Case Report

Open apex solutions: One-step apexification, salvaging necrosed teeth with open apex

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ABSTRACT
Open apices are a constant challenge to an endodontist. The one-step apexification technique in which an apical barrier is placed to achieve an adequate apical stop has become a popular procedure nowadays. This case series describes eight clinical cases with immature necrosed pulp which were subjected to one-step apexification procedure using different materials and techniques. The materials used varied from mineral trioxide aggregate (MTA) with hydroxyapatite (matrix), biodentine with hydroxyapatite (matrix), MTA alone, tailor-made gutta-percha with platelet-rich fibrin (matrix), and gutta-percha alone. All the cases were successful regarding the resolution of symptoms and periapical healing concluding that one-step apexification has successfully replaced the traditional methods of apexification. No matter what barrier is used or matrix is placed or not, healing takes place if the procedure is followed carefully using recommended protocols.

Keywords: Apexification, apical barrier, biodentine, hydroxyapatite, matrix, mineral trioxide aggregate

INTRODUCTION
Pulp necrosis (mostly due to trauma) in teeth with incomplete roots can arrest root development resulting in open apices.

Widely accepted management of these teeth require cleaning and filling of the canal with a material to induce a complete calcific barrier at the apex of the tooth for a root-end closure of incompletely developed apex. Thus, in this case series, nonsurgical management of symptomatic teeth with open apices with two different synthetic materials mineral trioxide aggregate (MTA) and biodentine was carried with matrix or without matrix and the favorable results were obtained.

CASE REPORTS
Case I (hydroxyapatite + biodentine and gutta-percha)
A 24-year-old male patient reported to the Department of Conservative Dentistry and Endodontics, with a chief complaint of pain and pus discharge in upper front teeth region for 3–4 months. Intraoral examination revealed tooth #22 was discolored, and sinus opening was visible in relation to the same tooth. Radiographs revealed wide canal with open apex and periapical radiolucency [Figure 1a]. Apexification with biodentine was planned as one of the best treatment options. The treatment plan was discussed with the patient and consent was taken. After rubber dam was applied, an endodontic access was established using Endo Access bur. Minimum instrumentation was performed and circumferential filing was done until 80 K file [Figure 1b]. Copious irrigation was performed with 0.5% sodium hypochlorite and normal saline using side-vented irrigation needle. Care was taken so that irrigant should not extrude through open apex. After the canal was completely dried with paper points, a small amount of hydroxyapatite crystals were placed at the apical portion of the canal and gently compacted using...
prefitted hand pluggers slightly beyond the apex to achieve a matrix [Figure 1c]. According to manufacturer’s instructions, biodentine was mixed and placed at the apical region to form the apical plug of 4 mm [Figure 1d]. Then, rest of the canal was obturated with tailor-made gutta-percha [Figure 1e and f]. The access cavity was closed temporarily with glass ionomer cement. After 3 weeks, the glass ionomer was replaced by a bonded resin restoration [Figure 1g] and the patient was kept on follow-up.

Case II (hydroxyapatite + mineral trioxide aggregate and gutta-percha)
A 17-year-old female patient reported with a chief complaint of discoloration in the maxillary left central incisor and subsequent pus discharge. A detailed case history revealed that she had experienced trauma in the same tooth 10 years back. Radiographic examination revealed wide-open apex with blunderbuss canal and periapical radiolucency [Figure 1h]. The apexification treatment with MTA was planned with the informed consent of patient’s parents. A similar protocol of treatment was adapted in this case, and apexification was done with MTA over hydroxyapatite matrix while remainder of the canal was filled with thermoplasticized gutta-percha [Figure 1i-k]. The patient became asymptomatic and showed healing on recall visits.

Case III (mineral trioxide aggregate and gutta-percha)
A 22-year-old male patient reported with a chief complaint of discoloration in the maxillary right central incisor with a history of trauma in the same tooth few years back. Radiographic examination revealed wide-open apex with blunderbuss canal and periapical radiolucency [Figure 1l]. Root-end closure with MTA was opted as a treatment of choice for this case. With the informed consent of patient’s parents, similar protocol of treatment was adapted. In this case, MTA was chosen as apexification material but without hydroxyapatite matrix and remainder of the canal was filled with thermoplasticized gutta-percha [Figures 1m and n]. Complete resolution of the symptoms was observed in subsequent follow-ups.

Case IV (biodentine and gutta-percha)
A 15-year-old male patient reported with a chief complaint of pus discharge in the maxillary left lateral incisor region. The concerned tooth tested negative to vitality tests and radiographic examination revealed periapical radiolucency in relation to 22 with wide canal and open root apex [Figure 1o]. In this case, biodentine was used for root-end closure after taking the patients’ consent. According to manufacturer’s instructions, biodentine was mixed and placed to form apical plug [Figures 1p and q]. No matrix was used in this case and rest of the canal was filled with thermoplasticized gutta-percha [Figure 1r].

Case V (mineral trioxide aggregate alone)
A 17-year-old male patient reported with fractured maxillary right central incisor with the history of trauma in the same tooth 9 years back. Radiograph showed blunderbuss apex of the right central incisor and periapical radiolucency with respect to the same tooth [Figure 2a]. White MTA was used for apexification. MTA was mixed according to the manufacturer’s recommendations and was carried into the root canal using amalgam carrier in small increments, and canal was completely filled with MTA without any matrix and gutta-percha. On recall visit, the patient was asymptomatic.
After the evidence of healing, the tooth was restored with post and metal-ceramic crown [Figures 2b and c].

Case VI (biodentine alone)
A 15-year-old male patient reported with a chief complaint of pus discharge in the maxillary left lateral incisor with the history of trauma in the same tooth 9 years back. Radiographic examination revealed wide canal with open apex and periapical radiolucency [Figure 2d]. Apexification was planned as a treatment option with the informed consent of patient’s parents. A similar protocol of treatment was adapted and complete obturation was done with biodentine alone without using any matrix and gutta-percha [Figure 2e and f]. Complete resolution of the symptoms was observed.

Case VII (platelet-rich fibrin as barrier and gutta-percha)
A 22-year-old female patient reported with the chief complaint of discoloration and subsequent pus discharge in the maxillary right central incisor. The patient gave a history of injury due to fall few years back. Radiographic examination revealed wide-open apex with blunderbuss canal and periapical radiolucency [Figure 2g]. In this case, the apexification treatment with platelet-rich fibrin (PRF) was elected with the informed consent of patient’s parents. PRF was placed as an apical barrier and remainder of the canal was filled with thermoplasticized gutta-percha [Figure 2h-j]. There was complete resolution of the symptoms in subsequent follow-ups.

Case VIII (gutta-percha alone)
A 29-year-old female patient reported to the Department of Conservative Dentistry and Endodontics with a chief complaint of discoloration in the maxillary right lateral incisor with the history of trauma in the same tooth 10 years back. Radiographic examination revealed wide canal with open apex and a periapical radiolucency [Figure 2k]. In this case, root-end closure was done with the help of customized gutta-percha. After complete debridement, canal was filled completely with tailor-made gutta-percha [Figure 2l-n]. In this case, complete resolution of the symptoms was observed in subsequent follow-ups.

**DISCUSSION**

With traditional means, induction of an apical barrier, regardless of the material used, takes at least 3–4 months and requires multiple appointments.\(^1,2\) Patient’s compliance with this regimen may be poor and they may fail to return for scheduled visits. Even the temporary seal may fail resulting in reinfection and prolongation or failure of treatment. For all these reasons, one-visit apexification has been suggested [Figure 3]. Morse et al.\(^2\) define one-visit apexification as the nonsurgical condensation of a biocompatible material into the apical end of the root canal. The rationale behind this is to establish an apical stop that would enable the root canal to be filled immediately. There is no attempt to induce root-end closure rather an artificial apical stop is created at the apex. A number of materials have been proposed including tricalcium phosphate, calcium hydroxide, freeze-dried bone and freeze-dried dentine, MTA, and biodentine for this purpose. Similarly, in above-mentioned case series, the endodontic management of traumatized nonvital immature permanent anterior teeth has been reviewed. Some traditional treatment options have stood the test of time and are still valid until today. Others have been reviewed and modified with the passage of time, as new science and new materials evolve to prove, disprove, or facilitate approaches to the management of these cases. Practitioners always need to be aware of changes that occur from time to time with respect to these recommendations for treatment, and of scientific studies that support or disprove treatment rationales.

The above-described cases had different degrees of open apices and associated apical periodontitis and were treated with different techniques. None of the patients had a medical
condition that would have interfered with our treatment protocol/outcome. Significant differences were seen in the treatment procedure and outcome with these materials but since host response plays a vital role in the outcome, it would be unjustified to compare these materials as such.

When treating nonvital teeth, the main issue is eliminating bacteria from root canal system. As instruments cannot be used properly in teeth with open apices, cleaning and disinfection of root canal system rely on the disinfecting agents such as sodium hypochlorite as an irrigant and calcium hydroxide as an intracanal dressing. There is an increased risk of extrusion of these disinfecting agents beyond apical foramen. Sodium hypochlorite is known to be toxic to the periapical tissues if goes beyond the apex; hence, it is advisable to use a less concentrated form which reduces its toxicity. In all the above cases, 0.5% sodium hypochlorite was used. Alternative antibacterial agents such as calcium hydroxide or triple antibiotic pastes have proven to be effective in cases with open apices for canal disinfection.

Many materials have been proposed for root-end closure, however, MTA by Torabinejad et al. has become material of choice for apexification. MTA has a range of advantages such as biocompatibility, hard tissue formation, sealing ability, and antibacterial property. Torabinejad et al. found that MTA has an antibacterial effect on five of nine facultative bacteria but no effect on any strict anaerobes. MTA is not affected by the presence of blood.

In 1997, Shabahang et al. compared MTA, osteogenic protein-1, and calcium hydroxide for apexification in dogs and found that MTA has maximum ability to form an apical barrier. He also concluded that it reduces root fracture. However, there are few concerns regarding MTA such as its long-setting time, poor handling characteristics, low resistance to washout before setting, possibility of staining tooth structure, presence and release of arsenic, and its high cost.

These disadvantages necessitate more ideal restorative materials. Biodentine was introduced in 2010 which is similar...
to MTA in its basic composition with the addition of setting accelerators which is calcium chloride; it not only results in fast setting but also improves handling properties and strength. Biodentine is superior to MTA in that its consistency is better suited to clinical use, ensures better handling, and safety, does not require a two-step obturation as setting time is faster, there is a lower risk of bacterial contamination.[3]

In the first two cases, hydroxyapatite barrier was created first as large periapical lesion necessitated to prevent extrusion of materials beyond the root apex. It was observed in both cases that this led to better periapical bone healing induced by hydroxyapatite barrier and apical plug formation by MTA and biodentine. Later, it was decided to try these biomaterials without hydroxyapatite matrix and MTA and biodentine were directly introduced into the canals forming an apical plug in a controlled manner. Both cases were later obturated with gutta-percha and subsequent follow-ups revealed good healing and resolution of symptoms.

To eliminate the number of steps and innovate modalities of managing such cases, it was further decided to obturate the canals with MTA and biodentine alone without gutta-percha in Case V and Case VI, respectively. The lesions responded well in these cases too.

PRF has been used for a long time as an alternative to matrix materials and it has also shown considerable success rates. Hence, it was also tried in one of these cases (Case VII) along with thermoplasticized gutta-percha for obturation and proved to be equally good as MTA and biodentine in performing one-step apexification.

As an experiment, conventional means of tailor-made gutta-percha obturation were tried in the last case (Case VIII) following all the recommended protocols of adequate cleaning and shaping. In this case, too considerable success was achieved, and the patient was symptomless after the management.

Steinig et al.[8] stated that the importance of one-step apexification technique lies in the expedient cleaning and shaping of the root canal system, followed by its apical seal with a material. Furthermore, the potential for fractures in immature teeth with thin roots is reduced, as a bonded core can be placed immediately within the root canal.[34]

**CONCLUSION**

Thus, it can be concluded that despite the different types of material used in various cases, the success in all the cases could be attributed to as follows:

1. Proper disinfection of the canal
2. Limiting the barrier and obturation within the canal
3. Fluid-tight seal with void less obturation
4. Healthy response to the patient's body.

Novel biocompatible materials such as MTA and biodentine are a boon in effective management of teeth with open apices. In cases, where hydroxyapatite or PRF barrier was first created as a large periapical radiolucency necessitated its use to avoid expulsion of materials beyond the root apex, although these materials can be limited with precise knowledge and experience. It was noted that in all cases periapical bone healing was appreciable and the patient was symptom-free during follow-ups. The healing could be attributed to following recommended protocols and response of the patient's body but still more comparative longer follow-ups and large-scale studies needed to be conducted to devise the exact material and technique which could give 100% results.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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