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Challenges and Treatment Strategies of Open Apex

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Abstract
Open apex are a challenge to an endodontist. Cleaning and filling of the root canal to induce a complete calcified barriers at the apex. Various treatment modalities are present to treat an immature open apices, open apex in nonvital teeth were confined to custom fitting the filling material, paste fills, and apical surgery. To create an apical barrier with a hard calcified tissue by apexification the main goal treatment. Biological healing is prove to be more beneficial in the long term. Further research is required into this novel approach to apexogenesis to assess the long-term prognosis of these teeth. Current research on pulp regeneration is growing and provides exciting possibilities for greater biological approaches to endodontics in the future.

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The golden rule of endodontic treatment is to remove all the debris, shape the root canal irrigate and obturate the canals efficiently in three dimensions in a specific amount of time and appointments of a reasonable time of a normal patient. Most of the endodontic treatment cases can be managed predictably and comfortably, there are some patients that defy the predictable routine treatment. This patients are those which have teeth with immature apical formation. Teeth with incomplete rhizogenesis, pose a special challenge to the dentists because of large open apices, divergent root walls, thin dentinal walls that are susceptible to fracture and frequent periapical lesions. This patients requires a specially treatment plan, different from the other patients, requiring much more time to complete depending on the degree of apical immaturity.[1]

Dental trauma happens most frequently in young patients, who generally presents with immature teeth. Root formation stops, when such teeth with open apex suffer from pulp pathology. Consequently, wide canals with thin and fragile walls and open or even ' blunderbuss' apex make chemo-mechanical debridement difficult and hamper apical closure.

There are two types of open apices and they are non – blunderbuss and blunderbuss.

In non – blunderbuss apices the walls of the canal are parallel to slightly convergent as the canal exits the root, the apex can be broad i,e cylindrical shape or tapered or convergent.

In blunderbuss the walls of the canal are divergent and flared, more in the buccolingual direction. The apex is funnel shape and typically wider than the coronal aspect of the canal. The word ' blunderbuss' basically refers to an 18th century weapon with a short and wide barrel. It derives its origin from the Dutch word DONDERBUS' which means ' thunder gun.

According to the width of the apical foramen and the length of the root, Cvek has classified five stages of root development.

Stage 1, describe as the teeth with wide divergent apical opening and a root length estimated to less than half of the final root length.

Stage 2 teeth with wide divergent apical opening and a root length estimated to half of the final root length.

Stage 3 teeth with wide divergent apical opening and a root length estimated to two thirds of the final root length.

Stage 4 teeth with wide open apical foramen and nearly completed root length.

Stage 5 teeth with closed apical foramen and completed root development.

Problems associated with incomplete rhizogenesis are large open apices with convergent, parallel and divergent shapes. There is presence of thin dentinal walls which are susceptible to fracture before, during or after treatment[6]. Immature permanent tooth has considerable capacity to heal after traumatic pulp exposure, so conservative pulp therapies are important to preserve pulp vitality and allow for continue root formation. It is often a challenge for the determination of working length in large open apex, the necessity of root canal preparation, and achieving control during obturation.[2,3]

The teeth with immature root development, necrotic pulp and apical periodontitis present faces a multiple challenges in the successful treatment; firstly the infected root canal cannot be cleaned and disinfected with standard root canal protocols using an aggressive procedure with endodontic files , secondly obturation possess next problem as there is no apical barrier for containing root filling without impinging on the periodontal tissues and finally the presence of thin roots which increases the susceptibility to fracture[4]. After traumatic injuries electric and thermal pulp tests may be unreliable. Laser Doppler flowmetry (LDF) is used for measurement of blood flow in traumatized teeth as to provide more accurate readings. The pulse oximeter also offers accurate means of monitoring pulp vitality by recording the oxygenation of pulp flow. Radiographic examination of teeth require good periapical and bitewing radiographs but it is difficult to determine if the pulp is reversibly or irreversibly affected. Combining the result of history, examination and diagnostic tests, clinical diagnosis of pulp vitality can be made accurately in most cases.

Treatment modalities - Two basic types of treatment modalities are

- Surgical methods
- Non–surgical methods

a) Surgical methods

In the case of blunderbuss apex, there is presence of periapical lesion which was treated surgically for many years. Dawood and pittford (1989) reported that obturation of the root canal with thermoplasticized gutta percha followed by periapical curettage can be clinically successful. Now because of advancements such as surgical operating microscopes, refined microsurgical instruments made the procedures more easy and convenient and will result in less trauma to the patient and faster postsurgical healing.

- Root End Filling- The objective of apical surgery is to surgically maintain a tooth that primarily has an endodontic lesion that cannot be resolved by conventional endodontic (re)treatment. It is therefore of clinical relevance to perform a thorough clinical and radiographic examination of the tooth before apical surgery (including adjacent and opposing teeth), in order to decide whether surgical or non-surgical endodontics should be considered. Only a tight and persistent apical obturation will allow periapical healing with good long-term prognosis. Thus, fulfillment of this requirement is of paramount importance during the surgical treatment.[2]

.b) Non-surgical methods There are various methods:

- Apexification
- Apexogenesis
- Revascularization,

Treatment of Teeth with Vital Pulp and Open Apices

When pulp exposure occurs in immature tooth due to caries or trauma, the exposed pulp can heal if protected from further injury. Treatment of immature teeth has changed dramatically in recent years as new concepts and materials have developed. Vital pulp therapies are the treatment of choice for traumatized and carious teeth with vital pulps and open apices . The approaches include indirect pulp capping in deep caries cavities and direct pulp capping or pulpotomy in cases of pulp exposure. The key to the success of vital pulp therapy might partly be strict case selection and proper treatment protocol.[3]

Treatment of Teeth with Necrotic Pulp and Open Apices - incomplete root development can provide a challenging situation in treatments. Firstly cleaning and shaping of blunderbuss canal is difficult. Secondly necrotic debris in wide root canal is difficult to completely disinfect. Thirdly thin and fragile dentine walls are liable to fracture. Fourthly there is risk of extending materials beyond apex. Three techniques are reported to obdurate an immature tooth which involved the use of a root filling material without the induction of the apical closure, as placement of large gutta-percha or customized guttapercha cone with sealer at the apex, placement of gutta-percha with sealer short of apex and periodical surgery.[4] These techniques does not provide apical barrier. The traditional approach to treat immature apex is apexification.

Apexogenesis/ vital pulp therapy -The terminology given by Walton and Torabinejad. " Apexogenesis is defined as treatment of a vital pulp in an immature tooth to permit continued root growth and apical closure. A vital pulp of an immature tooth may have a small exposure after trauma." – Ingle. " Physiologic root end development and formation" according to American Association of Endodontists in 1981. The procedure encourages normal root & apex formation of pulpally involved, vital permanent teeth with immature root development was given by AAPD Guidelines 1998.

INDICATIONS of Apexogenesis are immature tooth with incomplete root formation and damage to the coronal pulp with a presumed healthy radicular pulp. No formation of abscess, excessive hemorrhage, and no foul odor from the tooth involved and the radiographic appearance is normal. There should be absence of sensitivity to percussion and no abnormal responses to thermal stimuli. CONTRAINDICATIONS of Apexogenesis are avulsed and replanted or severely luxated tooth. Severe crown root fracture that requires intraradicular retention for restoration. Tooth with an unfavorable horizontal root fracture i.e. close to the gingival margin. Carious tooth that is unrestorable.[4]

Apexogenesis ranges between 1 and 2 years. The patient should be recalled at 3-monthly intervals in order to determine the vitality of the pulp and the extent of apical maturation and tooth development. If it is determined that the pulp has become irreversibly inflamed or necrotic, or if internal resorption is evident, the pulp should be extirpated and apexification therapy is initiated. To maintain the pulpal vitality, the remaining odontoblasts are allow to lay down dentin, producing a thicker root and decreasing the chance of root fracture. It promote root end closure, thereby allowing a natural apical constriction for root canal filling. Apexogenesis generate a dentinal bridge at the site of pulpotomy.

Apexification

Apexification (root end closure):

According to American Association of Endodontists 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 incomplete root in teeth with necrotic pulp.

Apexification term is defined as " a method to induce a calcified barrier in a root with open apex" . The infected necrotic pulp is removed up to the apex by means of mechanical debridement and antiseptic chemical irrigation. Apical hard tissue barrier formation following apexification is reparative process of the dentine-pulp complex. Root development continues in immature permanent tooth with infected necrotic pulps and apical periodontitis after apexification procedure with calcium hydroxide

 Indications of apexification
 Immature teeth with an infected pulp
 No history of spontaneous pain No sensitivity on percussion
 No haemorrhage
 Teeth must be ultimately restorable
 No vertical or horizontal root fracture
 No radiographic evidence of replacement resorption (ankylosis)
 Root length must be approximately half or more established
 Periapical radiolucency

Contraindications of apexification
 Purulent drainage
 History of prolonged pain
 Very short roots
 Marginal periodontal breakdown
 Vital pulp

Apexification requires the chemo-mechanical debridement of the canal followed by placement of an intracanal medicament to assist or stimulate apical healing and formation of a horizontal apical barrier at the apical end of the root canal to facilitate the subsequent obturation of the canal without voids and excess material in the periapical tissue.

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

Materials which can be used in apexification are amalgam, glass ionomer cement, composite, mineral trioxide aggregate, calcium hydroxide powder, freeze dried bone/dentin, resorbable ceramic, tricalcium phosphate, dentinal shavings.

Calcium hydroxide (multiple visit) apexification

Calcium hydroxide described by Hermann in 1930 as a pulp capping agent. Studies have been carried out confirming its bactericidal efficacy and in turn its ability to promote healing and the formation of a hard tissue barrier. These effects are directly related to calcium hydroxide's alkaline pH of 12.5, Calcium hydroxide also has the ability to dissolve necrotic pulp tissue. Apexification does not promote continued root development while calcium hydroxide has been shown to cause dentine brittleness via its proteolytic and hygroscopic properties. Andreasen et al. reported that long-term calcium hydroxide dressings could increase the risk of root fracture, hypothesizing that the high pH produced by the hydroxyl ions have a detrimental effect on the organic support (denaturation and dissolution of protein) of dentine. Therefore, although some disadvantages do exist with the multiple visit calcium hydroxide apexification technique, the clinician should bear in mind it is, to date, a technique which has been scrutinized and assessed for many years. It is a reliable and simple technique to carry out and therefore should not be readily dismissed as newer materials or techniques are proposed – the clinician should continue to consider and offer it as a treatment option.[5]

MTA apical barrier (single visit) apexification

MTA was initially proposed as an 'apical plug' in apexification cases in 1999. The authors at the time suggested that following 1 week with calcium hydroxide dressing, 3– 4 mm of MTA be placed apically with pluggers and paper points. MTA is composed of calcium silicate, bismuth oxide, calcium carbonate, calcium aluminate and calcium sulfate, and when mixed with water or saline is made up of 33% calcium, 49% phosphate, 2% carbon, 3% chloride and 6% silica. MTA takes up to 3 hours to set, has excellent sealing properties, is biocompatible and has the ability to set in a moist environment. Additionally, when set MTA comes into contact with fluid, calcium hydroxide is released. Friedland and Rosado deduced that this was the reason that MTA formed a hard tissue barrier similar to calcium hydroxide. As a result, MTA has been proposed as an excellent material in apexification cases.

Material used to induce Apexification in teeth with immature apices, Calcium hydroxide in the pulpless tooth was first reported by Kaiser in 1964[1]. Other medicaments used are Tricalcium phosphate, Collagen calcium phosphate, ResorbableTricalcium phosphate, Mineral trioxide aggregate, Biodentine, Bone morphogenic proteins.

In traditional method of apexification- Pure calcium hydroxide powder is mixed with sterile saline to a thick consistency. The calcium hydroxide is packed against the apical soft tissue with a plugged. This step is followed by backfilling with calcium hydroxide to completely fill the canal. The excess is removed from access cavity to level of the root orifices, and a well-sealing temporary restoration. A radiograph is taken in order to evaluate formation of hard tissue barrier.

Apexification using MTA provides an alternative treatment modality in immature pulpless, requires significantly less time. It has been used in both surgical and non-surgical applications including root end fillings, direct pulp caps perforation repairs in roots or furcations and apexification.

MTA has superior biocompatibility and sealing ability and is less cytotoxic than other materials currently used in pulpal therapy. The 5-mm barrier is significantly stronger and shows less microleakage as compared to the 2-mm barrier of MTA.

Currently MTA is available in two forms – white and gray MTA. Gray MTA was introduced but because of its discoloration white MTA was introduced. The tri mineral cement available now are used for revascularization.

Biodentine is a new bioactive dentin substitute cement. It is avalaible in a powder-liquid system; powder composed of Tri-calcium silicate, Di-calcium silicate, Calcium carbonate and oxide, Iron oxide, Zirconium oxide. Liquid consist of Calcium chloride, Hydro soluble polymer. Biodentine has some superior features than MTA. Biodentine ensures a better handling and safety than MTA. Biodentine may have more biomineralisation ability than MTA. The mechanical properties of Biodentine are similar to those of natural dentine. The major disadvantage of biodentine is its high alkalinity which induces denaturing of the organic matrix[3].

EndoSequence is a novel bioceramic material. It has a working time of more than 30 minutes and a setting reaction initiated by moisture with a final set achieved in approximately 4 hours. It is composed of calcium silicates, zirconium oxide, tantalumoxide, 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. Endosequence root repair material simulates tissue fluid, phosphate buffered saline and results in precipitation of apatite crystals that become larger with increasing immersion times concluding it to be bioactive.[3]

The current treatment defines regenerative endodontics as " biologically-based procedures designed to physiologically replace damaged tooth structures, including dentin and root structures, as well as cells of the pulp-dentin complex." Regenerative endodontics is a treatment revolution in dentistry- the era in which root canal therapy brings diseased teeth back to life, rather than leaving a " non- vital" or dead tooth in the mouth.

Revascularization 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, or equivalent over blood clot with a final restoration and follow-up at regular intervals. Revascularization can be carried out with or without the formation of blood clot. Hemorrhage is induced by over instrumentation into the remaining pulp tissue or periapical tissue. This procedure induces bleeding into the canal and the bleeding is left for 15 minutes so that the blood would clot in the canal and stopped at a level 3mm below CEJ. MTA is then placed over the blood clot. When these factors are isolated, then they are incorporated into a synthetic scaffold. Once the intracanal infection is controlled and a physical scaffold to promote cell growth and differentiation has been achieved, next important step is coronal seal to prevent reinfection. Patient is then recalled after 2- 3 weeks, if the tooth is asymptomatic then the temporary filling material and the cotton pellet is replaced with a bonded resin restoration or glass ionomer cement. The tooth should be followed up periodically to observe the maturation of the root. If no signs of regeneration are present after 3 months, then more traditional treatment methods can be initiated.[5]

Regeneration of tissue from cells in teeth itself.

Basically, body tissue is composed of two components: cells and the surrounding environment. The latter includes the ECM for cell proliferation and differentiation (natural scaffold). The revascularization method assumes that the root canal space has been disinfected and that the formation of blood clot yields a matrix (e.g., fibrin) that traps cells capable of initiating new tissue formation. It is different from apexification because not only the apex is closed but the canal walls are thicker as well. It is also different from apexogenesis which also accomplishes a closed apex and thicker dentinal walls, but, by the use of remaining vital root pulp.

The success of root canal revascularization is mainly due to the following facts: firstly, the immature avulsed tooth has an open apex, short root and intact but necrotic pulp tissue.. The speed with which the tissue completely revascularizes the pulp space is important because bacteria from outside are continually attempting to enter the pulp space. Thus, the race between proliferation of new tissue and infection of the pulp space favors the new tissue. Secondly, minimum instrumentation preserves viable pulp tissue which contributes to further development of open apex root. Thirdly, young patients have greater healing capacity and more stem cell regenerative potential.

The treatment of an immature tooth is a challenge. Difficulties with the stage in treatment present of many choice and strategies of treatment outcome. To overcome the challenges thorough knowledge of the root morphology and treatment options is important. The success of this treatment result from antibacterial and calcification inducing action of suitable materials. Recent advances like regeneration and stem cells have come into treatment options. With the advances in current research in this area will provide greater clarity with gene analysis and bring us closer to the therapeutic use of dental stem cells in clinical practice in future.

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