ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at: www.ijdsir.com
Volume – 6, Issue – 5, September - 2023, Page No. : 173 - 181

Management of open apex in Endodontics: A review

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Citation of this Article: Dr. Rashmi Misra, Dr. Sumita Bhagwat, Dr. Hitesh Pawar, Dr. Aashaka Vaishnav, Dr. Omkar Bhosale, Dr. Nidhi Basmatkar, "Management of open apex in Endodontics: A review", IJDSIR- September - 2023, Volume – 6, Issue - 5, P. No. 173 – 181.

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Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Immature tooth with necrosed pulp and periapical pathology is a major challenge and requires a well-organized treatment plan. Closure of the root apex is required to achieve success in such cases. Many materials have been introduced for apexification each having their own advantages and disadvantages. There is a plethora of research going on in dentistry with the focus not only on the treatment rationale but also on the materials. Its overview's apexification using Bio dentin, MTA and calcium hydroxide as well as different approaches for apex-genesis.

Keywords: Immature tooth, Bio dentin, MTA.

Introduction

The absence of sufficient root development to give a conical taper to the canal is referred to as an open apex. The structure of the apical foramen changes with age as root development begins after enamel creation is

complete.[1] The cells of the inner and outer enamel epithelia meet at the cervical loop, begin to proliferate, and create the Hertwig epithelial sheath. This sheath determines the size and shape of the tooth's root(s). Apical root closure occurs about 2-3 years after tooth eruption. However, there are times when the process of apex closure in permanent teeth is disrupted, resulting in open apices. It might be blunderbuss (funnel shaped) and divergent and flaring, or it can be non-blunderbuss (cylindrical shape) and parallel. [2][3]

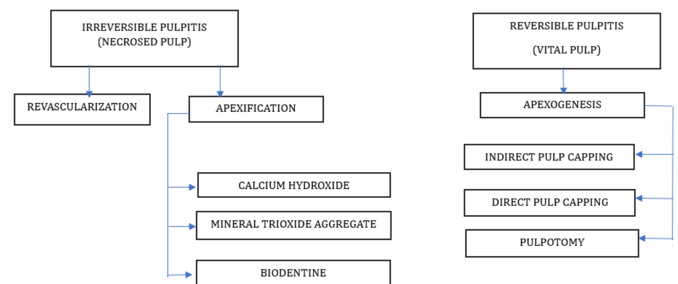
Etiology

The major irritants of the pulpal tissue include various bacteria, trauma, dental procedures generating thermal stimulation and chemical agent. Irritation of pulp tissue results in major changes in pulp microcirculation that can lead to pulp necrosis and arrest root formation. [4] Any kind of traumatic dental injury (eg: Ellis & Davey class III, IV fractures) [5], presence of periapical lesion foraminal and Para- foraminal resorption, poor control on working length and subsequent enlargement with both hand and rotary files, root end resection surgeries as well as peri radicular surgeries can lead to open apices.[6] Immature permanent tooth heals well after traumatic pulp exposure; henceforth conservative approach should be used firstly to preserve the vitality.

Diagnosis

Primary diagnosis of pulp vitality involves a thorough examination and dental history, checking for swelling, crown discoloration, caries, or mobility.[4] Vitality tests, such as electric and thermal tests, are limited in cases of traumatic injuries and open apices. Laser doppler flowmetry (LDF) and scanning laser doppler flowmetry (SLDF) are useful tools for measuring blood flow patterns.[7] Pulse oximeters are reliable and non-invasive diagnostic devices relying on oxygen saturation levels of arterial blood.[8] Radiographic examinations, such as intra-oral periapical radiographs and bitewing radiographs, help diagnose tissue conditions, caries progression, and root development stages. Cone beam computed tomography is more accurate than 2-D conventional radiographic techniques.[9] Early detection and detailed history, examination, and diagnostic tests can lead to a reliable clinical diagnosis of pulp vitality in most patients.[10]

Treatment



Apexogenesis

Apex genesis is defined as a vital pulp therapy procedure to encourage continued physiological development and formation of the root end.

Aims of apex genesis:

1. To allow continued development of the root length.
2. To maintain pulp vitality so as to allow continuous deposition of dentine.[11]
3. To promote the root end closure henceforth creating a natural apical constriction.
4. Generating a dentine bridge at the site of coronal pulpal exposure (pulpotomy) [12]

Indirect Pulp Capping

Indirect pulp capping is defined as procedure where in the deepest layer of the remaining affected carious dentine is covered with a layer of biocompatible material in order to prevent pulpal exposure and further trauma to the pulp.[figure 1]

Indications:

1. Permanent teeth.
2. Normal response to pulp vitality tests.

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3. No symptoms of pulpitis or diagnosis with irreversible pulpitis
4. Deep carious lesion radiographically with no periapical pathology.

Technique

It is a 2-step process involving removal of all the carious dentine and infected dentine. A thin deepest layer of affected dentine is left behind and is covered with a thick layer of biocompatible material like calcium hydroxide or mineral trioxide aggregate and an overlying interim restorative material is given. The objective is to decrease the amount of bacteria by acquiring a tight seal on the remaining caries from the biofilm of the oral cavity. After 3-8 weeks, if the patient presents asymptomatic, the hard layer of affected dentine is removed and a permanent restoration is placed.[4] Infected dentine removal causes remineralization, odontoblasts and reactionary dentine formation [13]. CAOH acts as an effective indirect pulp capping agent.[14]

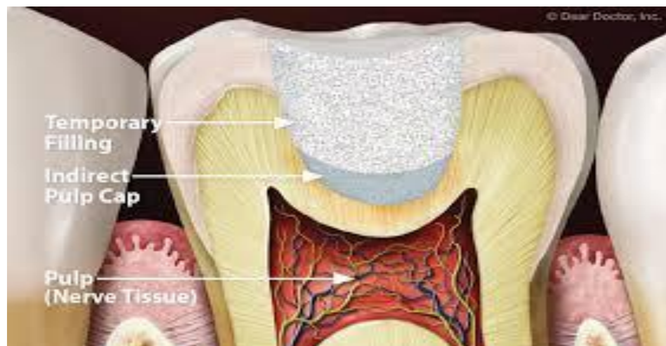

Figure 1: Indirect pulp capping with a pulp capping agent and a temporary restoration

Direct Pulp Capping: Direct pulp capping is defined as a procedure in which exposed vital pulp is covered with a protective dressing or base placed directly over the site of exposure in an attempt to preserve pulpal vitality. [figure:2]

Indications

1. Asymptomatic (no spontaneous pain, normal response to pulp vitality tests)
2. The pulpal exposure should be less than 0.5mm in diameter.
3. Haemorrhage from the exposure site should be controlled within 10 minutes.
4. The exposure occurred has to be clean and uncontaminated.
5. The pulpal exposure should be atraumatic and there should be no evidence of blood aspiration in the dentine. [12]

Technique

After rubber dam isolation, excavation of undermining enamel and carious dentine is done. Control pulpal bleeding with 3-6% sodium hypochlorite or 2% chlorhexidine.[11] If haemostasis is achieved within 10 minutes, pinpoint exposure is sealed with calcium hydroxide, and a permanent restoration is placed to prevent bacteria seepage.[4] MTA can be used as a direct pulp capping agent. The MTA is mixed and placed over the exposed pulp with 1.5mm thickness for an efficient seal. A moist cotton pellet is applied and an interim restoration is placed.[11] Signs and symptoms are assessed within 1-10days, cotton is removed, and an interim and final restoration is placed for a seal. These induce the release of growth factor proteins and bio active molecules from dentin matrix.[15] Reparative dentin is formed from odontoblast-like cells and not from primary odontoblasts as in case of indirect pulp capping [14].

Figure 2: A-caries progression involving distal pulp horn. B-excavation of caries and a pin point exposure with haemostasis achieved. C-direct pulp capping done

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with a suitable pulp capping agent. D-permanent restoration done to reduce the leakage.

Pulpotomy

Pulpotomy is defined as procedure in which a portion of the exposed coronal vital pulp is surgically removed as a means of preserving the vitality and function of the remaining radicular portion. [figure-3]

Indications

1. Carious or mechanical pulpal exposure more than 1mm in diameter.
2. Traumatic exposures of longer duration where coronal pulp is inflamed.
3. In permanent teeth with incomplete root formation.

Technique

The inflamed coronal portion of the pulp is removed with the help of sharp, sterile spoon excavator or a periodontal curette under anaesthesia in rubber dam isolation. Haemostasis can be achieved by 6% sodium hypochlorite, pressure application with moist cotton pellet, electrosurgery or with lasers. Blood clot should be removed. Once haemostasis is achieved, calcium hydroxide, MTA or biodentine with bacterial tight seal and coronal restoration with interim restorative material as base is completed. [11,12] Dentine bridge formation following apex genesis is a reparative process of dentine-pulp complex. Thus, the continued root formation is a normal physiological process.

Figure 3: A-Excavation of caries. B-Removal of the coronal pulp. C-achieving haemostasis. D-A suitable vital pulp medicament is placed followed by permanent restoration.

Vital Pulp Medicaments

A) Calcium hydroxide

Calcium hydroxide has higher PH which causes liquefaction necrosis and coagulation necrosis in the first week. The dentine matrix becomes visible in 30 days, and the dentinal barrier thickens after collagen layer secretion, triggering dentine deposition.[1]

Drawbacks: The formation of coronal hard tissue is prolonged (2-3 months), the calcium hydroxide medicament's dissolution may lead to microleakage. Bacterial contamination can also take place due to tunnel defects. The antimicrobial effects is limited to superficial layers of pulp and hence only in minimum pulpal inflammation, it is successful.[16]

B) Mineral Trioxide Aggregate (MTA)

MTA placement results in a higher pH for 8 weeks, leading to coagulation necrosis next to vital pulp in one week. A hard tissue barrier is formed in 2 weeks.[12] MTA forms a tight seal with dentin walls due to a chemical bond, creating a hydroxyapatite layer. This seal prevents bacterial penetration, enhances biocompatibility, sealing ability, and dentinogenic activity, potentially contributing to the material's successful performance.[17]

Drawbacks: Major drawback of MTA is its discolouration potential and long setting time. It has higher material cost and difficult handling properties.

Apexification

Apexification is a method of inducing apical closure through formation of mineralized tissue in the apical region of a non-vital tooth with an incompletely formed apex (open apex).

Working Length Determination

There are various methods to determine the working length in an open apex. EL Ayuoti proposed a tactile sensation method to determine the working length.[11].

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The use of electronic apex locators is more frequent. Sterile paper points can also be used but only in straight canals.[18][refer fig:4]

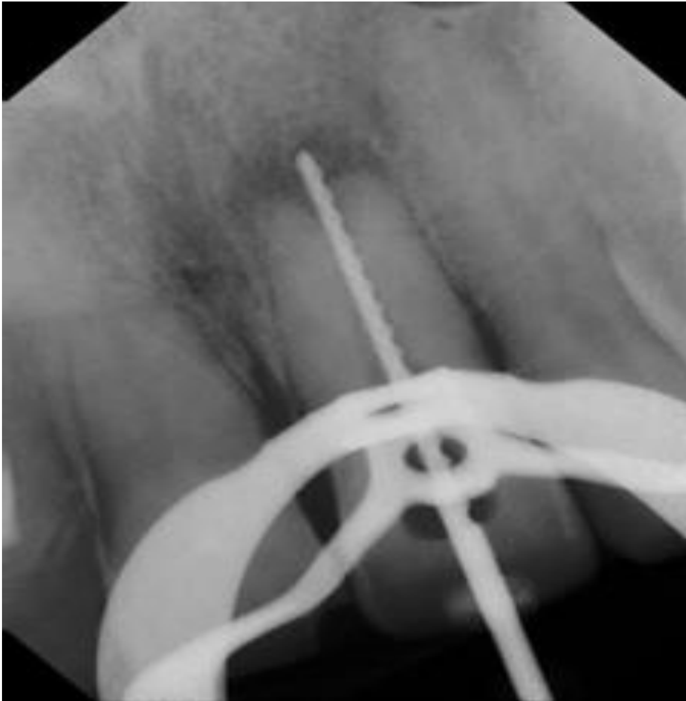

Figure 4: working length determination by using a k-file

Calcium Hydroxide (Multiple Visit Apexification):

Frank introduced the Ca(OH)2 apexification method in 1966[12], which involves filing with 0.5% NaOCl to remove necrotic pulp tissue.[9] Calcium hydroxide is added to dry the canal. It's recommended to replace calcium hydroxide after 5-6 appointments every 2-3 months.[19] This method doesn't support root development but creates a porous callus bridge (Swiss-cheese) appearance [9], closing open apices in teeth. Long term calcium hydroxide dressings increase the chances of root fracture. [fig:5}

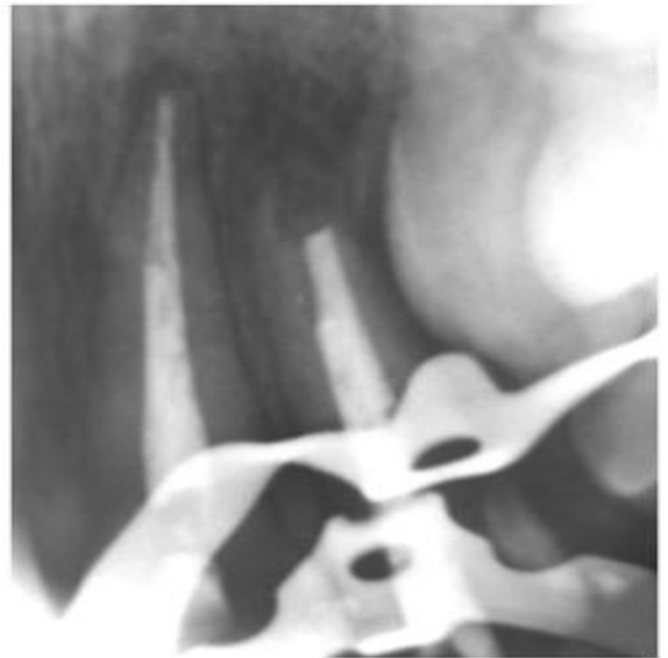

Figure 5: Apexification by calcium hydroxide

Single Step Apexification

The non-surgical condensation of a biocompatible material into the apical end of the root canal is defined as single step apexification. [fig:6] MTA can be used as an apical plug-in root canal obturation. MTA should be mixed to a thick creamy consistency, placed 1-1.5 mm short of working length, and condensed with minimal pressure until approximately 5mm is deposited apically. MTA, introduced by Torabinejad in 1993,[20] is a material used for apexification. It consists of tricalcium silicate, dicalcium silicate, calcium sulphate, tricalcium aluminate, tetracalcium-aluminoferrite, bismuth oxide, and distilled water. When placed against periodontal tissues, MTA causes a narrow zone of coagulation necrosis.[15] It modulates cytokine production and stimulates hard tissue cell differentiation, creating hydroxyapatite on the MTA surface and creating a biological seal between the root canal and MTA.[11] Moist cotton is placed for at least 6 hours, and the entire canal filled is with thermos-plasticized gutter percha or root filling [12]. Excessive lateral condensing forces should be avoided.[9] Calcium hydroxide medication

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followed by an apical plug of MTA may increase marginal adaptation and long-term prognosis for teeth with necrotic pulps and open apices as the acidic environment due to inflammation can cause porosity in set MTA and affect its sealing ability.[11] [ref: fig 7] Bio-dentine is a calcium silicate-based material which has higher biocompatibility than MTA. It was commercially available from 2009. [21] The final setting time is 45 minutes. The powder contains tricalcium silicate, dicalcium silicate, calcium carbonate, zirconium oxide, iron oxide and opacifiers. Liquid has Calcium chloride in aqueous solution with admixture of polycarboxylate.[22] The compressive strength, elasticity modulus and microhardness are comparable with that of natural dentine. The material is stable, less soluble, non-resorbable, hydrophilic, easy to prepare and place, needs much less time for setting, produces a tighter seal and has greater radiopacity. Bio dentine has a shorter setting time of 12 minutes as compared to that of MTA which is 2 hours 45 minutes. The manipulation and technique are same as that of MTA. As setting time is less, moist cotton need not to be placed after the placement of apical plug. The marginal sealing ability of calcium silicate-based materials is attributed to its ability to produce surface apatite crystals when in contact with the phosphates available in tissue fluids. The crystalline precipitates are formed through interaction of calcium and hydroxyl ions released from set material with phosphates. Dentine may uptake several elements released from bioactive materials which causes chemical and structural modification in dentine.[23] Hence Bio dentine has a distinct advantage over its closest alternatives in treatment of teeth with open apex.

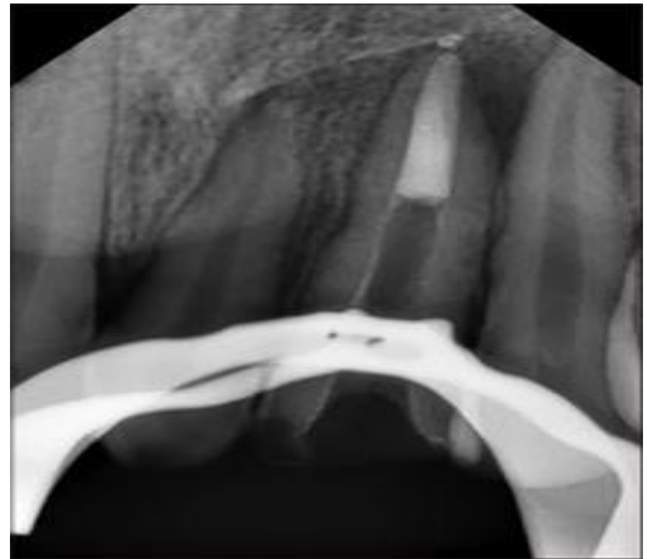

Figure 6: Single step apexification with MTA

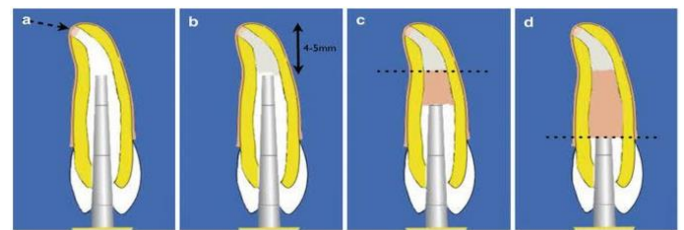

Figure 7: a: achieving an apical seal at the open apex. b: the apical plug should be condensed to form 4-5mm. c: backfill technique used for gutta-percha obturation over the plug. d: filling the whole canal till the cemento-enamel junticon.

Revascularization

This procedure is to revive tissues in the pulp space and continue root formation in immature teeth with non-vital pulp. The goal is to provide appropriate environment for regeneration of pulp i.e., absence of bacteria and necrotic pulp tissue, presence of a scaffold and a tight coronal seal. [24] [refer: fig-8]

indications

-The tooth must be non-vital.

-The tooth should not be suitable for Apexo genesis, Apexification, partial pulpotomy of root canal treatment.

-The tooth should be permanent with immature open apex with a diameter 1mm or wider.

-Patient should be adolescent (7-16yrs).

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The tooth is anesthetized and isolated under a rubber dam, irrigated with 2.5% sodium hypochlorite.[19] The canal is dried, and triple antibiotic paste (TAP) is placed. After a month, TAP is removed, the canal is irrigated with 2.5% sodium hypochlorite and 17% EDTA.[11] EDTA conditioning the dentin surface enhances pulp stem cell adherence and differentiation. A file is passed, and bleeding is induced, then MTA is placed over the clot, and moist cotton is placed.[22] Temporary restoration is given, and the patient is recalled after 24 hours, wherein a bonded restoration is placed.[19] Calcium hydroxide paste can be used as an intracanal medicament instead of triple antibiotic paste to disinfect the canal before bleeding. However, it may not be suitable if vital pulp tissue remains, as it may create calcified tissue and damage the Hertwig's epithelial root sheath, preventing odontoblasts from forming.[11]

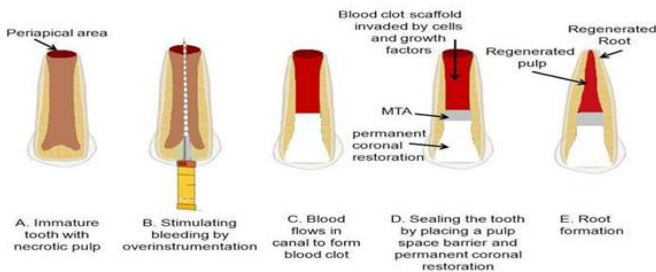

Figure 8

Drawbacks of regeneration are discolouration, long treatment period, poor root development, insufficient bleeding and root canal calcification.

Conclusion

The management of immature permanent teeth with non-vital pulp is a complex and demanding procedure that requires clinicians to employ various techniques and materials. These techniques include calcium hydroxide multi-visit apexification, apical barrier techniques with tricalcium-silicate materials, and revascularization endodontic procedures. Treatment outcomes usually depend on apex diameter, dentin thickness, disinfection, canal shape, periapical tissue response, and treatment duration. Each of these treatment alternatives has its own advantages and considerations.

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