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Management of Open Apex: A Review of Literature

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Abstract: Endodontic management of immature permanent teeth is still a challenge for both clinicians and researchers. Open apex is an unusual wide apical foramen that arises due multiple reasons such as incomplete development, extensive apical resorption, caries leading to pulpal necrosis or trauma before complete root formation, root-end resection, or maybe due to over instrumentation. Traditionally, calcium hydroxide was used for inducing the formation of an apical barrier. Currently, mineral trioxide aggregate (MTA) has shown promising results for apexification procedures. Recently some authors have shown that non vital, infected immature teeth can be alternatively treated by pulp regenerative process. Regenerative endodontics has brought a revolutionizing tissue engineering concept in the field of endodontics for the treatment of immature permanent teeth. It's been considered as a "paradigm shift" in the treatment modalities, as it fosters continued root maturation. Hence, this review of literature aims to discuss about various treatment modalities for management of open apex.

Keywords: Immature tooth, Open apex, Apexification

Introduction: One of the indispensable requisites for successful outcome of endodontic treatment is to achieve three dimensional fluid tight seal of a well disinfected root canal; and routine endodontic management is adequate to achieve the same for predictable and long-term prognosis of the teeth. However, certain clinical conditions like various anatomical, technical, pathological and iatrogenic complications defy routine protocol for its treatment to have predictable prognosis.[1]

Pulpal necrosis is a frequent sequale of trauma to the anterior teeth and if it occurs in young permanent teeth, this will result in the cessation of root development.[2] Cessation of root development results in teeth with open apex, thin root walls and poor crown root ratio that are difficult to instrument and impossible to seal.[3] Open apices are a problem for the realization of the root canal treatment because they favour the extravasation of irrigating solution and/or sealer into periradicular tissues, which can have a negative effect on the apical healing process.[4]

Traditionally customized gutta-percha cone was used to obturate immature canal space, but there is a danger of root fracture during lateral condensation. Long-term calcium hydroxide therapy was considered as the ideal treatment for such teeth, but this therapy has its own disadvantages, like multiple visits, relatively long period of time and alteration of mechanical properties of dentin.[5] This review article highlights wide variety of treatment option for managing teeth with wide open apices in vital and non-vital teeth such as apexogenesis, apexification procedures as well as revascularization.

Open Apex: Open apex is an unusual wide apical foramen that arises due multiple reasons such as incomplete development, extensive apical resorption, caries leading to pulpal necrosis or trauma before complete root formation, root-end resection, or maybe due to over instrumentation. Classically, there are two types of open apices; **Blunderbuss** were walls are divergent and flaring (apex being funnel shaped) whereas in **Non-Blunderbuss** walls may be slightly convergent to almost parallel.[6]

Challenging factors affecting the treatment of open root apex: Dental trauma is considered a multifactorial health problem worldwide that frequently requires multidisciplinary treatment planning to improve the quality of life of a patient. An immature root with a necrotic pulp and apical periodontitis presents multiple challenges to successful treatment.
These challenges are:

- Susceptibility to fracture: Immature apical formation is a challenging factor as large open apices with thin and divergent dentinal walls are prone to fracture.[7]
- Difficulty in complete disinfection and debridement of the root canal. Open apex poses difficulty in disinfection of the root canal. The infected root canal space cannot be disinfected with the standard root canal protocol using endodontic files aggressively as the coronal diameter of canal is often smaller than apical diameter.[8,9,10]
- Difficulty in obturation: Since there is no closure of the apex, formation of mineralized tissue in the apex becomes imperative for an apical seal in order that obturating material can be adapted 3-dimensionally in the root canal. The main purpose of endodontic treatment is to accomplish obturation of the root canal space completely and prevention of re-infection. Once the microbial phase of the treatment is completed, open apex do not provide an apical stop, thus allowing the root filling material to impinge the periodontal tissues making obturation difficult.[11,12]

Diagnostic intervention: Treatment plan majorly depends upon stages of root development and pulpal conditions. However pulp preservative strategies, early diagnosis, and intervention promote an environment for continued dentine apposition and root formation.[13]

Evaluation of pulp vitality is an important diagnostic aspect of treating young permanent teeth with open apex. Prior to completion of root formation, the sensory plexus of nerves in the subodontoblastic region is not well developed and are not fully innervated with alpha-myelinated axons: the neural components responsible for the pulpal pain response. In traumatized young permanent teeth with open apices, reliable test of the blood supply to the pulp, would enable the clinician to accurately differentiate between a pulp which is regaining its vitality and one which is becoming necrotic. The newer non-invasive pulp testing devices, such as laser Doppler flowmetry, dual wavelength spectrophotometry, pulse oximetry and light photoplethysmography have shown more accurate results by detecting the blood supply of the pulp.[14,15]

Different Treatment Options
Vital tooth with open apex
• Apexogenesis
Non vital tooth with open apex
• Apexification
• Revascularisation
Vital tooth with open apex[16]

Apexogenesis: When there is pulpal involvement of permanent teeth with incompletely formed roots, techniques for the induction of apical closure should be completed before endodontic therapy is begun. Apexogenesis refers to a vital pulp therapy procedure performed to encourage physiological development and formation of the root end.

Goals of Apexogenesis[17]
- Allow continued development of root length.
- Maintain pulp vitality, thus allow continued deposition of dentin.
- Promoting root end closure, thus creating natural apical constriction.
- Generating Dentine Bridge at the site of pulpotomy.

Procedure: Administer local anesthesia and place rubber dam, then remove all carious tooth structure then open up the pulp chamber and remove coronal pulp tissue with excavator. Care should be taken not to damage the radicular pulp and rinse all the residual debris. Haemorrhage should be controlled using moist cotton pellet over the amputated pulp. Ca(OH)2 mixture is placed over the pulp stumps, then temporary restoration. Follow-up radiographs are taken periodically to check the root development. Once root development is complete root canal treatment is done.[18,19]
Materials used for Apexogenesis
Calcium hydroxide, MTA, Calcium enriched mixture, Biodentine, Lasers
Indication
- Traumatized or pulpally involved vital permanent tooth when the apex is incompletely formed
- No history of spontaneous pain, sensitivity on percussion, or haemorrhage
- When radiographic appearance is normal.

Contraindication
- Evidence that radicular pulp has undergone degenerative changes
- Purulent drainage and periapical radiolucency

- History of prolonged pain
- Necrotic debris in canal

Non vital tooth with open apex

Apexification: The term apexification defined as the method of treatment aimed at inducing apical repair as a hard-tissue barrier across an open apex. This technique is usually prescribed in the management of pulpless permanent tooth with an open apex or even "blunderbuss" canal.[20]

Apexification is a conventional method for treating permanent teeth with open apices using calcium hydroxide dressings. Their procedures include chemo-mechanical canal debridement to a point just short of the apex, followed by placement of biocompatible material.[21]

Goal of Apexification procedure: The goal of apexification procedure is to induce the formation of apical barrier to prevent the passage of toxins and bacteria into periapical tissues from root canal.[19,21]

Material used for Conventional Apexification: Calcium hydroxide or its combination with other materials is the most frequently indicated material of choice for apexification. Apexification with calcium hydroxide involves multiple visits lasting for a period of 6 months to 2 years, until the root apex is closed. In one case report, Calcium hydroxide and Iodoform paste, i.e. Metapex (Meta Biomed Co. Ltd, South Korea), was placed into the root canals with the help of plastic needles supplied by the manufacturer. After drying the canals with sterile paper points, obturation was performed using a material of choice, e.g. Gutta Percha with a cold lateral condensation technique. Post-obturation radiograph showed an apical calcific barrier on both root tips of affected tooth.[27]

Drawbacks of Conventional Apexification Procedure: There are number of clinical problems in apexification procedure such as:[23]

1. Lack of specific treatment time
2. Long duration of treatment
3. Uncertain apical closure
4. Walls of the root are thin and susceptible to fracture

Outcome of Apexification Procedures: In 1966 Frank classified the outcome of apexification into 4 types:[24]

Type 1: Normal apexogenesis which is rare
Type 2: Dome shaped apical closure with blunderbuss appearance remaining
Type 3: No apparent radiographic change but positive stop at apex
Type 4: Hard tissue barrier short of apex leaving thin dentinal walls subject to further trauma

Single Visit Apexification: The use of calcium hydroxide for apexification, there is a probability of canal reinfection because the crown is only filled with temporary materials and also the chance of cervical fracture. To solve these problems, a single visit apexification procedure is recommended.[25] In 1990, Morse et al. defined single visit apexification as the nonsurgical condensation by a biocompatible material into the apical end of the root canal. The goal is to establish an apical stop that would enable the root canal to be filled immediately. There is no attempt of root-end closure; rather an artificial apical stop is created.[26]

Material used for Single Visit Apexification:

Mineral Trioxide Aggregate (MTA): MTA was the first material to be used to induce apical third barrier in single visit apexification procedures.[27] MTA is a low soluble material capable of healing as well as sealing root canals. It attains a pH of 12.5 after setting, which is favourable for its antimicrobial property. In 1993, MTA was introduced by Mohmoud Taorabinejad at Loma Linda University, California, USA, followed by approval in 1998 by the US Food and Drug Administration for endodontic applications.[28]

Clinical Steps in Single Visit Apexification with MTA[19]

First Visit

- Includes chemo-mechanical preparation, disinfecting the root canals and short-term dressing of canals with Ca(OH)2 for at least a week.

Second Visit

- Access is reopened & Ca(OH)2 paste is flushed out from the canals via 0.5% sodium hypochlorite and 17% EDTA
- Canals are fully dried and MTA is mixed to a correct consistency.
- Then the thick paste of MTA is placed into the apical portion of the root canal with a Half Hollen back instrument.

- MTA is then condensed (to the correct working length with large paper points or loose fitting pluggers) such that 3-4 mm apical plug is created and is confirmed using radiograph.
- Over MTA a moist cotton pellet is placed and tooth is temporarily restored with cavit for minimum 3-4 hours.
- In the next appointment, canals are filled with thermo-plasticized GP and cement following final closure with composite restoration.

Advantages of MTA[28]

1. Reduction in treatment time
2. Immediate restoration of the tooth
3. No adverse effect on the mechanical properties of root dentin.

Disadvantage of MTA[28]

1. Difficult manipulation.
2. Placement of the material in a wide open area is a challenging task and also there is a risk of extruding this expensive material into periapical tissues.

Biodentine: Biodentine is a calcium silicate-based material in which the powder component is mainly tricalcium silicate, dicalcium silicate, calcium carbonate, zirconium dioxide and liquid is calcium chloride in aqueous solution with an admixture of polycarboxylate.

Setting reaction is hydration reaction. Hydration of tricalcium silicate produces a hydrated calcium silicate gel and calcium hydroxide. The set mix consisting of unreacted tricalcium silicate grains are surrounded by layers of calcium silicate hydrated gel, which are relatively impermeable to water. The setting time of biodentine is 12 minutes.

Advantage of biodentine is that it does not stain tooth, it has micromechanical bonding so no surface preparation is required, and its microleakage resistance is enhanced by absence of shrinkage due to resin-free formulation and the material's biocompatibility.[29]

Revascularization: Revascularization can be defined as the invagination of undifferentiated periodontal cells from the apical region in immature teeth. Tissue ingrowth is directed toward the root canal space after passive decontamination that removes, partially or totally, pulp tissue and/or its necrotic remnants. Root canal space filled with blood clots from periapical tissues, which can contribute to transporting periodontal stem cells inside the root canal space. Periodontal/periapical cells have been related to the desired outcomes of pulp revascularization (root-end development and apical closure). The stem cells from apical papilla (SCAP) are capable of differentiating into odontoblast-like cell-forming root dentin. Another type of mesenchymal cells, which are called dental pulp stem cells (DPSCs), were discovered, to have the ability to differentiate into odontoblast-like cells and form pulp/dentine-like complex. Thus, the concept of revascularization has been used to form the vital tissue inside the root canal.[30]

Clinical Steps in Revascularization[30,31]

First visit

- An assessment of the patient should be performed, including the state of tooth development, extent and history of the endodontic infection, and the restorability of the crown, before the procedure is undertaken.
- Tooth should be anesthetized, a rubber dam placed, the tooth and working field disinfected, and straight-line access made to allow the necrotic tissue in the pulp chamber to be removed after initial irrigation of the root canal. The canal should be inspected by using dental magnification to confirm or refute the presence of residual vital tissue and the level to which it may be present in the root canal.
- Two pulp revascularization techniques are found in the literature: One using calcium dihydroxide and another using a triple antibiotic paste for disinfection of pulp necrosis. Both are two-step procedure.

Second visit

- Second step takes place 2 or 3 weeks after the first one, only if the tooth is asymptomatic and if there is a visual reduction of the apical lesion
- Bleeding is induced till the level of canal orifice by passing a file beyond working length which creates irritation in the periapical tissue.
- Canal is allowed to bleed for next 15 minutes thus allowing blood clot formation this serves as a protein scaffold and permitting 3D ingrowth of the tissue.
- Over the blood clot, MTA is condensed then moist cotton pallet to allow MTA set and well-sealed with temporary restoration.

- Few days later, cotton is removed and bonded restoration is placed over set MTA.
- Patient should be recalled every 6 month for clinical and radiographic examination to ensure thickening of dentine walls and continued root formation.

Advantage of Revascularization[31]

- A number of authors in the literature in their case reports and case series have reported revascularization to be a successful procedure with resultant increase in root length and thickness of dentinal walls.
- Many have also reported re-established tooth vitality or sensitivity after revascularization procedure.
- Obturation of the canal is not required unlike in calcium hydroxide-induced apexification, thus eliminates the chance for root fracture during lateral condensation.
- Achieving continued root development (root lengthening) and strengthening of the root as a result of reinforcement of lateral dentinal walls with deposition of new dentin/hard tissue.
- Root canal revascularization via blood clotting is a relatively simple and practical approach which can be accomplished with presently available instruments and materials. Moreover, the possibility of immune rejection and contamination can be averted since the root canal system is filled with patient's own blood cells.

Disadvantage of Revascularization[32]

- The source of the revascularized tissue has not been identified. Generally, tissue engineering does not rely on blood clot formation, because the concentration and composition of cells trapped in the fibrin clot is unpredictable.
- Difficult to achieve it in fully formed permanent teeth.
- Potential clinical and biological complications like crown discoloration, development of resistant bacterial strains (due to long term use of antimicrobial agents), allergic reaction to intracanal medicament.
- Potential risk of necrosis, if tissue is reinfected.

Factor affecting outcome of Revascularization

There are some factors that affect the results of regenerative endodontic treatment. To achieve successful results of the treatment procedure, a thorough understanding of these factors is very important.

Patient age and time elapsed since tooth become non-vital - Younger the patient and lesser the duration of time since the tooth become non-vital more is the likelihood that regeneration would occur.[33]

Disinfection of the canal - The absence of bacteria is critical for successful revascularization because the new tissue will stop at the level it meets bacteria in the canal space. In necrotic cases with apical periodontitis, it must be recognized that the vital tissue might not be normal pulp tissue, although root development continues and dentine maturation occurs. In teeth with open apices and necrotic pulps, it is possible that some vital pulp tissue and Hertwig's Epithelial Root Sheath remain. When the canal is properly disinfected, the inflammatory process reverses and these tissues may proliferate.[30]

Apex diameter: A tooth with an open apex allows the migration of mesenchymal stem cells into the root canal space, and this could allow the host cell homing to form new tissue in the root canal space. An apical opening of 1.1 mm in diameter or larger is beneficial, with natural regenerative endodontic treatment occurring in approximately 18%–34% of teeth with immature roots.[34]

Conclusion: Trauma or carious exposure in immature permanent teeth can lead to pulp necrosis, infection and arrested root development. The consequences of arrested development include roots with thin dentinal walls, open apices and an increased risk of root fracture. Various treatment modalities for management such teeth include calcium hydroxide apexification, MTA apexification, and endodontic surgeries. Apexification using calcium hydroxide although shown some success but it is less popular nowadays due to limitations like multiple visits, formation of porous barrier. Mineral trioxide aggregate (MTA) apexification is a commonly used treatment option for management of immature non-vital teeth. However, it does not strengthen the remaining root structure and the tooth remains fracture prone and non-vital. Regenerative endodontic procedures are designed to replace damaged structures, including dentin and root structures, as well as cells of the pulp-dentin complex. Thickening of root dentin and re-established tooth vitality are the significant outcome with revascularization which cannot be achieved with apexification procedure. Regenerative endodontics has brought a revolutionizing tissue engineering concept in the field of endodontics for the treatment of immature permanent teeth. It's been considered as a "paradigm shift" in the treatment modalities, as it fosters continued root maturation.

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