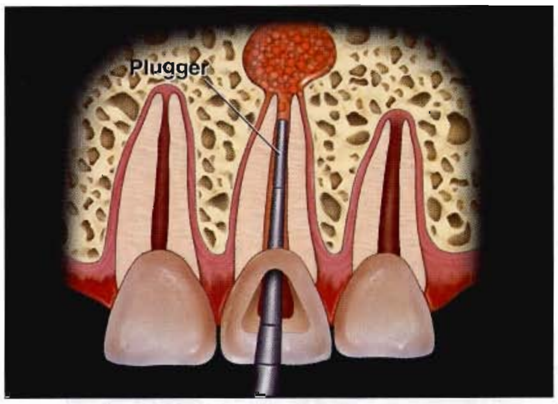

Figure 9. Illustration of plugger fitted to ~1.5 mm short of working length. Note that the instrument does not bind.

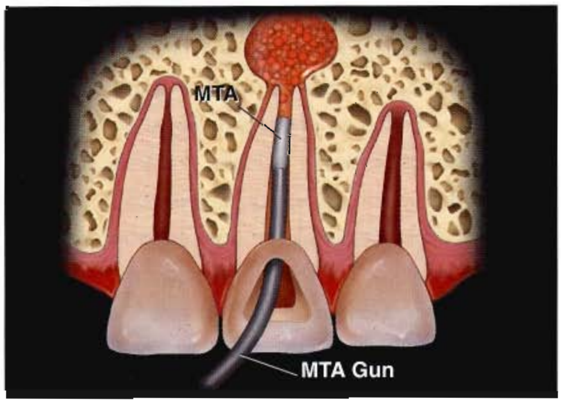

Figure 10. Initial placement of MTA in the cleaned and shaped root canal system.

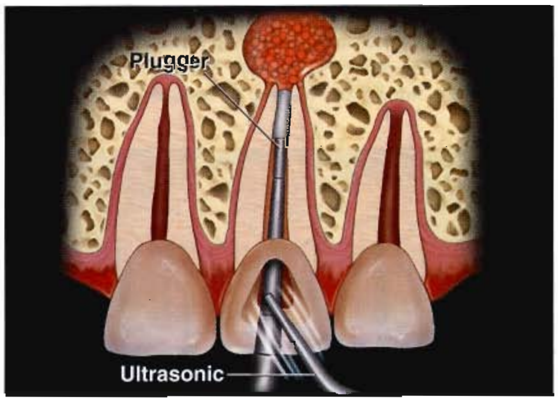

Figure 11. Diagram shows compaction of MTA with a plugger fitted loosely and ultrasonically vibrated.

completed in one appointment. Such treatment could be described as single-visit apical closure with MTA. When MTA is used in this manner, it becomes the final obturating material in the apical to middle third of the canal system. This technique can be accomplished as follows: an access opening is made, and the canal is cleaned and shaped using nickel-titanium rotary instruments with sodium hypochlorite used gently as the irrigant. The smear layer is then removed utilizing a combination of ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (Figures 6 through 8). Once cleaning and shaping is completed, a sequence of pluggers (generally used for warm vertical compaction) are loosely fitted in the root canal system. The smallest plugger should fit loosely ~1.5 mm from the working length (Figure 9). Mineral trioxide aggregate is then placed in the middle to apical third of the root canal system using an MTA gun and compacted with the series of pluggers previously fitted to the root canal system (Figure 10). The pluggers are vibrated ultrasonically to encourage compaction and flow of MTA to the apex (Figure 11). Once the MTA layer is adequately compacted to the working length and confirmed with a radiograph, the excess can be removed from the coronal third of the canal system by irrigation with sterile water. The remaining fluid is removed with sterile paper points (Figures 12 through 14). The remainder of the canal system can be restored with a core material that butts against the MTA (Figure 15). This layer can extend into the coronal third of the canal. Finally, composite resin is layered against the core material, extending to fill the access opening (Figures 16 through 18).

Discussion

Any extended treatment plan runs the risk of losing the patient due to geographical reasons. If a child moves during the course of treatment, it is difficult to ensure that dressing changes will be made as necessary until a barrier is formed. Repeated clinical visits can be disruptive

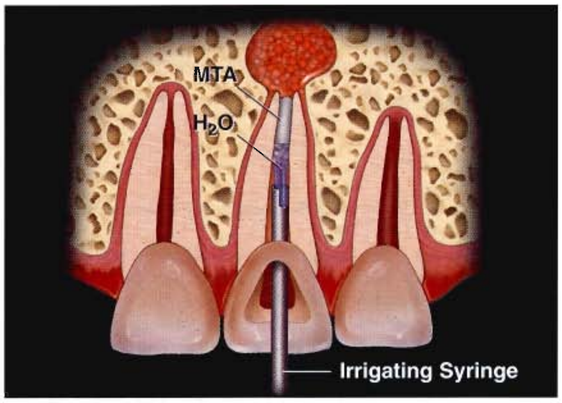

Figure 12. Mineral trioxide aggregate is compacted to working length. The excess is removed by irrigating with sterile water.

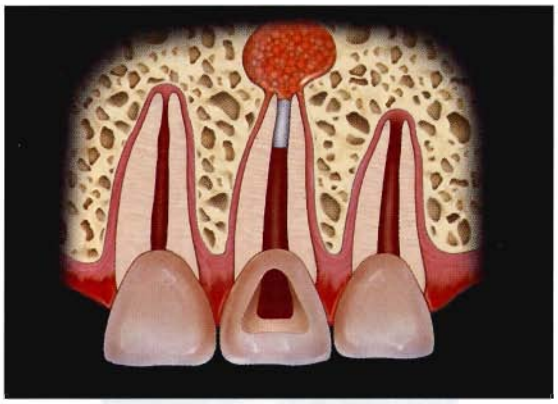

Figure 13. The MTA is compacted into place, and no excess is left in the coronal portion of the canal space.

Figure 14. Immediate postoperative radiograph of the left mandibular second premolar treated with placement of MTA in the apical third.

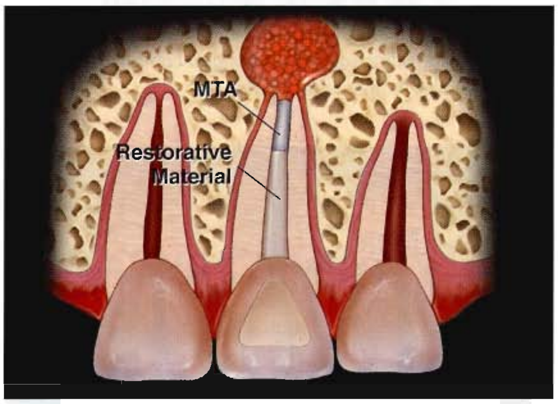

Figure 15. Illustration of MTA in place with the canal space and access opening restored.

and difficult to maintain. These appointments are also easy to forget, since the patient has little discomfort and the tooth looks normal clinically. Children may be more traumatized by apexification treatments that require repeated visits, and it is these younger children with very wide apices that often need extended treatments. Thus, the need for a reliable one-visit apexification treatment is evident.

As with any dental procedure, there are limitations to single-visit apical closure with MTA. Since some compaction of the MTA is necessary during placement, the thin dentin walls may be prone to fracture. Because of this, apexification with MTA may be contraindicated in extremely immature teeth with very wide-open apices. Another disadvantage is the risk of gingival staining and tooth discoloration due to the dark color of MTA. Staining is not a consistent sequelae of treatment but has been demonstrated. It is unknown whether MTA is the direct cause of the staining. White MTA has been manufactured for experimental purposes but is not yet available on the market. In the future, this option may provide a suitable alternative when staining is a concern.

Conclusion

Although these potential concerns must be addressed and considered, the potential advantages of single-visit apical closure with MTA outweigh any negatives. As previously discussed, one-visit treatment is always advantageous over multiple treatments that may occur over many months. Another positive aspect is that MTA provides scaffolding for the formation of hard tissue and the potential of a better biological seal.[9] When obturation finally occurs following hard tissue deposition with $Ca(OH)_2$, the clinician can never be sure of the integrity of the barrier. Single-visit apical closure with MTA avoids many of the pitfalls of traditional treatment methods. It is a viable option for treating immature teeth with necrotic pulps and should be considered as an effective alternative.

Figure 16. Six-month postoperative radiograph of the left maxillary central incisor with a bonded composite core material placed in the canal system.

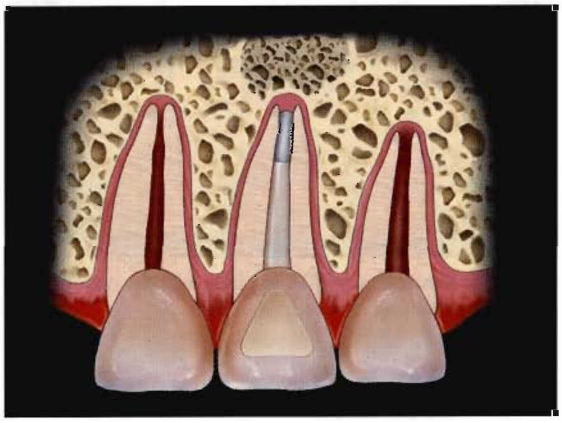

Figure 17. Diagram of new bone and periodontium formation in the periradicular region as a result of healing.

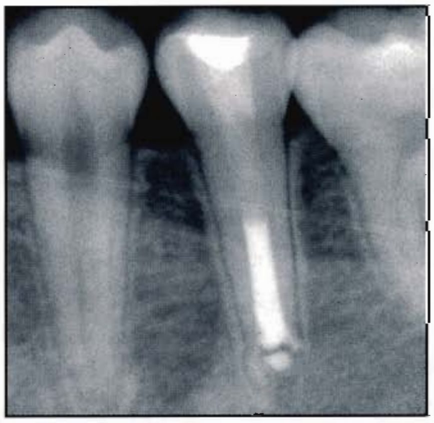

Figure 18. Six-month postoperative radiograph of the left mandibular second premolar with a bonded composite core material placed in the canal system. Note periradicular healing.

Acknowledgment

The authors declare no financial interest in any of the products cited herein.

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Continuing Education (CE) Exercise No. 18

18 CONTINUING EDUCATION

To submit your CE Exercise answers, please use the answer sheet found within the CE Editorial Section of this issue and complete as follows: 1) Identify the article; 2) Place an X in the appropriate box for each question of each exercise; 3) Clip answer sheet from the page and mail it to the CE Department at Montage Media Corporation. For further instructions, please refer to the CE Editorial Section.

The 10 multiple-choice questions for this Continuing Education (CE) exercise are based on the article "One-visit apexification: Technique for inducing root-end barrier formation in apical closures" by David E. Witherspoon, BDS, MS and Karla Ham, DDS, MS. This article is on Pages 455-460.

Learning Objectives:

This article discusses the causes and treatment approaches to apical closure and root-end barrier formation utilizing calcium hydroxide. Upon reading this article and completing this exercise, the reader should demonstrate:

- An understanding of the procedures for treating open apices with apexification.
- An awareness of the one-visit apexification technique to induce root-end barrier formation.
- The protocol for apical closure utilizing mineral trioxide aggregate (MTA).

1. In order for apexogenesis to occur, which of the following must be present?
a. Caries.
b. A necrotic pulp.
c. A primary tooth.
d. A vital pulp.

2. MTA may be contraindicated in:
a. The integrity of the barrier.
b. Extremely immature teeth with wide-open apices.
c. The presence of blood contamination.
d. All of the above.

3. To encourage apexification according to the Frank technique, how often should the $Ca(OH)_2$ dressing be replaced?
a. Every month.
b. Every 3 months.
c. Every 4 months.
d. Every 6 months.

4. What factor contributes to the time it takes for apical closure to occur?
a. Coronal leakage.
b. The number of $Ca(OH)_2$ dressings applied.
c. The stage of tooth development in which pulpal necrosis occurred.
d. All of the above.

5. MTA has been shown to have better marginal adaption than which of the following?
a. Geristore.
b. Composite.
c. Amalgam.
d. Glass ionomer.

6. Which component of MTA is theorized to react with tissue fluids to form $Ca(OH)_2$?
a. Silicate oxide.
b. Tricalcium oxide.
c. Tricalcium silicate.
d. Tricalcium aluminate.

7. Which of the following is NOT a property of MTA?
a. Biocompatibility.
b. Bactericidal effects.
c. Expansion upon setting.
d. Sets up in the presence of blood.

8. In a single-visit closure technique with MTA, the plugger should be filled loosely to:
a. Working length.
b. 5 mm short of working length.
c. .5 mm short of working length.
d. 1 mm to 2 mm short of working length.

9. The MTA should ideally extend from the apex to:
a. The pulp chamber.
b. The orifice of the canal.
c. The coronal of the canal.
d. The middle third of the canal.

10. What are the benefits of MTA apical closure over $Ca(OH)_2$?
a. More time is required.
b. A strong barrier is formed.
c. The antibacterial effects are better.
d. All of the above.