REVASCULARIZATION – AN OVERVIEW

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Abstract

An immature tooth with early irreversible pulp involvement presents with thin divergent or parallel dentinal walls. This situation creates clinical challenges in disinfection, and as a result, affects the long-term outcome of the treatment. Traditionally, calcium hydroxide has been used as the intra-canal medicament in apexification procedures. However, because of its high pH it will cause necrosis of tissues that can potentially differentiate into new pulp. Moreover, even if rendered successful, apexification procedures will leave a short root with thin dentinal walls with a high risk of root fracture.

Revascularization of a pulp-like tissue for dentine deposition will allow further development of the root and dentinal structure with a better long-term prognosis. The regenerative potential of dental pulp, particularly in immature teeth, has been considered extremely limited. However, improved understanding of pulpal inflammation and repair and improved dental materials and technologies make vital pulp therapy a viable alternative to root canal treatment.

Revascularization could be effective for managing immature permanent teeth with apical periodontitis. This article explores our knowledge in this regard and the future potential of saving or even regenerating the pulp as a routine dental procedure.

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Introduction

The traumatic injury of an immature permanent tooth can lead to the loss of pulp vitality and arrested root development. The consequences of interrupted development include a poor crown-root ratio, a root with very thin walls, an increased risk of fracture and an open apex[1]. The traditional endodontic management of such cases typically include debriding the root canal, disinfecting the space, and final obturation of the system proceeded either by an apexification procedure or by developing an apical barrier by using materials such as MTA[2].

The clinical procedure for apexification consists of applying calcium hydroxide as an intracanal medicament to induce an apical closure over time, this procedure has certain predictability of success, but it has the disadvantage of the necessity of multiple visits during a relatively long period of time (an average of 12 months) and the fact that there is no expectation that the root canal walls will be strengthened[3].

An alternative to traditional apexification is to place an artificial barrier at the apex to prevent the extension of filling material during obturation. The material of choice is MTA for its sealing ability and its biocompatibility. This latest technique is convenient because it is faster than the traditional apexification. This procedure can be completed within 2 appointments and a hard

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tissue barrier eventually forms against the MTA. However, even this alternative approach has the same dis-advantage of a tooth with thin dentinal walls and no further root development[4].

A novel concept of revascularization of immature nonvital, infected teeth was recently introduced. The concept of revascularization was introduced by ostby in 1961 and in 1966, Rule and winter documented root development and apical barrier formation in cases of pulpal necrosis in children. In 1972, Ham et al demonstrated apical closure of immature pulpless teeth in monkeys[5].

The development of normal, sterile granulation tissue within the root canal is thought to aid in revascularization and stimulation of cementoblasts or the undifferentiated mesenchymal cells at the periapex, leading to deposition of a calcific material at the apex as well as on the lateral dentinal walls. In 2001, Iwaya et al and in 2004 Banchs and Trope demonstrated the advantages of this treatment modality, which resulted in a radiographically apparent normal maturation of the entire root versus an outcome of only a calcific barrier formation at the apex after conventional calcium hydroxide induced apexification[6].

The ideal treatment to obtain further root development and thickening of dentinal walls in an immature tooth with apical periodontitis would be to stimulate the regeneration of a functional pulp-dentin complex. This outcome has been observed after reimplantation in avulsed immature permanent teeth. It has been proposed that reimplantation of the tooth with an open apex permits coronal proliferation of tissue, leading to replacement of the necrotized pulp and subsequent continued development of the root. Although the histologic identity of this pulp-like tissue is generally unknown, radiographic presentation often includes progressive thickening of the dentinal walls and apical closure[7].

This approach involves the use of an antibiotic paste to disinfect the canal, and, after which, no artificial materials were used to fill the canal space. This allows the vital tissue to regenerate in the canal space. Although an apexification procedure has been used by clinicians for decades, this new approach that is more conducive to tissue regeneration has been considered to be a better option for dealing with immature teeth with nonvital pulp and even for cases with severe periapical infection[8].

Reports have shown that even the immature permanent tooth with non-vital pulp and apical periodontitis can undergo pulp regeneration or revascularization. Because the term regeneration is based on clinical and radiographic outcomes and not histologic or biochemically based assessments, one can only make a clinically functional interpretation of the healing process. It is not known whether a complete pulp-dentin complex has been regenerated. However, once the regeneration protocol is completed, these teeth can continue to develop, with the radiograph presentation of full tooth development and the clinical presentation of an asymptomatic functional tooth[9].

An empty canal space will not support in growth of new tissue from the peri-apical area on its own[10]. Early studies on attempted revascularization used blood or blood substitutes to act as a scaffold to aid the in-growth of new tissue into the empty canal space. Revascularization research has also studied collagen solutions as artificial scaffolds in the canal space. A series of studies using bovine collagen with crystals of calcium and phosphate, as nucleation centers for hydroxyapatite formation, achieved some revascularization success; however, most of his work used teeth with vital pulps[11].

Procedure

The typical revascularization protocol advocates that the immature tooth, diagnosed with apical periodontitis, should be accessed and irrigated with either 5% NaOCl + 3% H_2O_2 or 5.25 % NaOCl and PeridexTM[12]. An antimicrobial agent (either an antibiotic such as metronidazole + ciprofloxacin [12] or ciprofloxacin + metronidazole + minocycline[13] or $CaOH_2$ [7]) should be then applied into root canal system, and the access cavity is sealed. After an average of 3 weeks, in the absence of symptoms, the tooth is re-entered, the tissue is irritated until bleeding is started and a blood clot produced, and then MTA is placed over the blood clot, and the access is sealed. Within the next 2 years a gradual increase in root development can be observed[2].

Mechanism of revascularization

It is possible that a few vital pulp cells remain at the apical end of the root canal[5]. These cells might proliferate into the newly formed matrix and differentiate into odontoblasts under the organizing influence of cells of hertwig's epithelial root sheath, which are quite resistant to destruction, even in the presence of inflammation. The newly formed odontoblasts can lay down atubular dentin at the apical end, causing apexogenisis, as well as on lateral aspects of dentinal walls of the root canal, reinforcing and strengthening the root[14].

Another possible mechanism of continued root development could be due to multipotent dental pulp stem cells, which are present in permanent teeth and might be present in abundance in immature teeth. These cells from the apical end might be seeded onto the existing dentinal walls and might differentiate into odontoblasts and deposit tertiary or tubular dentin[15].

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. The evidence in support of this hypothesis is presence of cementum and Sharpy's fibers in the newly formed tissues[16].

The fourth possible mechanism of root development could be attributed to stem cells from the apical papilla or the bone marrow. Instrumentation beyond the confines of the root canal to induce bleeding can also transplant mesenchymal stem cells from the bone into the canal lumen. These cells have extensive proliferating capacity[17].

Another possible mechanism could be that the blood clot itself, being a rich source of growth factors, could play an important role in regeneration. These include platelet-derived growth factor, vascular endothelial growth factor (VEGF), platelet-derived epithelial growth factor, and tissue growth factor. They stimulate differentiation, growth, and maturation of fibroblasts, odontoblasts, cementoblasts, etc from the immature, undifferentiated mesenchymal cells in the newly formed tissue matrix[6].

Discussion

Regeneration of tissues rather than replacement with artificial substitutes is an emerging and exciting field in the health sciences. Revascularization of infected, nonvital, immature teeth has been documented to stimulate regeneration of apical tissues and to induce apexogenesis and is emerging as a new treatment modality for such teeth. It was earlier unthinkable that the tissue in the periapical region of a nonvital infected tooth could regenerate. Therefore, a classic treatment option for such teeth was to perform surgical endodontic procedure to seal the wide-open, often blunderbuss apical opening. Although success can occur by using a surgical approach with retrograde seal, there are disadvantages. It is an invasive procedure with its accompanying short comings, including possibility of surgical complications as well as increased cost of treatment and possibility of surgical complications as well as increased cost of treatment and possible psychological distress, especially in children. Surgical treatment might also lead to a compromised crown:root ratio in a tooth already weakened as a result of immature root development[6].

Revascularization is the procedure to reestablish the vitality in a nonvital tooth to allow repair and regeneration of tissues. The rationale of revascularization is that if a sterile tissue matrix is provided in which new cells can grow, pulp vitality can be reestablished. Revascularization protocols are derived from the observations of reimplanted and autotransplanted teeth in experimental animals in which necrotic pulp, if free of infection, provided a matrix into which the cells from the periapical tissues could grow and reestablish pulp vascularity, slowly replacing the necrotic tissue. In immature, infected, nonvital teeth, infection control is achieved with minimal instrumentation, depending more on aggressive, copious irrigation with sodium hypochlorite, chlorhexidine, or povidone-iodine[18].

Some authors have suggested the use of ciprofloxacin and metronidazole paste[13] or calcium hydroxide paste[7] to control the infection.

The advantages of pulp Revascularization lie in the possibility of further root development and reinforcement of dentinal walls by deposition of hard tissue, thus strengthening the root against fracture.

It requires a shorter treatment time; after control of infection, it can be completed in a single visit. It is also very cost-effective, because the number of visits is reduced, and no additional material (such as TCP, MTA) is required.

Obturation of the canal is not required unlike in calcium hydroxide induced apexification, with its inherent danger of splitting the root during lateral condensation. However, the biggest advantage is that of 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.

Though, there are few limitations of revascularization. Long-term clinical results are as yet not available. It is possible that the entire canal might be calcified, compromising esthetics and potentially increasing the difficulty in future endodontic procedures if required.

In case post and core are the final restorative treatment plan, revascularization is not the right treatment option because the vital tissue in apical two thirds of the canal cannot be violated for post placement.

The notion that successful regeneration depends on a race between the new tissue and bacteria populating the pulp space is strengthened by the fact that the incidence of Revascularization is enhanced if the apex shows radiographic opening of more than 1.1 mm and the tooth is replanted with in 45mins[5].

Successful Revascularization of the pulp canal and continued root formation of immature teeth have been demonstrated after appropriate root canal disinfection and the presence of a blood clot in the canal for human and in animals. The blood clot acts as a scaffold for tissue ingrowth[11].

An empty tube will not support the ingrowth of tissues from the periapical region. Thibodeau et al showed that roots containing a blood clot after disinfection had better treatment outcomes in a dog model than those that did not have a blood clot in the apical part of the canal. Besides acting as a scaffold, the blood clot might also contain growth and differentiation factors that might be important for successful revascularization of the empty pulp canal.

All cases of unfavorable revascularization outcome apparently were related to a failure to induce any bleeding in the canal.

The absence of a blood clot has been shown to have a negative impact on successful revascularization of the pulp. A series of cases reported by Rui Yu Ding et al, showed an increased root lengths and narrowing of the canal space. However, it remains uncertain whether the thickened canal wall was actually made up of dentin.

Conclusions

Revascularization of the pulp of immature permanent teeth with apical periodontitis is a clinical possibility; a treated tooth might even respond normally to electric pulp test after about a year. This treatment modality should be preferred to the traditional apexification.

Declaration of Interest

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