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Review Article

Recent Advances in Apexification

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Received: January 04, 2020; **Published:** January 22, 2020

Abstract

Introduction: Apexification is the process of formation of an apical barrier in immature teeth with necrotic pulp. The procedure includes removal of necrotic pulp followed by debridement of the canal and filling it with calcium inducing material like calcium hydroxide and Mineral Trioxide Aggregate. Recently, many calcium forming materials have been developed in the market that is replacing MTA and conventional calcium hydroxide making single visit apexification possible.

Aim of Work: This review aims to highlight the process of apexification and talks about the new materials used for debridement and filling of the canal.

Methodology: This review is a comprehensive research of PUBMED from the year 1960 to 2018.

Conclusion: Immature teeth with necrotic pulp have a complicated treatment plan. Apexification aims at the induction of an apical closure and continued development of root. Calcium Hydroxide is the gold standard used for apexification, but recently MTA has proven to be as successful. Biodentine further gives the advantage of lesser setting time and hence facilitates single visit apexification.

Keywords: *Apexification; Immature Teeth; Irrigants; Apexification Restoration*

Introduction

The process of forming a barrier apically in cases of the immature tooth, which have open apex and a non-vital pulp to contain the filling materials that are placed in the root canal space is called apexification. Materials like calcium hydroxide and mineral trioxide aggregate have the ability to produce a calcium barrier at the apex of the tooth which allows apexification and helps in the conservative treatment of the immature tooth. If an immature tooth is diagnosed to be non-vital and it is made clear that there is not going to be an increase in the length and width of the root, then apexification is carried out. The difference between the process of apexogenesis and apexification mainly lies in the vitality of the pulp, teeth with vital pulp go for apexogenesis, and non-vital pulp for apexification [1].

Methodology

A comprehensive and systematic search was conducted regarding Recent Advances in Apexification. PubMed search engine (http://www.ncbi.nlm.nih.gov/) and Google Scholar search engine (https://scholar.google.com) were the mainly used database. All relevant available and accessible articles were reviewed and included.

The terms used in search were: apexification, immature teeth, irritants, apexification restoration.

Development of root in immature teeth

Once the development of enamel and dentin reaches the cementoenamel junction, root formation starts. The whole process starts with the formation of Hertwig's Epithelial root sheath (HERS), which removes the lining between inner and outer enamel epithelium. After the first layer of dentin is laid down the HERS starts deforming and loses the proximity with the root surface and is now present as tubules or strands near the outer root surface [2]. The shape of the root is determined by HERS, and the epithelial diaphragm leads to formation of apical foramen. After the tooth erupts in the oral cavity, there is about 3 years gap in the completion of root formation [2].

Injury to immature teeth with developing roots

30% of children with immature teeth are prone to traumatic injuries [3]. These injuries generally tend to occur in patients before root formation [4] is completed which may cause pulpal inflammation and necrosis of the teeth. HERS is generally very susceptible to trauma, but this layer has a high degree of vascularity and increased number of cells that lead to continuation of root formation even if there is presence of any inflammation and necrosis [5]. Because of this reason the vitality of the tooth should be maintained at any cost so that development of the root is not hampered [6]. A vital pulp is thought to be the source of undifferentiated cells that later give rise to hard tissue formation. It also prevents the ingrowth of periodontal ligament cells which will lead to blockade of the root canal [7].

Diagnosis of cases for apexification

Apexification of teeth can be done in teeth that have nonvital pulp. To decide the treatment plan of the tooth, the pulpal status of the tooth should be clear to the clinician. The clinical and radiographical assessment has to be done preceded by a history of thorough symptoms and cause of the injury or duration of decay. History of pain should be considered explaining the duration, aggravating and relieving factors. If the pain is severe and spontaneous and lasts for more than a short duration of time, it indicates irreversible pulpitis, and the pulp has to be completely removed [9].

Objective testing is also required to confirm the diagnosis like percussion, thermal, and electric pulp testing. If the tooth is tender on percussion it suggests that there is apical periodontitis, and there is inflammation in the periapical tissue. If the patient has a throbbing pain and severe tenderness is present on touching the tooth, it suggests pulpal necrosis [8]. Objective tests for vitality in immature teeth do not always give the most accurate result as the nerves in the sub-odontoblastic region are not fully developed and cannot register the appropriate response [8]. Radiographic tests also won't be very accurate in immature teeth as there is a presence of radiolucent area in the apex of the root showing the dental follicle, which can also represent a periapical lesion which is not present in the area. to avoid this confusion, the easy way out is to compare the periapical region of the other sound teeth [9].

The results of one test cannot give the appropriate diagnostic result, and hence a combination of radiographic, symptomatic and clinical tests gives the most accurate diagnosis of the tooth. If the tooth is diagnosed as having a necrotic pulp, then apexification of the tooth is the treatment of choice [10].

Apexification

Earlier, the process of apexification included the removal of pulp followed by filling of the canal with filling material or paste fills and sometimes followed by apical surgeries [11-13]. Earlier studies have described the use of custom made gutta-percha cones for the obturation of root with open apex, but that becomes difficult in the clinical scenario as the apex of the root is wider than the coronal portion that makes the obturation difficult. In case we try to enlarge the coronal aspect of the tooth, that will require cutting a lot if the radicular dentin, which may cause weakening of the root and could lead to fracture of the tooth [1].

Surgical intervention of young, immature teeth is not generally advised as the bone surrounding the tooth is in the forming stage, and walls are weakened which might lead to shattering of the wall during apical surgery. Apicoectomy also reduces the length of the root and disturbs the crown root ratio [14].

The process of apexification (Figure 1a-1d) involves the removal of necrotic pulp tissue followed by irrigation of the canal and placement of intracanal medicament. This procedure, although has not been clinically proven successful and many authors have different view [15]. Nygaard-Ostby suggested that during debridement of the canal if the endodontic file is taken beyond the apex and bleeding is initiated it may lead to vascularization of the canal which will cause the formation of apical barrier [15].

In another study conducted by Moller., *et al.* [16] he concluded that the removal of necrotic pulp tissue will lead to healing of the periapical area and will cause the root formation without the use of intracanal medicament [16]. Some authors have suggested that debridement of the canal may lead to damage to the cells and should be done with utmost care if done at all [17]. Irrigating solutions generally used for apexification is mentioned in table 1.

Most of the earlier works have shown that, to induce the closure of the apex, antibiotic and antiseptic pastes must be used. The antiseptic paste that is used is left in the canal as a temporary filling material until the more permanent filling of the canal is done [18].

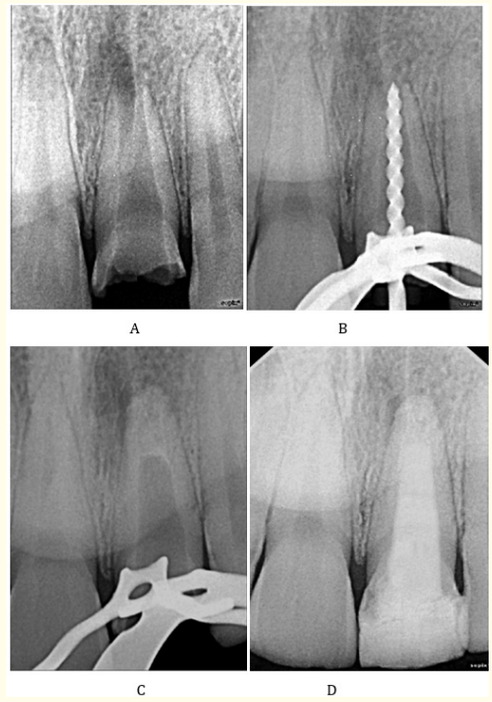

Figure 1: *(a) Immature teeth with undeveloped root with open apex (b) determining the working length and cautious filing of the canal followed by copious irrigation (c) Apical barrier formation using Biodentine (d) retrograde filling with Gutta Percha [19].*

Irrigant	Antibacterial Property
Sodium Hypochlorite	High dissolution property should be used in low concentration
EDTA	Low dissolution and antibacterial property, removes smear layer can be used copiously
Chlorhexidine	Antibacterial against Gram-Positive and negative bacteria. No dissolution capacity.
MTAD (Mixture of Tetracycline citric acid and Detergent)	Antibacterial due to the presence of tetracycline, no dissolution property.
Iodine potassium Iodide	Antibacterial with no dissolution
HEBP	Antibacterial and no dissolution
Qmix	Antibacterial and no dissolution
Citric acid	Very less antibacterial, removed the smear layer, no dissolution

Table 1: *Irrigants used for apexification [1].*

Materials used for apexification and recent advances

Calcium hydroxide

Calcium hydroxide is the most wildly accepted material used for apical barrier formation. It was first introduced by Kaiser [20] in 1964, and he mixed it with camphorated parachlorophenol (CMCP) to induce apical closure. The root canal is debrided, and a temporary paste is placed in the canal, which acts as a medicament. Calcium Hydroxide with CMCP has been suggested by many authors and has been proven successful [21,22]. Cresatin has also been used and is proven to be less toxic than CMCP. To reduce the toxicity, vehicles like saline, distilled water, and methylcellulose have also been suggested by Heithersay [23,24].

Debriding of the canal is an important factor in the success of the apexification process. The antibacterial property of calcium hydroxide also helps in reducing the contamination in the canal. Hydroxyl ion that is released from calcium hydroxide damages the bacterial DNA, cytoplasmic membrane and causes protein denaturation leading to the death of the bacteria [25]. Heithersay suggests that the calcium barrier that is formed at the apex is because of the increased release of calcium ions [23]. The effects of Calcium hydroxide are further described in table 2.

Calcium Hydroxide	
Physical effects	**Chemical effects**
The canal, when filled with calcium hydroxide, is protected from the ingress of bacteria.	Cellular metabolism and enzymatic reactions of the bacteria are suppressed
It holds the growth factors and further kills any bacteria that may be present in the canal after chemomechanical debridement of the canal is done.	The cytoplasmic membrane of the bacterial cell is damaged.
	It causes the DNA to split, which ceases the replication of the bacteria.

Table 2: *Chemical and physical effects of calcium hydroxide [1].*

Different schools of thought are present as to what should be the duration of the calcium hydroxide dressing. Abbot [26] has suggested that calcium hydroxide should be replaced frequently so as to check the status of the barrier formation and also increases the speed of the calcific bridge that is formed. Other studies suggest that calcium hydroxide should be changed only once or as and when any symptoms occur [27]. Out of the 10 studies that were reviewed for the results of apexification it was found that 74 - 100% gave a positive result with the use of calcium hydroxide [28].

Mineral trioxide aggregate (MTA)

MTA is a hydrophilic powder and consists of trisilicate cement. It was introduced in the year 1998 and is shown to have good biocompatibility, sealability and low solubility. Various studies have shown successful results of apexification done by Mineral Trioxide Aggregate, and the apical barrier that is formed has a better consistency [29].

Biodentine

Biodentine is a calcium silicate-based cement and has been used as a dentine replacement material. Due to the increased setting time of MTA, Biodentine is a good alternate for single visit apexification procedures [30].

Platelet rich fibrin

Sometimes to reduce the chances of apical extrusion of the filling material, a matrix should be placed before placement of the filling material. PRF contains leukocyte matrix, which includes cytokines platelet and stems cells within it, and they are biodegradable that help the epithelial cell to migrate. Growth factors are realized by PRF within a span of 1 - 4 weeks [31].

Bioaggregate

Also known as DiaRoot, Bioaggregate is also a tricalcium cement. It contains nano sized particles of Aluminium, which is mixed with deionized water. It is highly bioinductive and has a higher fracture resistance compared to MTA and lesser dislodging property [32].

Single visit apexification

The conventional apexification process takes 3 - 4 months to show healing signs and requires more than one appointment. Compliance of the patients is also an important factor in the success of such cases, and since the age group of these patients does not guarantee good compliance, one visit apexification should be practiced. Morse has suggested that in a single visit apexification, more than creating apical root closure, it's more important that a root end seal is made [33]. Witherspoon and Ham have suggested that MTA can be used as the filling material and that acts as a scaffold and form the biological seal [34]. For a single visit apexification, utmost importance should be given to irrigation, and debriding protocols and all the contaminants should be removed from the canal. A number of studies have shown clinical success when MTA is used for single sitting apexification [34,35].

Post apexification restoration

The dentinal walls in the immature tooth root are very thin and hence require a good reinforcement to prevent them from fracture. Newer dentin bonding agents can be used for this purpose and have shown good clinical results. Resin modified Glass ionomer cement can also be used for the same. Even though the restorative material used should reinforce the canal, it should allow access to the apical portion of the canal when required. Katebzadeh., et al. [36] have suggested a technique in which a post was made of clear curing material. When required the post is later removed, and a channel for calcium hydroxide is created through it [36].

Conclusion

Immature teeth with necrotic pulp have a complicated treatment plan. Apexification aims at induction of an apical closure and continued development of root. Calcium Hydroxide is the gold standard used for apexification, but recently MTA has proven to be as successful. Biodentine further gives the advantage of lesser setting time and hence facilitates single visit apexification.

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Volume 19 Issue 2 February 2020