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Pulp Revascularization: A Review

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Abstract

Endodontic treatment of immature teeth is challenging to the clinicians because of the open apex of the root canal. The conventional treatment can control infection, while the root development usually remains impaired. Therefore, a regenerative endodontic procedure, the pulp revascularization method has emerged in which a new tissue is expected to be formed from the tissue present in the teeth, allowing for the continuation of the development of the root and at the same time reducing the chances of root fracture during the obturation.

Keywords – ***APEXIFICATION, APEXOGENESIS, PULP REVASCULARIZATION***

I. INTRODUCTION

Traumatic dental injuries (TDI) comprises 5% of all injuries for which people seek treatment.These are most common amongst young children with great frequency in preschoolers, school-age children, and young adults.[1,2] The traumatic injury of an immature permanent tooth can cause pulpal necrosis and interrupted root development.[3] The results of arrested root development are a poor crown-root ratio, a root with very thin walls, an increased risk of fracture, and an open/blunderbuss apices. Open apex can also occur as a result of pulpal necrosis due to caries before the completion of root development.[4] It can also form in a mature root as a result of extensive apical resorption due to orthodontic treatment, inflammatory root resorption, and periradicular surgery. Hence, management of permanent anterior teeth with necrotic pulp with/without apical closure poses a challenge to endodontists.[5]

The conventional treatment to treat open apex teeth can be successful with parallel canal walls where modified obturation techniques can be used by manipulating gutta-percha points without creating an apical barrier (parallel canal wall). These modifications include blunted tip, inverted cones, apical impression heat chemicals, roll cone heat chemicals, heat polymerized polymethyl methacrylate (PMMA) resin.[6,7] Many difficulties were encountered during such treatment because of divergent walls such as the thin fragile lateral dentinal walls could fracture during mechanical filling, due to wide root canal containing large volume of necrotic debris was difficult to disinfect completely and the technique required precise fabrication of gutta-percha cone and root might split during lateral condensation.[8] Hence, a new technique called Apexification technique was introduced for the pulpless teeth and which promoted apical closure by the insertion of a MTA (Mineral Trioxide Aggregate) barrier or with periodical exchanges of calcium hydroxide, enhancing further obturation. This process was named as apexogenesis and its goal targeted at the preservation of vital pulp tissue so that the continued root development with apical closure would occur.[9]

The American Association of Endodontists defined this therapy as a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incompletely formed root in teeth with necrotic pulp.[10] Despite the fact that this technique stimulated apical barrier formation but due to the thin dentin walls due to the thin dentin wall, the teeth were more susceptible to root fractures.[11] Recently, as a promising alternative to apexification, regenerative endodontic procedures have been emerged due in particular to advantages like root development and reinforcement which prevented root fractures by increasing the root length and thickening the dentin wall.[12]

The regenerative endodontic treatment of nonvital infected teeth takes place in two ways:

(a) Tissue engineering technology: characterized by the active regeneration of the dentin-pulp complex in order to implant or regenerate the pulp.

(b) Pulp revascularization: a procedure in which a new tissue is expected to be formed from the tissue present in the teeth, allowing for the continuation of the development of the root.[13]

II. HISTORICAL ASSOCIATION OF REVASCULARIZATION

Revascularization concept was first introduced by Ostby in 1961 [14] and Rule and Winter in 1966 [15]documented root development and apical barrier formation in cases of pulpal necrosis in children. Ham *et al*. in 1972 [16] cited the apical closure of immature pulpless teeth in monkeys. Iwaya *et al.*in 2001 [17] and Banchs and Tropein 2004 [18] demonstrated the advantages of this treatment modality that resulted in a radiographically apparent normal maturation of the entire root. Pulp revascularization is described as a regenerative treatment of necrotic immature teeth that involves inducing the formation of a blood clot within the previously disinfected canal, by involving the recruitment of stem cells from the apical region. [19]

Regeneration of tissue comparable to pulpal tissue and to reactivate dentinogenesis is the key objective of this therapeutic approach which will become non-existent following the necrosis of pulp tissue, and subsequently allowing the development of the root. [20]

III. CONCEPT OF PULP TISSUE REGENERATION

Two possible approaches are described to explain the pulpal tissue regeneration. The first being revascularization that is defined as the invagination of undifferentiated periodontal cells from the apical region in immature teeth. Hence, a new pulp tissue is expected to grow into the root canals from the remaining tissues that exist apically in the root canal.[18] The second concept explains the replacement of the diseased pulp with a healthy tissue that is able to revitalize the tooth and thereby, restore formation of dentin. The stem cell therapy, gene therapy, three-dimensional (3D) cell printing, scaffold implantation, and pulp implantation are suggested for this approach.[21,22]

In the procedure of pulp revascularization of a necrotic tooth induction of blood clot which consists of cross-linked fibrin act as a scaffold. It serves as a pathway for the migration of regenerative cells into the root canal space. These cells differentiate into odontoblasts and deposit hard tissue both at the apical end and lateral root walls. [23]

IV. THE ORIGIN OF REGENERATIVE CELLS RESPONSIBLE FOR REVASCULARIZATION

Regenerative cells may develop from vital pulp cells present at the apical end of the root canal. These cells might differentiate into odontoblasts under the influence of cells of Hertwig's epithelial root sheath.[24] The possible mechanism of continued root development could be due to following theories. Firstly, because of multipotent dental pulp stem cells, which are 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 hence, deposit tertiary or a tubular dentin.[25] Secondly, due to the presence of stem cells in the periodontal ligament which can proliferate, grow into the apical end 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 presented by documentation of cementum and Sharpe's fibres in the newly formed tissues.[26,27] Thirdly, due to the presence of 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 transplantation studies have shown that human stem cells from bone marrow can form bone or dentin in vivo.[28,29] Lastly, it could be because of the blood clot itself, being a rich source of growth factors, could play an important role in regeneration. These growth factors include platelet derived growth factor, vascular epithelial growth factor (VEGF) Platelet derived growth factor which could stimulate differentiation, growth and maturation of fibroblasts, odontoblasts, cementoblasts etc from the immature and undifferentiated mesenchymal cells in the newly formed tissue matrix. [30]

V. RATIONALE OF REVASCULARIZATION

Windley *et al*. [31] documented that following factors are essential for the successful revascularization of immature teeth with apical periodontitis. 1. Canal disinfection: being regarded as a key factor for successful treatment. 2. Scaffold placement in the canal for the growing tissues: Once canal disinfection has been completed, the apex is mechanically irritated to induce clot formation, which will serve as a scaffold for tissue generation. 3. Bacteria-tight sealing of the access aperture: the access cavity is restored using a material that seals it against bacteria. The revascularization technique depends on the induction of bleeding through the open apical foramen into the chemically cleaned canal. The canal dentin and the blood clot provide scaffolds in the root canal revascularization. More recently, platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) are suggested as further possible scaffolds .[22]

INDICATION for pulpal revascularization is currently limited to immature teeth, but this treatment has been successful in some cases, performed on mature teeth. [32]

VI. CLINICAL STEPS IN PULP REVASCULARIZATION

Although there is no standard protocol for pulp revascularization technique, various clinicians have used different methods for the same. There are mainly two main steps for the pulp revascularization protocol. The first one called disinfection and a second one called regeneration.

For disinfection purpose, mixture of antibiotics which were initially recommended (metronidazole, ciprofloxacin, and minocycline) is now no longer advisable to use. This blend has an indisputable bactericidal effect but with certain side effects such as development of resistance, staining etc. make the benefit/safety ratio unfavourable to their use. Disinfection is now achieved with both low sodium hypochlorite irrigation at a low concentration of 1.5% and intra channel calcium hydroxide medication left in place for 15 days. Two to three weeks later, the regeneration step is performed, and after removal of the medication, the root canal is rinsed with a solution of sodium hypochlorite at 1.5%; then with a solution of EDTA at 17%, left in place for two minutes. This EDTA treatment will eliminate the first layer of dentin, the one which was in contact with sodium hypochlorite and which is contaminated by residual chlor, the latter being toxic to future cells; and on the other hand, EDTA will release the intrinsic growth factors of dentin which will subsequently participate in the regeneration process. At the infected canal, revascularization is performed with a strongly pre-bent file that is placed beyond the foramen of the tooth, this file is then animated by a continuous rotational movement, the part of this instrument that is beyond the apex will tear the apical papilla and cause a bleeding that is allowed to rise up within the canal to the amelococementary junction. Blood clot will be formed after a few minutes and is covered with a collagen sponge before the cavity could be filled with bio dentine or MTA. [19,33-35]

ADVANTAGES TO REVASCULARIZATION APPROACH

1. 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.
2. Obturation of the canal is not required unlike in calcium hydroxide–induced apexification, thus eliminating the chance for root fracture during lateral condensation
3. From the tissue engineering perspective, pulp regeneration of mature teeth have the advantage of restoring the neurovascular system of the root canals, which provides the tooth with an immune system to defend against the microbial defiance.[19,22,36]

VII. LIMITATIONSTO REVASCULARIZATION APPROACH

The problem of the revascularization of mature teeth is that they have fewer progenitor cells than immature teeth hence, a difficulty exists in inducing bleeding, disinfection of root canal because of the closed apex which gives less chance to stem cells to migrate to the canals. Furthermore, long-term clinical results are as yet not available, and source of regenerated tissue has not been identified. Secondly, revitalized tooth may susceptible to further pulp disease and may require retreatment, It is quite possible that the entire canal might be calcified, compromising aesthetics and potentially increasing the difficulty in future endodontic procedures if required. Thirdly, 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 couldn't be violated for post placement and lastly, the revascularization method assumes that the formation of a blood clot yields a matrix that traps the cells capable of forming new tissue. But the concentration and composition of cells trapped in the fibrin clot is unpredictable. This limitation can be overcome by use of platelet concentrates. Platelet rich plasma is an ideal scaffold for revascularization. [19,22,36]

VIII. CONCLUSION

In an immature necrotic tooth revascularization can be achieved after successful vital pulp therapy. A treated tooth contains some form of vital tissue in the root canal spaces. Whether the new vital tissue is truly pulp or pulp-like is of little consequence, as long as there is continued development of the root canal walls and apex, which strengthens the tooth against future fracture. Treated tooth might even respond normally to electric pulp test after about a year. One of the most challenging aspects of developing a regenerative endodontic therapy is to understand how the various component procedures can be optimized and integrated to produce the outcome of a regenerated pulp-dentin complex. Hence, needful studies and case trials should be conducted in future to study the viability of pulp revascularisation.

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