REVIEW ARTICLE

Apexification-Then and Now: A Review

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ABSTRACT

Apexification is a technique to generate a calcific barrier in a root with an open apex or the sustained apical development of an incomplete root in teeth with necrotic pulp. In contrast, apexogenesis describes the continued physiologic development and formation of the root's apex in vital young permanent teeth. Apexification has been routinely practiced in immature teeth with necrotic pulp for many decades. This paper reviews the past, present and recent concepts used for apexification.

KEYWORDS: Apexification, Apexogenesis, Immature permanent teeth

INTRODUCTION

According to American Association of Endodontists, Apexification is defined as a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incomplete root in teeth with necrotic pulp.[1]

An alternate treatment approach is used when pulpal necrosis occurs in immature teeth (i.e. the teeth with open apex). These immature teeth usually have thin, fragile walls making it difficult to sufficiently clean and to attain the required apical seal. Conventionally, the method has been to use calcium hydroxide to induce apexification after disinfection of the root canals in the traditional manner. Completion of endodontic therapy is delayed until root-end closure is completely achieved by apexification.[2]

DIAGNOSIS & CASE ASSESSMENT

Cautious case assessment and precise pulpal diagnosis is significant in the treatment of immature teeth with pulpal injury. Clinical assessment of pulpal status requires a comprehensive history of subjective symptoms, thorough clinical and radiographic examination and carrying out diagnostic tests. Precise pain history must be obtained. The duration, nature of the pain, aggravating and relieving factors must be considered. Duration of pain might vary, however pain that persist for more than a few seconds in a tooth with a vital pulp indicates irreversible pulpitis. When pain is spontaneous, severe and long lasting, this diagnosis is about certain. If the pain is throbbing in nature and the tooth is tender to touch, pulpal necrosis with apical periodontitis or acute abscess is expected. Substantiation from objective tests is essential. These comprise visual examination, percussion testing and thermal and electric pulp testing. The existence of a swelling or sinus tract denotes pulpal percussion indicates inflammation in the periapical tissues. In the immature teeth, pulp vitality testing usually gives erratic response because the sensory plexus of nerves in the sub odontoblastic region is not well developed as root formation is incomplete, and any injury to it give unreliable responses.[3,4] Over-dependence on the results of pulp vitality tests in immature teeth, especially the electric pulp testing is not suggested. Radiographic interpretation in these immature teeth with open apex can be challenging. In normal condition radiolucent area is present surrounding the developing apex of an immature tooth with a healthy pulp hence it is tricky to distinguish between this normal finding and a pathologic radiolucency due a necrotic pulp. Comparing the periapical region with that of the contralateral tooth may be useful. Although it is not possible to set up a close association between the results of these vitality tests and the histological diagnosis, an accurate clinical diagnosis of pulpal vitality can be made in majority of cases by merging the outcome of the history, examination and diagnostic tests. When the pulp is judged to be vital, apexogenesis techniques can be performed. In case of a necrotic pulp, apexification is done.[4]

Apexogenesis (root formation): Apexogenesis describes the continued physiologic development and formation of the root's apex in vital young permanent teeth. It can be achieved by implementing the appropriate vital pulp therapy techniques [5]

Apexification (root end closure): Apexification is a technique of inducing root end closure in an immature nonvital permanent tooth by removing the coronal and radicular tissue and placing a suitable biocompatible agent.

- *Indications:* This procedure is indicated for nonvital immature permanent teeth.

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- *Objectives:* This procedure should induce apical barrier which can be confirmed by clinical and radiographic assessment. There should be no evidence of post-treatment adverse clinical signs or symptoms of pain, sensitivity, or swelling. Root fracture, lateral root pathosis or external root resorption should not be evident during or following therapy.[5]

In the past, techniques like custom fitting the filling material, paste fills and apical surgery were used for the management of non-vital immature teeth. Later the investigations focused on inducing apical closure using antibiotic and antiseptic pastes.[6,7]

Calcium hydroxide: There are various products for inducing apical closure, but calcium hydroxide is the widely accepted material. Non-vital immature teeth undergoing apexification are first disinfected with irrigants like sodium hypochlorite and chlorhexidine then the canal is packed with calcium hydroxide paste for further disinfection and inducing apical closure by the formation of an apical calcific barrier.[8] Kaiser in 1964 introduced the use of calcium hydroxide in apexification, he also stated that this material, when mixed with camphorated parachlorophenol would induce the formation of a calcified barrier across the apex. Klein and Levy explained the successful induction of an apical barrier using calcium hydroxide and Cresatin (Premier Dental Products). When used as a root canal medicament Cresatin showed a minimal inflammatory potential and significantly less toxicity than camphorated parachlorophenol. Later investigators mixed calcium hydroxide with saline, sterile water or distilled water to further reduce the potential for cytotoxicity.[4] Heithersay successfully used the combination Calcium hydroxide and methylcellulose (Pulpdent Corporation, Watertown, MA, USA). Reduced solubility in tissue fluids and a rigid consistency are the two advantages of 'Pulpdent' over calcium hydroxide.[9]

Calcium hydroxide has antimicrobial action. The discharge of hydroxyl ions from calcium hydroxide damages the cellular component of bacteria by chemically altering the lipopolysaccharide. Various biological properties of bacteria are also affected.[10] Calcium hydroxide induces hard tissue formation, and early evidence suggests that high pH of calcium hydroxide may contribute to its osteoinductive property.[11] Histologically, the calcified tissue that forms over the apical foramen has been identified as an osteoid or cementoid material.[12] The normal time required to attain apexification is 6–24 months (average 1 year ± 7 months) however it can take up to 4years also.[13] In dental literature there is difference on how often the canal should be refilled with Calcium hydroxide paste to produce apexification, and the decision appears to be empirical. According to Tronstad et al, refilling every 3–6 months is favoured. Cohen & Burns suggested refilling only if there is radiographic evidence of resorption of the paste. Chosack & Cleaton-Jones suggested that after initial root filling with calcium hydroxide, there was nothing to be gained by its replacement either monthly or after 3 months for at least 6 months.[13]

Limitations of calcium hydroxide apexification are:

- Long time-span of the entire treatment;
- Multiple visits needed requiring patients cooperation and increased clinical costs
- Increased risk of tooth fracture using calcium hydroxide as a long-term root canal dressing

These shortcomings led to the utilization of mineral trioxide aggregate to fill the apical end without the need for calcific barrier formation.[8]

Mineral trioxide aggregate: Mineral trioxide aggregate (MTA) was first developed by Torabinejad and members at the Loma Linda University, California, USA. Initially it was used as a root-end filling material in endodontic treatment.[14] It is a mixture of dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, tetracalcium aluminoferrite and bismuth oxide. Setting time of grey MTA differs with manufacturers, for ProRoot MTA it was reported to be 2 h and 45 min (± 5 min) and MTA-Angelus it was10min.[15] MTA showed low solubility and a radiopacity that was little higher than that of dentin. It also demonstrated an excellent biocompatibility and sealing ability.[4] Antimicrobial properties of MTA was related to its pH, it has a pH of 12.5 comparable to that of calcium hydroxide.[16] In comparison to Calcium hydroxide, MTA appears to be more predictable with consistent hard-tissue formation. When MTA used for apexification, it shortens the treatment duration and produces more favorable results. Many suggests one-visit apexification technique with MTA, which offers major advantage over traditional Calcium hydroxide methods.[8]

One visit apexification: One-visit apexification is defined as the non-surgical condensation of a biocompatible material into the apical end of the root canal. The basis is to create an apical barrier that would facilitate the root canal to be filled instantly. Only an artificial apical stop is created and no effort to induce root end closure is taken.[17] MTA acts as a scaffold for the formation of hard tissue and provides better biological seal.[18] In this technique thorough cleaning and shaping of the root canal system is done. Then, MTA is introduced as an apical seal followed by the immediate placement of a suitable bonded restoration within the root canal .[19] Though the advances with MTA and bonded restorations show a better outcome, it cannot yield the result that apexogenesis can attain, i.e. maturation of the root end with better thickness of the root.[8] Therefore, alternative approaches that allow the apical maturation should be pursued.

A PARADIGM SHIFT IN THE MANAGEMENT OF PERMANENT IMMATURE TEETH

A number of case reports have illustrated continued root development in treated necrotic immature teeth but, few

cases have reported continued root development in teeth with infected root canal and draining sinus tracts. This is achieved through regenerative endodontic and revascularization procedures. These treatment procedures are termed as 'a paradigm shift' in the endodontic management of necrotic immature teeth. Initial studies suggests that, the continued root development in regenerative endodontic procedures are due to the part played by stem cells from pulp and periodontium.[20]

For the success of these procedures tri-antibiotic pastes are generally used to eliminate the intra-radicular infection. The tri-antibiotic paste is usually a combination of ciprofloxacilin, metronidazole and minocycline. This combination of drugs has also been shown to be effective in eliminating bacteria in the deep layers of root canal dentine. Discoloration of the tooth is the main disadvantage of this combination and it is due to the presence of minocycline.[20]

It was suggested that calcium hydroxide may not be a suitable intra canal medicament in regenerative procedures because of the potential to form calcified tissue preventing the pulp from regeneration .[21] Another concern is that Calcium hydroxide may damage the Hertwig's epithelial root sheath and destroys the surrounding undifferentiated cells that become odontoblasts.[8]

Common factors and important observations in the success of regenerative endodontics are:

- The presence of a wide and open apex.
- Stem cell regenerative potential is high due to the young age of the patient.
- Care should be taken not to instrument the canal walls.
- Irrigation with sodium hypochlorite proves to be effective.
- Calcium hydroxide may not be a suitable intra canal medicament in regenerative procedures because of the potential to form calcified tissue preventing the pulp from regeneration. It also destroys viable cells that differentiate into odontoblasts.
- The use of a tri-antibiotic paste consisting of ciprofloxacin, metronidazole and minocycline is effective for eliminating bacteria from the infected root canal system.
- Blood clot formation allows tissue regeneration by acting as a protein scaffold.
- The use of MTA to complete the coronal seal which has known biological conductive properties to ensure an adequate coronal seal.[20,22]

Some authors have suggested that the regenerative process may be initiated by the remaining viable pulpal tissue in necrotic teeth. A study on dog teeth has shown that these tissues originate from the periodontal ligament and consists of dentine, cementum and bone like material rather than pulp tissue with only a 30% chance of pulp tissue re-entering the pulp space.[23,24]

CONCLUSION

Compared to calcium hydroxide, MTA is effective in treating immature permanent teeth with necrotic pulps with the advantage of reduced treatment time and more predictable barrier formation. The shortcoming is similar to calcium hydroxide that the placement of an apical plug does not account for continued root development along the entire root length. Complete root development is possible with regenerative endodontic procedures, and there is a paradigm shift in the endodontic management of immature permanent teeth with necrotic pulps using regenerative endodontic procedures. In future conventional apexification procedures might be replaced completely by these newer methods.

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