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Revascularization: An update

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Abstract
The management of necrotic immature, permanent teeth presents a clinical challenge because of incomplete root development, unfavourable 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. Conventionally, tooth that has lost its vitality is being treated by apexification. Through this technique, the formation of an apical barrier to close the open apex is promoted so that the filling materials can be confined to the root canal but it involves long-term periodic exchanges of calcium hydroxide paste into canal which may lead to weakening of the canal and tooth fracture. Recently, revascularization is introduced as a new treatment modality for immature non-vital teeth. Revascularization not only provides apical closure but also increases the dentine wall thickness. As there is diversity in the treatment protocol for revascularization, it is pivotal to describe and discuss these protocols guiding researches in this field and thereby providing the clinicians to succeed in the treatment of non-vital tooth with immature apex. Hence, the present review aims to provide complete protocol on revascularization.

Keywords: immature teeth, regenerative endodontics, revascularization

Introduction

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 trauma is another common etiological factor, with incidence of trauma to permanent teeth in adults of 33%. Trauma can completely or partially discontinue the apical blood supply of the traumatized tooth via displacement or crushing the surrounding blood vessels. If the apical blood supply cannot be re-established or is inadequate, pulp necrosis will occur [1].

The treatment of young permanent non-vital immature tooth still presents multiple challenges in pediatric and endodontic dentistry. Conventional endodontic treatment using standard mechanical instrumentation and irrigation has been proven ineffective to achieve proper cleaning and disinfection of the overall dentin wall, particularly at the diverged apex [2]. Furthermore, an inadequate apical seal in such cases is a major problem during a conventional nonsurgical endodontic approach. The presence of thin apical root thickness creates a significant risk of root fracture under occlusal forces [3]. The traditional management of such cases includes an apexification technique using calcium hydroxide or mineral trioxide aggregate (MTA) and biodentine. This technique is successful in including apical closure; however, there is no expectation of root lengthening [4].

Recently, 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) [5].

The stem cells from apical papilla (SCAP) are capable of differentiating into odontoblast-like cell-forming root dentin. Another type of mesenchymal cells, which are called dental pulp stem cells (DPSCs), were discovered, to have the ability to differentiate into odontoblast-like cells and form pulp/dentine-like complex. Thus, the concept of revascularization has been used to form the vital tissue inside the root canal [5]. Hence present

review of literature provides complete overview on concept of revascularization.

Pulp Revascularization Concepts

There are a number of theories that explain the mechanism of revascularization. The periradicular zone of immature young permanent teeth has many multipotent periodontal cells which have great potential to differentiating into new fibroblast and cementoblasts [6]. Hence, it has been suggested that differentiated cementoblasts and fibroblast are responsible for increasing dentinal walls and apical closure [7]. A second possibility involves the in growth of SCAP (Stem cell from apical papilla) that could proliferate inside root canals through the blood induction of periapical tissues, since these cells have high proliferative capacity, probably being transported inside root canals in association with bleeding induced from the periapical tissue [6]. The third possible mechanism could be attributed to the presence of stem cells in the periodontal ligament which can proliferate, grow into the apical end and within the root canal, and deposit hard tissue both at the apical end and on the lateral root walls [7]. In addition to the above mentioned hypothesis, various growth factors incorporated in the blood clot and/or dentine may play an important role in the cell proliferation inside the root canal space. Finally, the root anatomy of immature teeth (e.g., presenting open apex, wide root canal, and thin radicular dentine walls) may favour the communication of the canal space and periodontal tissue to achieve apical healing with periodontal tissue. With regard to the apical opening, revascularization seems to be more predictable when the apical diameter is >1 mm and is unlikely to occur in apical openings narrower than 0.3 mm [5].

Table 1: Landmarks in Revascularization

1961	Concept was first introduced by Ostby.
1966	Rule and Winter documented root development and apical barrier formation in cases of pulpal necrosis in children.
1972	Ham *et al*. demonstrated apical closure of immature pulpless teeth in monkeys.
2001	Iwaya *et al*. demonstrated the advantages of this treatment modality, which resulted in a radiographically apparent normal maturation of the entire root.
2004	Banchs and Trope et al. published a case report of a new treatment procedure for management of open apex called "revascularization."

Rationale of Revascularization

According to Windley *et al*. (2005) [8], the successful revascularization of immature teeth with apical periodontitis is mainly dependent upon:

1. Canal disinfection:
2. Scaffold placement in the canal for the growing tissues:
3. Bacteria-tight sealing of the access aperture:

Protocol for Revascularization

Case selection: Currently, there is no evidence-based guideline to help clinicians determine which condition of cases can be treated with this conservative approach. It has been reported that pulp revascularization can occur most predictably in teeth with open apices. An apical diameter of at least 1 mm (mesiodistally) radio graphically is necessary to allow in growth of vital tissue. The presence of a Periradicular radiolucency or a negative vitality test are not determining factors in case selection as vital pulp tissue or apical papilla may be present in the canal and at the apex [9].

Clinical Procedure

Based on disinfection method pulp revascularization techniques can be of two types: One using calcium hydroxide and second is by using a triple antibiotic paste. Both are two visit procedures [10]. Second visit takes place 2 or 3 weeks after the first one, only if the tooth is asymptomatic and if there is a visual reduction of the apical lesion. In pulp revascularization, at 3 months post-operative, the tooth is normally asymptomatic, and about 9 months later, X-ray radiography shows an increasing thickness of dentinal walls and an apical closure. Root development and apical closure may be visible after 3 months [11].

First Appointment

During the first visit, minimal instrumentation and irrigation with 2.5% sodium hypochlorite for over 20 min after excavation of the coronal pulp [12]. Over instrument could not only increase the fragility of dentin walls but also injure stem cells present in the apical area of these dentin walls. These also contain growth factor imprisoned during dentinogenesis. Growth factor and other cells essential for the regeneration process could also eliminated by instrumentation. Most of authors agree to advocate no instrumentation procedure [5].

Disinfection with copious irrigation, and with the use of the calcium hydroid or "3 mix-MP" triple antibiotic paste, consisting of equal quantities of ciprofloxacin, metronidazole, and minocycline (concentration = 20 mg/ml) in propylene glycol or macrogol ointment (as a carrier), for a period of 3 weeks [12, 13].

Table 2: Different intracanal substances used for Disinfection in literature [14]

Author	Substance
Aggarwal	Calcium hydroxide, Metronidazole, Ciprofloxacin, Minocycline
Lenzi and Trope	Metronidazole, Ciprofloxacin, Minocycline, Saline
Pramila and Muthu	Metronidazole, Ciprofloxacin, Minocycline
Rule and Winter	Polymix B sulphate, Neomycin sulphate, Bacitracin, Nystatin
Jadhay	Metronidazole, Ciprofloxacin, Minocycline
Prabhakar AR	Ciprofloxacin, Metronidazole, and Minocycline
Kvinnsland	Calcium hydroxide + IRM

Second Appointment

Before initiating the revascularization procedure patient is evaluated for any signs and symptoms of an acute infection (swelling, pain, sinus tracts etc). The antimicrobial treatment is repeated if resolution has not occurred. Anesthesia without vasoconstrictor is used which will facilitate the ability to induce bleeding into the canal, following isolation and reestablishment of coronal access, tooth should be copiously and slowly irrigated with NaOCl and saline, with gentle agitation with a small file to remove antimicrobial paste. Dry the canal with sterile paper points [13]. Haemorrhage is induced by over instrumentation with either endodontic files or an endodontic explorer penetrating slightly into the remaining pulp tissue or periradicular tissue. This procedure induces bleeding into the canal, and the bleeding is left for 15 min so that the blood would clot in the canal and stopped at a level 3 mm below CEJ. MTA is then placed over the blood clot [5, 11].

Coronal Barrier

MTA is known for its excellent biocompatibility and sealing ability. Once the blood clot is formed within the root canal MTA is placed carefully over the clot [15]. A small piece of Collacote may be placed at the pulp chamber to support the MTA which has to be placed over it. This is followed by the placement of a wet cotton pellet and temporary restorative filling. The patient is then recalled after 2–3 weeks, and if the tooth is asymptomatic, then the temporary filling material and the cotton pellet are replaced with a bonded resin restoration or glass ionomer cement [5].

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].

Merits of Revascularization [9, 13]

1. Root canal revascularization through blood clotting is a relatively simple and practical approach, which can be accomplished with presently available instruments and materials.
2. Obturation of the canal is not required unlike in calcium hydroxide–induced apexification, thus eliminates the chance for root fracture during lateral condensation.
3. Achieving continued root development (root lengthening) and strengthening of the root as a result of reinforcement of lateral dentinal walls with deposition of new dentin/hard tissue.

Demerits of Revascularization [16, 17]

1. Number and type of the progenitor/stem cells entrapped in the fibrin clot is unpredictable, particularly in older patients and may lead to the disparity in the result.
2. Another disadvantage is revitalized tooth may susceptible to further pulp disease and may require retreatment, It is possible that the entire canal might be calcified, compromising aesthetics and potentially increasing the difficulty in future endodontic procedures if required
3. Potential risk of necrosis, if tissue is reinfected.
4. Long-term clinical results are as yet not available, and source of regenerated tissue has not been identified.
5. Difficult to achieve it in fully formed permanent teeth.
6. The revascularization method assumes that the formation of a blood clot yields a matrix that traps the cells capable of forming new tissue.

Conclusion

In conclusion, revascularization induced maturogenesis, can provide several advantages over conventional apexification procedures. It is a technically simple treatment with advantageous outcomes because, unlike apexification, it promotes thickness of the dentin wall width and apical closure, avoiding weakening of the tooth. A detailed histopathological study is necessary to demonstrate the actual contents of pulp space after revascularization procedures.

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