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Case Report

Apexification: Evolution of Materials and a Case Report

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Abstract

The completion of root development and closure of the apex occurs up to 3 years after eruption of the tooth. Traumatic injuries to young permanent teeth often result in pulpal inflammation or necrosis and subsequent incomplete development of dentinal wall and root apices resulting in open apex. The golden rule in the practice of endodontics is to debride and obturate the canals as efficiently and three dimensionally as possible in an amount of time and appointments that are reasonable to the patient. Apexification of immature permanent tooth is necessary for complete obturation of root canal space to prevent reinfection. Various materials such as amalgam, glass ionomer cement, composite, mineral trioxide aggregate, calcium hydroxide powder, freeze dried bone/dentin, resorbable ceramic, tricalcium phosphate, dentinal shavings has been used for apexification. Since the past decade significant evolution has taken place in the field of endodontic materials. Bioceramics has made endodontic treatment more efficient due to their osteoconductive properties.

Keywords: *Apexification; MTA; Open Apex; Bioceramics*

Abbreviations

$Ca(OH)_2$: Calcium Hydroxide; CMCP: Camphorated Parachlorophenol; MTA: Mineral Trioxide Aggregate; NaOCl: Sodium Hypochlorite

Introduction

The American Association of Endodontists has defined apexification 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].

Such teeth with incomplete root formation, is a special challenge to all dentists because of the large open apices, divergent root walls and thin dentinal walls that are susceptible to fracture and frequent periapical lesions [2].

Causes of open apex

Incomplete development: The major cause for open apex is pulp necrosis due to trauma/caries during tooth formation [2].

The completion of root development and closure of the apex occurs up to 3 years after the eruption of the tooth. Root development begins when enamel and dentin formation has reached the future cementoenamel junction. Hertwig's epithelial root sheath is responsible for determining the shape of the root and apex. The epithelial diaphragm surrounds the apical opening to the pulp and eventually becomes the apical foramen. An open apex is found in the developing roots of immature teeth until apical closure occurs approximately 3 years after eruption [3]. Traumatic injuries to young permanent teeth affect about 30% of children. These injuries often result in pulpal inflammation or necrosis and subsequent incomplete development of dentinal wall and root apices resulting in an open apex. The golden rule in the practice of endodontics is to debride and obturate the canals as efficiently and three dimensionally as possible in an amount of time and appointments that are reasonable to the patient [4,5].

An open apex can also occasionally form in a mature apex as a result of extensive apical resorption due to orthodontic treatment, periapical pathosis or trauma, root end resection during peri-radicular surgery, over-instrumentation [2].

Challenges of immature teeth/open apex

Management of immature teeth with necrotic pulps has been considered a challenge. The most important difficulty is to achieve an adequate apical seal in open apex using conventional root canal therapy. Interrupted root development leads to weak and thin dentinal walls which are liable to fracture before, during or after treatment. Also there will be frequent periapical lesions associated with or without apical resorption and compromised crown root ratio [2].

Management of immature teeth/open apex

The goal of apexification is to obtain an apical barrier to prevent the passage of toxins and bacteria into periapical tissues from root canal [6]. In the literature, many materials and techniques have been used for apexification.

Obturation without creating apical barrier

- Customized cone technique using blunted tips, inverted cones, apical impression heat chemicals and rolled cone heat chemicals
- Thermoplasticized obturation
- Short-fill technique

Obturation after creating apical barrier

- Root end induction of calcific barrier/apexification by induction of blood clot in the peri-radicular region, using antibiotic pastes, calcium hydroxide mixed with various materials, collagen calcium gel, bone morphogenic proteins and tricalcium phosphate

Placement of artificial barriers (root-end filling materials)

Root end filling materials such as amalgam, glass ionomer cement, composite, mineral trioxide aggregate, calcium hydroxide powder, freeze dried bone/dentin, resorbable ceramic, tricalcium phosphate, dentinal shavings.

Since the past decade significant evolution has taken place in the field of endodontic materials. Bioceramics has made endodontic treatment more efficient due to their osteoconductive properties. Bioceramics are classified into three categories, namely, bioinert, bioactive and biodegradable. They include substances such as bioactive glass, glass ceramics, alumina, zirconia, coatings and composites, hydroxyapatite, radiotherapy glasses and resorbable calcium phosphates [7-10].

Calcium hydroxide

Calcium hydroxide was introduced in dentistry by Herman (1920). Kaiser introduced the use of calcium hydroxide ($Ca(OH)_2$) to induce apical closure in 1964. He proposed the formation of calcified barrier in the apex by mixing $Ca(OH)_2$ and CMCP (camphorated parachlorophenol). This technique was first reported by Granath in 1959 and later popularized by Frank in 1966 [11,12].

Calcium Hydroxide and methylcellulose

Apical closure of immature teeth was induced by Heithersay and others using calcium hydroxide and methylcellulose (Pulpdent). It has the advantages of firm physical consistency and decreased solubility in the tissue fluids [12,13].

Calcium Hydroxide and metacresylacetate

The use of metacresylacetate (Cresatin) and calcium hydroxide has minimal cytotoxicity as compared with CMCP.

Calcium hydroxide has also been mixed with distilled water, sterile saline, sterile water, a mixture of CMCP and Cresatin, anesthetic solution, Ringer's solution and idoform (Vitapex). Various antibiotic pastes containing cresol, zinc oxide, clove oil, thymol has also been used [12].

Although calcium hydroxide has been the material of choice for apexification, this chemical has several disadvantages such as difficulty of the patient's recall management and delay in the treatment. This procedure takes at least 3 - 4 months and requires multiple appointments [13]. Patient compliance with this regimen may be poor and many fail to return for scheduled visits. The temporary seal may fail resulting in reinfection and prolongation or failure of treatment. Furthermore, there is a risk of tooth fracture after dressing with calcium hydroxide for extended periods [15]. The most promising alternative to calcium hydroxide is MTA.

Tricalcium Phosphate

The use of tricalcium phosphate as an apical barrier was first reported by Brilliant and Coviello in 1979. The apical 2 mm of the canal was packed using Tricalcium phosphate and followed by condensation with Gutta percha [16,17].

Dentine Chips

Dentine chips were used to create apical barrier to obtain biological apical seal [16].

Calcium phosphate ceramics and hydroxyapatite

The use of calcium phosphate ceramics and hydroxyapatite was reviewed by Okamoto and Higashi in 1996 and indicated the formation of osteodentin and tubular dentin [16,18].

Calcium Silicate Based Materials

These materials were introduced in endodontics as root replacement materials. The first calcium silicate based material introduced in dentistry was Mineral Trioxide Aggregate (MTA).

Mineral Trioxide Aggregate (MTA)

This material was first introduced in 1993. MTA is a powder consisting of fine hydrophilic particles of tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide. It has low solubility and a radiopacity that is slightly greater than that of dentin. This material has demonstrated good sealability and biocompatibility. MTA has a pH of 12.5 after setting which is similar to the pH of calcium hydroxide and it has been suggested that this may impart some antimicrobial properties [19-21]. Shababhang., et al. concluded that MTA produced apical hard tissue formation with significantly greater consistency. For these reasons one-visit apexification has been suggested [14].

MTA can be used for one visit apexification where an artificial barrier will be created, so that root canal can be completely obturated immediately, without delaying the treatment for the root end closure [12].

Various types of MTA are available such as iron containing MTA , (Eg: Gray ProRoot Mineral Trioxide Aggregate); iron free MTA (Eg: White ProRoot Mineral Trioxide Aggregate); and fast setting MTA ,(MTA Angelus).

MTA has been widely used in one-visit apexification. Witherspoon and Ham describe a technique using MTA and asserted that MTA provides scaffolding for the formation of hard tissue and the potential of a better biological seal. They conclude that this technique is a viable option for treating immature teeth with necrotic pulps and should be considered as an effective alternative to calcium hydroxide apexification [14].

Tricalcium silicate cements

Calcium silicate cements predominantly containing tricalcium silicate are introduced to overcome the limitations of MTA such as low compressive strength and long setting time, Eg: Biodentine. Calcium carbonate is added to reduce the setting time. This bioactive cement is available as powder and liquid. The powder consists of tri-calcium silicate, di-calcium silicate and oxide, calcium carbonate, zirconium oxide, iron oxide. liquid consist of calcium chloride and hydro soluble polymer. When compared with MTA (2 hours 45 minutes), Biodentine is a bioactive material which induces the differentiation of odontoblast-like cells has a short setting time of 12 minutes22, 23 and increases biomineralization and, murine pulp cell proliferation .22,23,24 High alkalinity induces denaturion of the dentin organic matrix is the main disadvantage of Biodentine [25].

Tricalcium silicate-based sealer forms a better seal in root canal as it crystalizes in the dentinal tubules. Eg: BioRoot RCS. It is a powder liquid system and powder consists of mixture of povidone, zirconium oxide and tricalcium silicate. The liquid consists of polycarboxylate and calcium chloride [26].

Bioceramic material

Various bioceramic materials were introduced in endodontics in the last decade. These can be powder- liquid based (Eg: Bioaggregate) or single component , paste form or putty(Eg: iRoot SP, iRoot BP, Endo Sequence EndoSequence BC Sealer, EndoSequence BC RRM (Root Repair Material)).

Bioaggregate is a calcium silicate based material without alumina and higher amount of phosphate. On mixing BioAggregate powder with BioA Liquid (deionized water), a nano-composite network of gel-like calcium silicate hydrate is formed, and forms a hermetic seal when applied inside the root canal. iRoot SP is a calcium silicate based root canal sealers, and iRoot BP is a calcium silicate based root canal repair material. These material set slowly once placed utilizing the moisture either in the oral cavity or from interstitial tissue fluid. The particle size of the fillers are reduced to such a level that they can penetrate the dentinal tubules [27].

EndoSequence is a novel bioceramic material. It has a working time of more than 30 minutes and setting reaction is initiated by moisture with a final set achieved in approximately 4 hours. It is composed of calcium silicates, tantalum oxide, zirconium oxide, calcium phosphate monobasic, and filler agents. It contains nanosphere particles that allow the material to enter into the dentinal tubules and interact with the moisture present in the dentin. On setting, it creates a mechanical bond and renders the material with exceptional dimensional stability. Also its high pH has resulted in superior biocompatibility characteristics [26,27]. EndoSequence precipitates apatite crystals which become larger with increasing immersion times and this concludes it to be bioactive [28].

Case Report

A 20-year-old female patient was reported to the Department of Conservative Dentistry and Endodontics with a chief complaint of discolored maxillary right central incisor. History revealed that the patient had suffered trauma 12 years back and undergone treatment in a private clinic. The medical history was not significant. Clinical examination revealed greyish discoloration of tooth 11. The tooth did not demonstrate any abnormal mobility or sensitivity to percussion. Both cold and electric sensibility tests failed to elicit any response. Radiographic examination revealed an immature tooth 11 with a wide open apex (Figure 1). After discussing different treatment options with the patient, apexification of 11 using Mineral Trioxide Aggregate followed by crown was recommended.

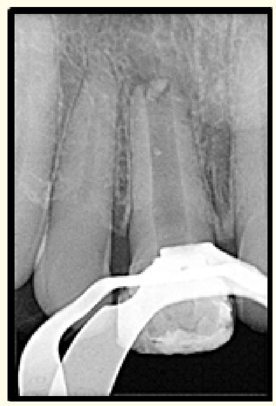

Figure 1: *Preoperative radiograph showing 11 with open apex.*

Crown was removed. Access opening was modified, and working length was determined. Biomechanical preparation was carried out using 80 size k file with circumferential filing motion. Root canal debridement was done using alternative irrigation with 2.5% NaOCl and normal saline. The canals were dried using sterile paper points. MTA was prepared according to manufacturer's guidelines immediately before use, placed into the canals using MTA carrier and compacted with a hand plugger to create an apical plug of 3 to 4 mm (Figure 2). A moist cotton pellet was placed in the canal, and the access cavity was closed with a temporary restoration material.

Figure 2: *Radiograph immediately after MTA apexification*

Patient was recalled on the following day and obturation was completed using roll cone technique (Figure 3). Access cavity was sealed with glass ionomer cement.

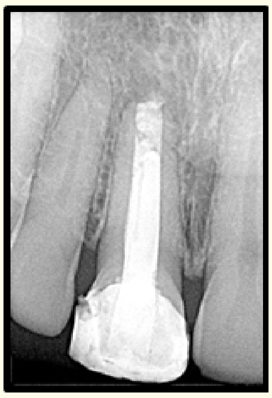

Figure 3: *Post obturation radiograph.*

Discussion

Immature teeth with open apex is also known as Blunderbuss canals. The word 'blunderbuss' refers to an 18th century weapon which has a short and wide barrel. The terminology is derived from the Dutch word 'DONDERBUS' which means 'thunder gun'. The walls of the canal are flaring and divergent, the apex is wider than the coronal aspect of the canal and funnel shaped. Hence it is difficult to obtain apical seal in blunderbuss canal. Various materials such as calcium hydroxide and its various formulations, Calcium silicate based materials MTA and its three types and various bioceramic materials are available for providing apical barrier in open apex cases. In this clinical case white ProRoot MTA is used. It has long setting time of 2 hour and 45 minutes. Hence the obturation of the tooth is done in two steps. In the first day MTA apexification was done and the following day obturation was completed using roll cone technique.

Conclusion

Apexification of immature permanent tooth is necessary for complete obturation of root canal space to prevent reinfection. With the evolution in the field of endodontic materials, various root canal filling materials are available for apical barrier formation. Hence the clinician has to select the apical filling material based on the clinical scenario and the properties of the various materials available.

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