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Management of Non-Vital Immature Teeth-A Review

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Abstract
The major challenges associated with endodontic treatment of teeth with open apices are achieving adequate access to the wide canal, complete debridement, canal disinfection and optimal sealing of the root canal system. In the absence of a natural apical constriction, it is imperative to create an apical barrier and allow three-dimensional adaptation of obturating material within the root canal system.
The aim of this review is to discuss the aetiology, anatomic features, diagnosis and management of teeth with immature open root apices. The contemporary concepts of management of immature non-vital teeth include either apexification or regenerative endodontics. Single visit apexification procedure aims at formation of an apical barrier using bioceramic materials like mineral trioxide aggregate (MTA) and Biodentine against which the obturating material can be condensed. Regenerative endodontics is a biologically based endodontic therapy that aims to promote normal physiological development in immature permanent teeth with pulpal necrosis.
Keywords- *Nonvital teeth, Open apex, Immature teeth, Apexification, Regenerative Endodontics*

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I. Introduction

One of the essential 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. Immature nonvital teeth is one such condition. Such teeth with incomplete rhizogenesis or blunderbuss canals pose a special challenge to three-dimensional seal because of large open apices, divergent root walls and thin dentinal walls that are susceptible to fracture and frequent periapical lesions. [1]

The presence of healthy pulp is essential for continued root development and apical closure, which may take up to 3 years after eruption of the tooth.[6] Dental caries and trauma are the most common challenges to the integrity of a tooth as it matures. When the pulp undergoes inflammatory changes or becomes nonvital due to these challenges, the dentin formation and root growth ceases.[2]

Clinical success of an endodontic treatment is related to accurate diagnosis and full understanding of the biological processes to be facilitated by the treatment.[3] Patients who present with non-vital immature apical formation, require a special tailored treatment plan, often times requiring more than one year to complete, depending on the apical immaturity, stage of root development, age of the patient, pulpal status, periodontal status, discoloration, periapical status, compliance of the treatment protocol, restorability and type of trauma.[4]
This review article highlights wide variety of treatment option for managing teeth with wide open apices in non-vital teeth such as apexification procedures as well as revascularization and regeneration.

II. Etiology Of Open Apices:

i. Developmental anomalies

Dens invaginatus is a developmental abnormality of teeth resulting from an invagination of the enamel organ. According to Oehlers classification, in type 3 the invagination penetrates through the root to open in apical region resulting in open apex.[5] Regional Odontodysplasia is an uncommon, developmental anomaly of the dental hard tissues that affects ectodermal and mesodermal dental components. The pulp chambers and canals are enlarged, and the roots appear short and stubby with open apices.[6]

ii. Pulp necrosis

The open apex typically occurs when the pulp undergoes necrosis as a result of caries or trauma, before root growth and development are complete. Caries is a multifactorial disease involving bacteria and their by-products, which can penetrate the pulp causing inflammation and fibrosis of pulp tissue. Long-term inflammation or repeated insults reduce the pulp's ability to repair itself and eventually necrosis will spread to the entire canal.[7]

Dental trauma is another common aetiological factor, with an incidence of 33% of trauma to cause pulp necrosis in permanent teeth in adults. Trauma can completely or partially sever the apical blood supply of the traumatised tooth via displacement or crushing the surrounding blood vessels.[8] If the apical blood supply cannot be re-established or is inadequate, pulp necrosis will occur.[9] Trauma between ages 8 and 10 years is of significance as root development of permanent teeth is often incomplete and pulp necrosis prevents continued root development. Pulp necrosis varies with the type of dental trauma as follows: enamel infraction (0%), concussion(3%), extrusion (26%), lateral luxation (58%), avulsion (92%), intrusion (94%).[10]

iii. Resorption

Extensive apical resorption due to orthodontic treatment, or apical replacement root resorption or Orthodontically induced inflammatory root resorption (OIIRR).

Pressure due to excessive forces of orthodontic tooth movement compresses the PDL, damages the cementum and provides the continuous stimulus for the resorbing cells. It was found that 5 to 10 years after completion of the treatment, 42.3% of the maxillary central incisors, 38.5% of the maxillary lateral incisors and 17.4% of the mandibular incisors had undergone apical resorption.[11] Inflammation in conjunction with injury to the root's protective covering is the major local cause of inflammatory root resorption. Infection stimulates an inflammatory response, resulting in resorption of a susceptible (unprotected) root surface.[12]

Resorption due to Cyst and Tumors- The ameloblastomas proved to have a root resorptive potential far greater than the cystic lesions considered. It is suggested that the capacity of the dentigerous cyst for root resorption may be the result of its origin from the dental follicle, which is associated with resorption of the roots of primary teeth during normal tooth succession.[13] It is a commonly accepted theory that a malignant tumor does not cause root resorption because its invasion is too rapid.[14]

iv. Loss of apical constriction

Open apex may also be iatrogenic, that is induced by the operator or clinician as the result of over-instrumentation during canal preparation. Sometimes instrumentation with larger file beyond the anatomic apex causes widening of the apical foramen.[15]

v. Root end resection during periradicular surgery.

Microsurgical principles in apical surgery include production of a small osteotomy for access to the root end, resection of the root end perpendicular to the long axis of the root, inspection of the resected root face for microstructures, and preparation of a root-end microcavity. This resected root face and root end microcavity is larger than the usual size of closed open apex.[16]

III. Diagnosis

The accurate diagnosis of teeth with open apex is crucial in the management and long-term survival of the affected teeth. Diagnostic procedures should follow a consistent order that includes comprehensive medical and dental history, extraoral and intraoral clinical examination including hard tissue examination for any traumatic injuries of teeth, pulpal status, periodontal status examination to arrive at the final diagnosis when required.

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.[17,18] It may be difficult to differentiate between this finding and a pathologic radiolucency resulting from a necrotic pulp. Comparison with the peri-apex of the contra lateral tooth may be helpful.

Open apices may have two configurations:

Non blunderbuss canals where the walls of the canal may be parallel to slightly convergent as the canal exits the root. Hence the apex, therefore can be Broad (cylinder shaped) or Tapered (convergent).

Blunderbuss canals where the walls of the canal are divergent and flaring, more especially in the buccolingual direction - The apex is funnel shaped and typically wider than the coronal aspect of the canal.

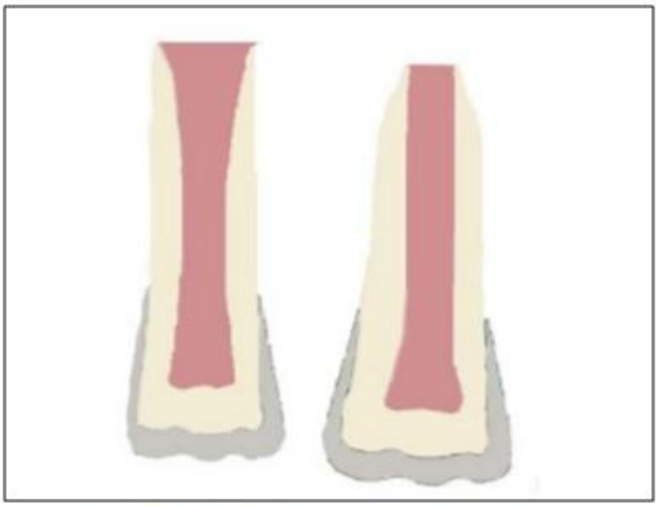

Figure.1 Blunderbuss Non blunderbuss

IV. Treatment Modalities And Guidelines For Teeth With An Incompletely Formed Apex (Open Apex) And A Necrotic Pulp

A customized cone (blunt end, rolled cone), a short fill technique, periapical surgery (with or without a retro grade seal), were the earlier techniques used for the management of the open apex in non-vital teeth. However, a number of authors have described that the use of custom fitted gutta-percha cones is not advisable as the apical portion of the root is frequently wider than the coronal portion, making proper condensation of the gutta-percha impossible. The associated limitations of these procedures diverted interest towards therapies that aimed to induce a calcified barrier in a root with open apex or promote continued root development of an incompletely formed root in teeth with necrotic pulps. Therefore, now the interventions used for immature permanent teeth with necrotic pulps can be broadly categorized into multi- step apexification techniques, single- step apexification techniques and regenerative endodontic procedures.

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 incompletely formed root in teeth with necrotic pulps.[19]

Conventional multi-visit apexification:

Disinfection of the Canal: After access to the canals is prepared, a file is placed to the estimated length. When the length has been confirmed radiographically, very light filing (because of the thin dentinal walls) is performed with copious irrigation with 0.5% NaOCl. A lower strength of NaOCl is used because of the increased danger of placing the agent through the apex in immature teeth. The canal is dried with paper points and a creamy mix of calcium hydroxide [$Ca(OH)_2$] is placed into the canal with a lentulo spiral. Additional disinfecting action of $Ca(OH)_2$ is effective after its application for at least 1 week, so the continuation of treatment can take place any time after 1 week. Further treatment should not be delayed more than 1 month, since the $Ca(OH)_2$ could be washed out by tissue fluids through the open apex, leaving the canal susceptible to reinfection.[20]

Hard-Tissue Apical Barrier using $Ca(OH)_2$: Formation of the hard-tissue barrier at the apex requires a bacterial free environment. $Ca(OH)_2$ is used for this procedure. Pure $Ca(OH)_2$ powder is mixed with sterile saline to a thick paste consistency which is packed against the apical soft tissue with a plugger to initiate hard-tissue formation.[21] This step is followed by backfilling with $Ca(OH)_2$ to completely fill the canal. When a hard-tissue barrier is indicated radiographically and can be probed with an instrument, the canal is ready for filling.

$Ca(OH)_2$ has been the material of choice for apexification procedures for many years and has shown success rates of up to 90%. However, achievement of complete apical seal in teeth with open apices with its use is still debatable due to the formation of porous callus bridge with “Swiss cheese” appearance. The apical barrier formation can take long time and is dependent on the size of the lesion. Long-term $Ca(OH)_2$ application may also alter the mechanical properties of dentin leading to increased risk of root fracture after treatment. Therefore, short-term use of $Ca(OH)_2$ followed by MTA apical plug formation may improve long-term prognosis in apexification procedures.[22]

Single visit apexification

Apexification using MTA is an alternative treatment modality in immature pulpless teeth. MTA offers a barrier at the end of the root canal (apical plug) in teeth with necrotic pulps and open apices that permits vertical condensation of warm guttapercha in the remainder of the canal.

Technique: A disinfection protocol explained in multivisit management is followed and then MTA is used to create a hard-tissue barrier. Calcium sulphate, PRP or PFR is pushed through the apex to provide a resorbable extra radicular barrier against which MTA is packed. The MTA is mixed and placed into the apical 3 to 4 mm of the canal in a manner similar to the placement of $Ca(OH)_2$. A wet cotton pellet should be placed against the MTA and left for at least 6 hours. After the MTA is fully set, the entire canal is then filled with a root filling material. The cervical canal is then reinforced with composite resin to below the marginal bone level.

A variety of synthetic and autogenous materials such as calcium sulfate, resorbable collagen, hydroxyapatite, dentin chips and collagen membranes have been tried as an internal matrix. Autogenous materials are usually preferred over synthetic materials as there is minimal possibility of allergic reactions with them, and they aid in wound healing, unlike their synthetic counterparts. Vivek Sharma et al. stated that combination of PRF as a matrix and MTA as an apical barrier is a good option for creating artificial root-end barrier.[23] A prospective clinical study by Sarris S et al. of open apex teeth obturated with MTA in one appointment demonstrated healing rates that ranged from 81–100%, with 94.1% clinical success and 76.5% radiographical success when MTA was used as an apical plug in permanent incisors.[24]

Regenerative endodontics

In the year 2001, a new treatment option termed ‘revascularization’ was introduced in endodontics to manage an immature permanent tooth with necrotic pulp. The term ‘regenerative endodontics ’ was adopted by the American Association of Endodontists in 2007, based on a tissue engineering concept. Regenerative endodontics applies the concept of the triad of tissue engineering, stem cells, biomimetic scaffold, and bioactive growth factors in the canal space to regenerate the pulp tissue damaged by infection , trauma or developmental anomalies.[25]

The Clinical procedure for a Regenerative Procedure are as follow:[26]
First appointment:

1. Oral prophylaxis should be done. 2. After administering local anaesthesia access cavity is prepared. Loose and necrotic pulp tissues is removed from canal. 3. Mechanical instrumentation of the root canal walls should be avoided. 4. Copious, gentle irrigation with 20ml NaOCl using an irrigation system that minimizes the possibility of extrusion of irrigants into the periapical space. Lower concentrations of NaOCl are advised [1.5% NaOCl according to AAE & 1.5% to 3% according to ESE (20mL/canal, 5 min) irrigation time may be increased to 10 seconds]. Irrigate the canal with sterile physiological saline (5mL) to minimize the cytotoxic effects of sodium hypochlorite on vital tissues. 5. Dry canals with paper points. 6. Irrigate with EDTA (20 mL/canal, 5 min), with irrigating needle positioned about 1 mm from root end, to minimize cytotoxicity to stem cells in the apical tissues. 7. Place $Ca(OH)_2$ or low concentration of triple antibiotic paste into the root canal. If the triple antibiotic paste is used: a) pulp chamber should be sealed with a dentin bonding agent [to minimize risk of staining] and b) mix 1:1:1 ciprofloxacin: metronidazole: minocycline to a final concentration of 0.1-1.0 mg/ml. Triple antibiotic paste has been associated with tooth discoloration. Double antibiotic paste without minocycline paste or substitution of minocycline for other antibiotic (e.g., clindamycin; amoxicillin; cefaclor) is another possible alternative as root canal disinfectant. Deliver into canal system via syringe. 8. Seal with 3-4mm of a temporary restorative material such as Cavit™, IRM™, glass- ionomer or another temporary material.

Second Appointment (1-4 weeks after 1st visit)

1. Assess response to initial treatment. If there are signs/symptoms of persistent infection, consider additional treatment time with antimicrobial, or alternative antimicrobial. 2. Anesthesia with 3% mepivacaine without vasoconstrictor, rubber dam isolation, disinfection of operating field. Remove temporary seal. 3. Irrigate with 17% EDTA (20mL, 5 min), use of side-vented needle and place 2 mm above vital tissue. Irrigate with sterile physiological saline (5mL) to reduce adverse effects of irrigants on target cells. Remove excess liquid with paper points. 4. Induce bleeding into canal system by over-instrumenting (endo file, endo explorer). An alternative to creating of a blood clot is the use of platelet-rich plasma (PRP), platelet rich fibrin (PRF) or autologous fibrin matrix (AFM). 5. Allow the canal to fill with blood until 2 mm below the gingival margin that allows for 3-4 mm of restorative material & to wait for blood clot formation for 15 min. 6. Place a resorbable matrix such as CollaPlug™, Collacote™, CollaTape™ over the blood clot to a diameter larger than the coronal

part of the root canal and a height of 2–3 mm, allow the matrix to soak with liquid to avoid formation of a hollow space. 7. Place a hydraulic calcium silicate based cement on top of the collagen matrix in a thin homogeneous layer of about 2 mm underneath the cement–enamel junction. 8. Apply a flowable, light-curable glass–ionomer (3 to 4 mm layer). 9. Seal with adhesive restoration.

Follow-up

Follow-ups should be performed after 6, 12 and 18 and 24 months, after that annually for 5 years. A 3 month follow-up is recommended in cases of longstanding infection, difficult elimination of signs of inflammation (e.g. second application of intracanal dressing), the presence of inflammatory root resorption or where alternative treatment (e.g. autotransplantation) has to be considered.

Treatment choice selection can be done based on Cvek's classification of development.[27]

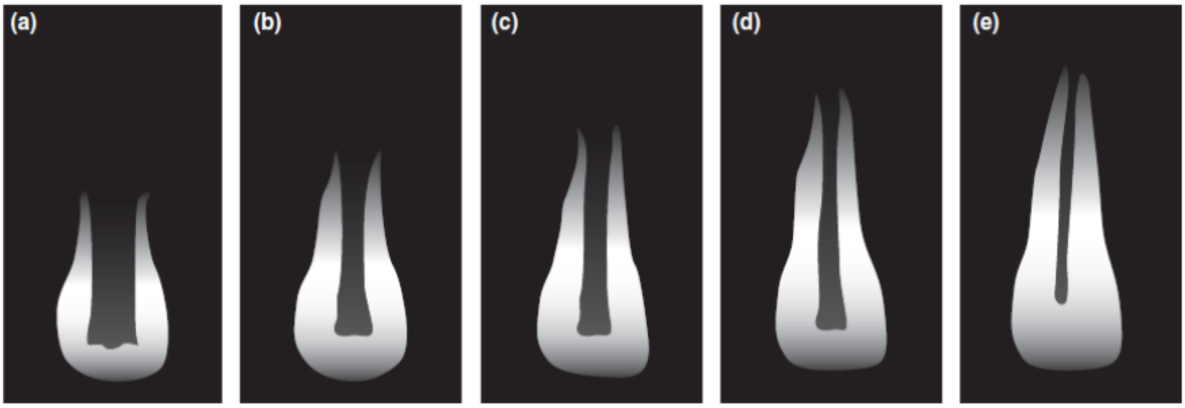

Figure 1. Figure 2. Examples of teeth with respect to the stage of root development. a, b, c, d and e, stages 1, 2, 3, 4 and 5, respectively;1–4 = immature teeth, 5 = mature teeth.

V. Discussion

- It is recommend that immature permanent teeth with necrotic pulp at the stage 1 (less than1/2 of root formation with open apex), stage 2 (1/2 root formation with open apex) and stage 3 (2/3 of root development with open apex) are suitable for Regenerative Endodontic Treatment (RET) because of the short root, thin canal walls and wide-open apex as apexification has no potential for root maturation (thickening of the canal walls and/or continued root development).
- Immature permanent teeth at stage 4 (nearly completed root formation with open apex) can be managed with either RET or an apical MTA plug and root canal filling because the canal walls have enough thickness and strength.
- Immature permanent teeth with a necrotic pulp requiring post for adequate coronal restoration are not suitable for RET and better treated with apical MTA plug and root canal filling.
- In immature posterior permanent teeth with pulp necrosis and apical pathosis, MTA apexification is the treatment of choice. Though it is difficult to work in posterior teeth because of poor visibility, less accessibility due to the narrow canal diameter, and reduced mouth opening when compared to the anterior teeth. However, following the described technique can overcome the endodontic challenges in achieving a proper apical plug in posterior teeth.
- The treatment of immature permanent teeth after failed RET includes, regenerative endodontic retreatment or apexification.
- Many studies have shown that discolouration is a significant aesthetic problem following regenerative endodontic treatment. This is of particular concern for traumatized anterior teeth as appearance and pleasing aesthetics are patient-centred outcomes. Bleaching of discoloured teeth is generally effective to improve the aesthetic outcome. To minimize the risk of discolouration, Biodentine instead of MTA can be used.[28]
- It was found that revascularization procedures can be implemented in any age; however, younger age groups are better candidates for revascularization procedures than older age groups.[29]

Regenerative endodontic procedures are highly successful. When compared with MTA apexification, studies have reported similar success and survival rates for regenerative endodontics, in the range of 90-100%. Although clinical trials with longer follow-ups are limited, they have reported favorable outcomes. In addition to the resolution of clinical signs and symptoms and periapical healing, regenerative endodontic procedures facilitate an increase in root length and width which is very significant compared to apexification procedures. This substantial increase in root development is a crucial benefit as it has a positive effect on the longevity of the immature tooth. These advantages are unparalleled with any other endodontic treatment.

VI. Conclusion

Management strategies for treating immature, permanent teeth with necrotic and infected pulps and open apices are changing from the apexification procedure with calcium hydroxide to the MTA apical barrier technique and regenerative endodontic procedures. The major reason lies in regenerative procedures allowing for continued root development, while apexification does not. Where insufficient root length and width is observed in an infected, immature permanent tooth, it would be advantageous to begin regenerative endodontic procedures in an attempt to promote continued root development. The patient should be warned that it is possible that continued root development may not occur, in which case, apexification treatment should be commenced, preferably using MTA.

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