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 – 5, Issue – 1, January - 2022, Page No. : 95 - 102

Apexification: A Comprehensive Review

[1]Dr. Abhilasha Agarwal, Junior Resident, Department of Paediatric and Preventive Dentistry, King George's Medical University, Lucknow, Uttar Pradesh.

[2]Dr. Jay Somkuwar, Junior Resident, Department of Paediatric and Preventive Dentistry. King George's Medical University. Lucknow, Uttar Pradesh.

[3]Dr. Dipika Yadav, Junior Resident, Department of Paediatric and Preventive Dentistry King George's Medical University, Lucknow, Uttar Pradesh.

[4]Dr. Jyoti Solanki, Junior Resident, Department of Paediatric and Preventive Dentistry King George's Medical University, Lucknow, Uttar Pradesh.

[5]Dr. Shruti Khanna, Senior lecturer, Department of Prosthodontic Crown & Bridge, Sardar Patel Post Graduate Institute of Dental and Medical Sciences, Lucknow, Uttar Pradesh.

[6]Dr Sadhika Sadhar, Senior lecturer, Department of Pediatric and Preventive Dentistry, GIDSR, Ferozepur, Punjab.

Corresponding Author: Dr. Abhilasha Agarwal, Junior Resident, Department of Paediatric and Preventive Dentistry, King George's Medical University, Lucknow, Uttar Pradesh

Citation of this Article: Dr. Abhilasha Agarwal, Dr. Jay Somkuwar, Dr. Dipika Yadav, Dr. Jyoti Solanki, Dr. Shruti Khanna, Dr Sadhika Sadhar, "Apexification: A Comprehensive Review", IJDSIR- January - 2022, Vol. – 5, Issue - 1, P. No. 95 – 102.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Pulp necrosis of immature permanent teeth represents a significant challenge for clinical management as root development ceases and open apices remain. The aetiology of pulp necrosis in immature permanent teeth can include caries, trauma or the presence of the dental anomalies, dens invaginatus and dens evaginatus. Depending upon the vitality of the affected pulp, two approaches are possible, apexogenesis or apexification. As always, success is related to accurate diagnosis and a full understanding of the biological processes to be facilitated by the treatment. Present review of literature includes the various aspects of management of immature non vital tooth with recent advancement in procedures and materials in achieving the apical closure of affected root apices.

Keywords: Apexification, Apexogenesis, Single visit apexification

Introduction

The presence of healthy pulp is essential for root development and apical closure. It is well established that pulp necrosis of immature, permanent teeth can halt

continued root development, producing a tooth with an open apex. The most common causes of pulp necrosis in immature, permanent teeth are dental caries. Dental caries is a chronic infectious disease resulting from the penetration of oral bacteria into the enamel and dentin. Microorganisms subsequently trigger inflammatory responses in the dental pulp. The proliferation and metabolic activity of these microorganisms lead to the release of bacterial components into dentinal tubules and their diffusion towards the peripheral pulp. Bacterial invasion results in irreversible chronic pulp inflammation, most often after a long phase of chronic inflammation. Subsequently, pulp necrosis, infection of the root canal system, and periapical disease may occur. Other causes include dental trauma, dental anomalies like dens evaginatus and dens invaginatus etc.[1,2]

The management of necrotic immature, permanent teeth present a clinical challenge because of incomplete root development, unfavorable crown to root ratio and poor long-term prognosis. The resultant thin, dentinal walls and open apex make root canal debridement difficult and a lack of apical closure complicates the root filling procedure and attainment of an apical 'seal'. The thin dentinal walls also increase the risk of future root fracture of these teeth under occlusal forces.[3,4]

Apexification of non-vital immature teeth with calcium hydroxide has proven to be a reliable and the most welcome addition to the therapeutic armamentarium since Frank described it in 1966. The unpredictable and lengthy course of treatment presented challenges, particularly as it required a high level of patient compliance. For this reason, one visit apexification has been suggested.[5]

In 1993, a new endodontic material, mineral trioxide aggregate (MTA) was developed by Torabinejad, and coworkers, It has been proposed as a material for one visit apexification as it combines a bacteriostatic action, biocompatibility and a favorable sealing ability.[5]

Present review of literature includes the various aspects of management of immature non vital tooth with recent advancement in procedures and materials in achieving the apical closure of affected root apices.

Apexogenesis V/S Apexification[6,7]

- **Apexogenesis (Root formation):** Apexogenesis describes the continued physiologic development and formation of the root's apex in vital young permanent teeth. It can be achieved by implementing the appropriate vital pulp therapy techniques 5
- **Apexification (Root end closure):** Apexification is a technique of inducing root end closure in an immature non-vital permanent tooth by removing the coronal and radicular tissue and placing a suitable biocompatible agent.

Causes of open apices[5]

1. **Incomplete development:** The open apex typically occurs when the pulp undergoes necrosis as a result of caries or trauma, before root growth and development is complete (i.e. during Cvek's stages 1-4).
2. **Extensive apical resorption:** Due to orthodontics, periapical pathosis or trauma
3. **Root end resection:** During periradicular surgery
4. **Over-instrumentation:** In cases of establishing drainage though root canals and removing gutta-percha points during retreatment, an apical constriction might sometimes be inadequately removed.

Types of open apices [3,8]

These can be of two configurations

- **Non blunderbuss:** Broadly opened apex (Cylinder – shaped root canals).
- **Blunderbuss:** Funnel shaped apex (Apical opening can be wider than the coronal root canal orifice (inverted root canal conicity).

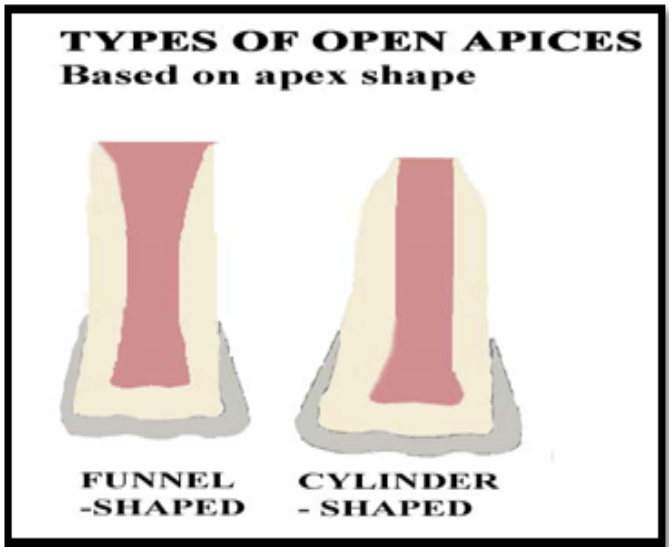

Figure 1: Types of open apices.

Diagnosis and case assessment: Clinical assessment of pulpal status requires a thorough history of subjective symptoms, careful clinical and radiographic examination and performance of diagnostic tests. The importance of careful case assessment and accurate pulpal diagnosis in the treatment of immature teeth with pulpal injury cannot be overemphasized.[6]

An accurate pain history must be obtained. The duration and character of the pain and aggravating and relieving factors should be considered. Duration of pain may vary but pain that lasts for more than a brief period (a few seconds) in a tooth with a vital pulp has been thought to be indicative of irreversible pulpitis. When pain is spontaneous and severe, as well as long lasting, this diagnosis is almost certain. If the pain is throbbing in character and the tooth is tender to touch, pulpal necrosis with apical periodontitis or acute abscess is likely. Confirmation from objective tests is necessary which include visual examination, percussion testing and thermal and electric pulp testing. The presence of a swelling or sinus tract indicates pulpal necrosis and acute or chronic abscess respectively. Tenderness to percussion signifies inflammation in the periapical tissues.[9]

Vitality testing in the immature tooth is inherently unreliable as these teeth provide unpredictable responses to pulp testing. Prior to completion of root formation, the sensory plexus of nerves in the sub-odontoblastic region is not well developed and as the injury itself can lead to erratic responses over reliance on the results of clinical tests of pulp vitality, particularly by the use of electric pulp testing devices, is not recommended.[4,10]

Radiographic interpretation of immature tooth can be difficult. A radiolucent area normally surrounds the developing open apex of an immature tooth with a healthy pulp. It may be difficult to differentiate between this finding and a pathologic radiolucency resulting from a necrotic pulp. Comparison with the periapex of the contra lateral tooth may be helpful in diagnosis.[9]

Unfortunately, it has not been possible to establish a close correlation between the results of these individual tests and the histological diagnosis but it is hoped that by combining the results of the history, examination and diagnostic tests, an accurate clinical diagnosis of pulpal vitality can be made in most cases. When the pulp is deemed vital, apexogenesis techniques can be attempted and a necrotic pulp condemns the tooth to apexification.[4]

Methods for the treatment of teeth with an incompletely formed apex (open apex) and a necrotic pulp

According to **Morse et al (1990)**[11] there are at least 5 methods of treating a tooth that has a necrotic pulp and an open apex.

These methods are

1. **A customized cone (Blunt end, rolled cone):** Filling the root canal with the large (blunt) end of a gutta percha cone or customized gutta percha cones with a sealer.

2. **A short fill technique:** Filling the root canal well short of the apex (before the walls have diverged) with

gutta percha and sealer or zinc oxide eugenol (ZOE) alone.

3. Periapical surgery (with or without a retro grade seal): Filling the root canal with gutta percha and sealer and then performing periapical surgery with or without a reverse seal.

4. Apexification (Apical closure induction): Inducing apical closure by the formation of an apical stop [Calcium hydroxide, Ca $(OH)_2$) is generally used)] against which a permanent root canal filling can subsequently be inserted.

5. One visit apexification: Placing a biologically acceptable substance in the apical portion of the root canal (Dentinal chips or tricalcium phosphate have been used) thus forming an apical barrier. This is followed by filling the root canal with gutta percha and sealer.

Calcium hydroxide: Although a variety of materials have been proposed for induction of apical barrier formation, calcium hydroxide has gained the widest acceptance. Calcium hydroxide was introduced by Hermann in the 1920's for endodontic treatment. The use of calcium hydroxide was first introduced by Kaiser in 1964 who proposed that this material mixed with camphorated Para chlorophenol (CMCP) would induce the formation of a calcified barrier across the apex. This procedure was popularized by Frank (1966) who emphasized the importance of reducing contamination within the root canal by instrumentation, medication and decreasing the canal space temporarily with a resorbable paste seal.[12,13]

Klein SH et al. (1974) and others described successful induction of an apical barrier using calcium hydroxide and Cresatin (Premier Dental Products). Cresatin had been shown to have minimal inflammatory potential as a root canal medicament and to be significantly less toxic than CMCP. To further reduce the potential for cytotoxicity, the use of calcium hydroxide mixed with saline, sterile water or distilled water has been investigated with similar clinical success.[14,15] Heithersay GS (1970) and others have used calcium hydroxide in combination with methylcellulose (Pulp dent Corporation, Watertown, MA, USA). Pulp dent has the advantage of decreased solubility in tissue fluids and a firm physical consistency.[13]

Mechanism of action of $Ca(oh)_2$ to induce formation of a solid apical barrier: Some of the postulated mechanisms of the osteoconductive effects of Ca $(OH)_2$ are as follows[6]

1. Presence of high calcium concentration increase the activity of calcium dependent pyrophosphatase: Mitchell DF et al. (1958)[16] studied the osteogenic potential of calcium hydroxide when implanted into the connective tissue of rats. They concluded that calcium hydroxide had a unique potential to induce formation of heterotopic bone in this situation.

Heithersay GS (1970)[13] has postulated that calcium hydroxide may act by increasing the calcium concentration at the precapillary sphincter, reducing the plasma flow. In addition, the calcium ion can affect the enzyme pyrophosphatase, which is involved in collagen synthesis. Stimulation of this enzyme can facilitate repair mechanisms.

2. Direct effect on the apical and periapical soft tissue: Holland et al. (1977)[17] have demonstrated that the reaction of the periapical tissues to calcium hydroxide is similar to that of pulp tissue. Calcium hydroxide produces a multilayered necrosis with subjacent mineralization. Schroder U et al. (1971)[18] have postulated that the layer of firm necrosis generates a low-grade irritation of the underlying tissue sufficient to produce a matrix that mineralizes. Calcium is attracted to

the area and mineralization of newly formed collagenous matrix is initiated from the calcified foci.

3. High pH, which may activate alkaline phosphatase activity: It appears that the high pH of calcium hydroxide is an important factor in its ability to induce hard tissue formation. Javelet et al (1985)[19] compared the ability of calcium hydroxide (pH 11.8) and calcium chloride (pH 4.4) to induce formation of a hard tissue barrier in pulp less immature monkey teeth. Periapical repair and apical barrier formation occurred more readily in the presence of calcium hydroxide.

4. Antibacterial activity: It has been demonstrated that apical barrier formation is more successful in the absence of microorganisms and the antibacterial efficacy of calcium hydroxide has been established. The antimicrobial activity is related to the release of hydroxyl ions, which are highly oxidant and show extreme reactivity. These ions cause damage to the bacterial cytoplasmic membrane, protein denaturation and damage to bacterial DNA.

According to Heittersay GS (1970)[13] the basic pH of calcium hydroxide and its physical presence within the root canal space is thought to provide a potent antibacterial effect, prevent ingress of granulation tissue and inhibit osteoclastic activity. These characteristics encourage the formation of hard tissue at the root apex.

Inherent disadvantages of conventional Ca(oh)2 apexification[4,20]

1. Patient Compliance: More apexification cases are started than completed. Patients or parents lose interest in such a length to complete, multiple appointment procedure.

2. Fracture before completion of treatment: Although crown and root fractures are an unpredictable happening, they do occur occasionally in these immature wide canal incisors with in root walls.

3. Referring dentists: Referring dentists generally do not like the idea of waiting for nearly 1 year to have the case back in their practice.

4. Inconvenience of multiple appointments in the young adult patient: In these cases, a discolored tooth is commonly the motivator. It is usually after initial diagnosis by their dentist that patients know about their apical immaturity and its relationship to the discoloration. However the multiple appointments entailed by the apexification procedure. Obscures the real chief complaint of this young adult group, which is improving esthetics quickly.

5. Precise prognostic assessment sometimes impossible: An incisor with a hidden root fracture could be unwisely and wastefully treated by apexification before the true nature of the problem is noticed. This is an ever-present possibility in immature teeth usually devitalized by trauma.

6. Patient management: Behavioral problems in young patients are difficult to manage and sometimes exacerbated by multiple appointments.

7. Economics: After telling the cost for multiple appointments, plus the time taken off from the work in the case of an adult, it is evident that apexification is an expensive, time-consuming proposition.

Single visit apexification: Induction of apical healing, regardless of the material used, takes at least 3-4 months and requires multiple appointments. 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. The importance of the coronal seal in preventing endodontic failure is well established.[4,6 \]

For these reasons one-visit apexification has been suggested**.** Morse DR et al. (1990)[12] define one-visit apexification as the non-surgical condensation of a

biocompatible material into the apical end of the root canal. The rationale is to establish an apical stop that would enable the root canal to be filled immediately. There is no attempt at root end closure. Rather an artificial apical stop is created.[11]

One-visit apexification is defined as the non-surgical condensation of a biocompatible material into the apical end of the root canal. The basis is to create an apical barrier that would facilitate the root canal to be filled instantly. Only an artificial apical stop is created and no effort to induce root end closure is taken.[21] MTA acts as a scaffold for the formation of hard tissue and provides better biological seal.[22] In this technique thorough cleaning and shaping of the root canal system is done. Then, MTA is introduced as an apical seal followed by the immediate placement of a suitable bonded restoration within the root canal.[23] Though the advances with MTA and bonded restorations show a better outcome, it cannot yield the result that apexogenesis can attain, i.e. maturation of the root end with better thickness of the root.[24] Therefore, alternative approaches that allow the apical maturation should be pursued.

Paradigm shift in management of non-vital teeth with open apex

Revascularization is introduced as a new treatment modality for immature non-vital teeth. Revascularization can be defined as the invagination of undifferentiated periodontal cells from the apical region in immature teeth. Tissue in growth 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 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).[25]

Revascularization should include appropriate case selection, with a strict disinfection protocol and use of antimicrobial paste to achieve complete asepsis and blood clot formation in canal space followed by placement of an MTA barrier over blood clot with a final restoration and follow up at regular intervals.[26]

Regenerative endodontics is a “biologically based procedures designed to replace damaged structures, including dentin and root structures, as well as cells of the pulp-dentin complex” and because of the emergence of this concept, clinicians should re-evaluate existing treatment modalities while developing the treatment of certain clinical cases.[27]

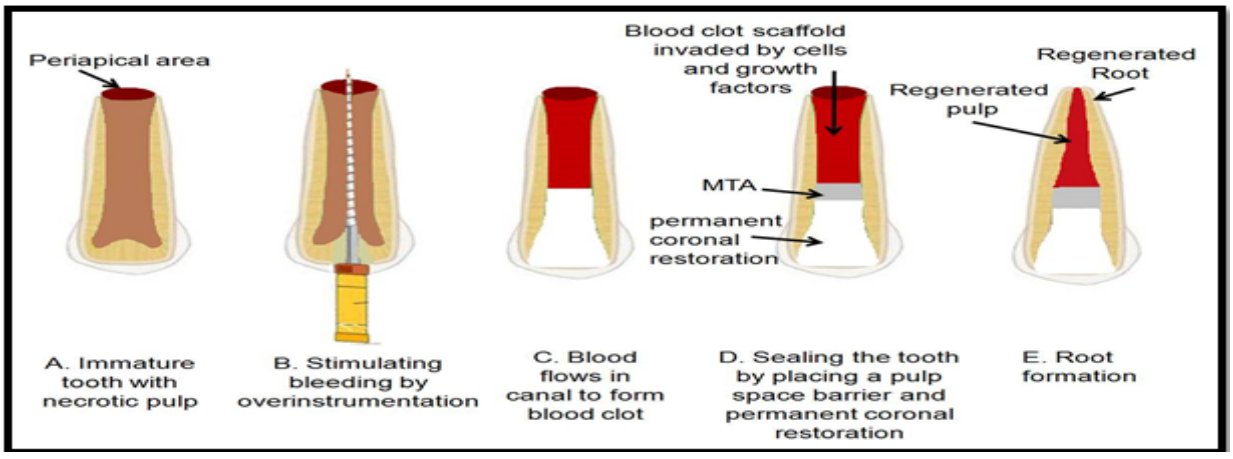

Figure 2: Clinical Steps in Revascularization.

Conclusion

Calcium hydroxide apexification remains the most widely used technique for treatment of necrotic teeth with immature apices as it has high success rates are. As compared to calcium hydroxide, MTA is effective in treating immature permanent teeth with necrotic pulps with the advantage of reduced treatment time and more predictable barrier formation. The shortcoming is similar to calcium hydroxide that the placement of an apical plug does not account for continued root development along the entire root length. Complete root development is possible with regenerative endodontic procedures, and there is a paradigm shift in the endodontic management of immature permanent teeth with necrotic pulps using regenerative endodontic procedures. In future conventional apexification procedures might be replaced completely by these newer methods. Prospective clinical trials comparing these alternative techniques are required.

References

1. Flanagan TA. What can cause the pulps of immature, permanent teeth with open apices to become necrotic and what treatment options are available for these teeth. Aust Endod J.2014 Dec;40(3):95-100.
2. Kumar G.S. Text book of orban's oral histology and embryology. 14th ed. Elsevier;2015.14-21p.
3. Smyth R, Philpott B. Management-of-the-opex-apex-in-endontics [Internet]. Available From URL https://www.sdmag.co.uk/2017/07/25/management-of-the-open-apex-in-endodontics.
4. Rafter M. Apexification: a review. Dent Traumatol. 2005 Feb;21(1):1-8.
5. Ananthraj A, Praveen P, Venkata Raghavan K, Prathinha Rani S, Sudhir R, Murali Krishnan B. Challenges in pulpal treatment of young permanent teeth a review. J Dent Sci Res. 2011;2(1):142-55.
6. American Academy of Pediatric Dentistry clinical Guideline on Pulp Therapy for Primary and Immature Permanent Teeth. Reference manual 2009; 33:11-12
7. Paulindraraj S, Venkatesan R, Suprakasam S, Christopher A. Apexification-Then and Now: A Review. Int J Dent Med Res 2015;1(6):193-196.
8. Kumar P, Arora S, Dhingra D. Blunderbuss Canal: An Enigma for Endodontic Practitioners. Ind J Dent Sci. 2013;3(5);58-60.
9. Klein H. Pulp response to an electric pulp stimulator in the developing permanent anterior dentition. J Dent Child 1978; 45:23–5.
10. Avinash R. Salgar, Manoj G. Chandak.N U Manwar. Blunderbuss canal: a challenge for endodontist. Endodontology 77-81
11. Morse DR, O'Larmic J, Yesilsory C. Apexification: review of the literature. Quint Int. 1990 Jul;21(7):589-98.
12. Huang G.T.-J. Apexification: the beginning of its end. International Endodontic Journal 2009; 42:855–866.
13. Heithersay GS. Calcium hydroxide in the treatment of pulp less teeth with associated pathology. J Br Endod Soc 1975; 8:74–93.
14. Klein SH, Levy BA. Histologic evaluation of induced apical closure of a human pulp less tooth. Oral Surg Oral Med Oral Pathol. 1974 Dec;38(6):954–9.
15. Mohammadi Z, Dummer PM. Properties and applications of calcium hydroxide in endodontics and dental traumatology. Int Endod J. 2011 Aug;44(8):697-730.

16. Mitchell DF, Shank walker GB. Osteogenic potential of calcium hydroxide and other materials in soft tissue and bone wounds. J Dent Res. 1958;37(6):1157-63.
17. Holland R, de Mello W, Nery MJ, Bernabe PF, de Souza V. Reaction of human periapical tissue to pulp extirpation and immediate root canal filling with calcium hydroxide. J Endod.1977 Feb;3(2):63-7.
18. Schroder U, Granath LE. Early reaction of intact human teeth to calcium hydroxide following experimental pulpotomy and its significance to the development of hard tissue barrier. Odontol Revy. 1971;22(4):379–95.
19. Javelet J, Torabinejad M, Bakland L. Comparison of two pH levels for the induction of apical barriers in immature teeth of monkeys. J Endod. 1985;11(3):375–8.
20. Aggarwal V, Miglani S, Singla M. Conventional apexification and revascularization induced maturogenesis of two non-vital, immature teeth in same patient: 24 months follow up of a case. J Conserv Dent. 2012 Jan;15(1):68-72.
21. Witherspoon DE, Ham K. One-visit apexification: technique for inducing root-end barrier formation in apical closures. Pract Proced Aesthet Dent. 2001; 13:455–60.
22. Steinig TH, Regan JD, Gutmann JL. The use and predictable placement of mineral trioxide aggregate in one-visit apexification cases. Aust Endod J 2003; 29:34–42.
23. Thompson A, Kahler B. Regenerative endodontics – biologically-based treatment for immature permanent teeth: a case report and review of the literature. Australian Dental Journal 2010; 55: 446–452.
24. Huang G.T.-J. Apexification: the beginning of its end. International Endodontic Journal 2009; 42:855–866.
25. Gopal R, Doifode D, Surana P, Lunia S, Sadhu RS, Aafreen S. Revascularization: A New Hope for Necrotic Permanent Teeth with Immature Apex - A Review. Int J Oral Care Res 2018;6(1): S89-96.
26. Iwaya S, Ikawa M. Revascularization of a tooth with apical periodontitis and a sinus tract. Dent Traumatol, 2001; 17:185-187.
27. Daali M, Rajbanshi L. Regenerative endodontics: Changes, chances and challenges of revascularization in pediatric dentistry. SRM J Res Dent Sci. 2014; 5:186-9.