ABSTRACT
Treatment of necrotic immature teeth has always been a challenge in endodontic, as the thin dentinal walls and open apices does not allow the cleaning and obturation of the canals by the conventional methods. Traditionally, apexification with the multiple sitting calcium hydroxide placements or the single visit artificial apical barrier technique was used, but both of these processes do not allow the continuation of root development. Thus, a new treatment protocol was proposed to treat these cases by Revascularization. Revascularization is a regenerative treatment and a biologically based alternative approach to treat necrotic immature teeth that unlike apexification allows continued root development along with increased dentinal wall thickness. There are enormous cases reported in the literature which shows that revascularization is the possible, promising and practical and valuable treatment plan. However, histological studies on human revascularized teeth and more clinical studies are recommended.

KEYWORDS Revascularization, Regeneration, Repair.

INTRODUCTION - The ideal objective of the treatment of established diseases, including the irreversible pulpitis and apical periodontitis is to restore the original architecture and biological function of the injured tissue or organ. But, it becomes a challenge, when the disease gets extensive before the complete formation of the tissue and thus, we need the treatment modality that can allow healing of the injured tissue as well as the continued development of the organ. One such challenge in endodontics is to treat an immature necrotic tooth with open apices. The traditional treatment options were the apexification with calcium hydroxide or the placement of artificial apical plug with MTA. Although these procedures can form apical plug, they do not allow the continuation of root development, which leads to fragile root structure. A more conservative approach and a shifting paradigm for the treatment of non-vital immature teeth by revascularization procedure have thus been proposed.

The procedure requires minimal or no instrumentation but copious antiseptic irrigation, disinfection of the canals and induction of intracanal bleeding to make the environment conducive for repair and regeneration. Regardless of biomaterials and techniques used in endodontic therapy, control of infection plays the most important role in regeneration and repair of the pulp. An appreciation of underlying biological processes taking place in dentin pulp complex during injury and repair, and how treatment events can modify the dentin-pulp complex, offer considerable potential for exploiting the regenerative potential of these tissues. Revascularization procedure have been shown radiographically to induce increased thickening of the canal walls by deposition of hard tissue and continued root development in immature permanent teeth with necrotic pulp and apical periodontitis / abscess.

Revascularization - rationale and mechanism of the procedure Revascularization is proposed as regenerative treatment and a biologically based alternative approach to treat necrotic immature teeth that allows continuation of root development. By definition, regeneration is the replacement of damaged tissue by the same cells with the restoration of the biological function of the injured tissue. In contrast; repair is the replacement of damaged tissue.
by different tissue such as fibrosis and scarring. The rationale of revascularization is that if a sterile tissue matrix is provided, it acts like a scaffold on which stem cells can grow and pulp vitality can be reestablished. In the necrotic immature teeth, there is possibility that a few vital pulp cells remain at the apical end of the root canal. These cells or the stem cells from the periodontal ligament/ apical papilla/bone marrow might proliferate into the newly formed matrix and differentiate into odontoblasts under the organizing influence of the cells of Her twigs’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 apexogenesis as well as on lateral aspects of the dentinal walls of the root canal, reinforcing and strengthening the root. There are 3 components contributing to the success of this procedure. They include stem cells that are capable of hard tissue formation, signaling molecules for cellular stimulation, proliferation, and differentiation, and finally, a three dimensional physical scaffold that can support cell growth and differentiation.

**The clinical procedure**

After the local anesthesia and application of the rubber dam, an access cavity is prepared on the involved tooth. The canals are properly disinfected by the copious irrigation and intra- canal medicaments. Irrigation removes about 10% of bacteria and the most commonly used irrigants for revascularization are sodium hypochlorite, sodium hypochlorite in combination with chlorhexidine, sodium hypochlorite in combination with hydrogen peroxide. The intra canal medicament provides about 70% disinfection. There are various intra canal medicaments used in different case reports like triple antibiotic paste, calcium hydroxide and formacresol. There were different protocols used for disinfection in different studies, it seems that Naocl 5.25% passive irrigation for 20 minutes followed by triple antibiotic dressing leads to favorable outcomes. Instrumentation is contraindicated, there should be minimal or no filing done. After the proper intra- canal disinfection, bleeding is induced inside the canal by irrigating the apical tissues with the sterile file, endodontic explorer, paper point or needle. Blood scaffold provides a rich source of growth factors which can help in differentiation of the stem cells and thus leads to continued root development. After the formation of blood clot, the orifice of the canal is sealed with MTA, a biocompatible sealing material, which allows the regeneration of new tissues adjacent to it and finally a double coronal seal, is provided by placing resin bonded restoration over the MTA.

**DISCUSSION & CONCLUSION**

An open apex is usually found in a developing root of an immature tooth, and apical closure takes place approximately 3 years after tooth eruption. When the pulp gets necrosed before the root development is completed, dentin formation ceases and root growth is arrested. Moreover, immature teeth that have open and often divergent apices are not suitable for complete cleaning and obturation with traditional techniques and materials. In addition, because of their thin dentinal walls, these teeth are susceptible to subsequent fracture after treatment. Therefore, teeth with necrotic pulps and immature apices often present special challenge to endodontist. Traditionally, apexification with calcium hydroxide or the artificial apical barrier with MTA was used to create the apical barrier before the obturation of the root canals. However, these procedures might not result in complete root formation and might not completely reduce the chances for root fracture. The ideal treatment outcome should be regeneration of pulp with the continuation of root development. And hence, a call for the paradigm shift and new protocol for management of these cases by revascularization procedure has been proposed. Revascularization is a regenerative treatment and a biological base alternative approach to treat necrotic immature teeth that, unlike apexification and artificial apical barrier techniques, allow continuation of root development. Revascularization is a useful procedure in the young permanent teeth because there is greater healing capacity and stem cell regenerative potential in young teeth and the open apex may foster the in growth of tissues into the root canal space. Elimination of microorganisms and necrotic tissues from the root canal system is the key factor in successful revascularization. As, Root dentinal walls are so thin that any instrumentation makes them weaker and more susceptible to future fractures. Chemical disinfection methods are used instead of chemomechanical means. Sodium hypochlorite, sodium hypochlorite in combination with chlorhexidine, sodium hypochlorite in combination with hydrogen peroxide are the most commonly used irrigants in revascularization procedure. Further, disinfection is achieved by intra- canal medicaments like triple antibiotic paste, calcium hydroxide and...
formocresol. Human dentin contains several angiogenic growth factors that can promote tissue regeneration in the root canal space. Therefore, the blood clot in the empty disinfected root canal space that contains various growth factors provides a protein rich scaffold for the stem cells to differentiate. Stem cells are defined as clonogenic self renewing progenitor cells that can generate one or more specialized cell types. To date, several types of stem cells have been isolated from teeth, including dental pulp stem cells (DPSCs), stem cells from apical papilla (SCAPs), periodontal ligament stem cells (PDLSCs). These cells have the capacity to differentiate into odontoblast like cells and produce dentine – like structure and results in root development and revascularization of the pulp. The bacterial tight coronal seal is very important for the procedure. A double seal over the blood clot is formed by MTA and a resin bonded restoration. MTA forms apatite –like layer when comes in contact with physiological fluids and thus results in biological seal. Calcium enriched mixture (CEM) is also used in one study instead of MTA. There are several advantages of revascularization reported like shorter treatment time after control of infection it can be completed in a single visit. It is also very cost effective, because number of visit is reduced. Obturation of canal is not required. However, the biggest advantage is achieving continued root development and strengthening of the root as a result of reinforcement of lateral dentinal wall with deposition of new dentine/hard tissue. The only few limitations of revascularization are long term clinical results are yet not available and it is possible that the entire root canal might be calcified, compromising esthetics and potentially increasing the difficulty in future endodontic procedures if required.

The outcome of the revascularization depends on the clinical condition of the tooth after root canal disinfection. The ideal situation is that there is surviving pulp and apical papilla tissue after root canal disinfection. It may lead to increased thickness of root dentine and complete root formation. The stem cells from the apical papilla have the capacity to give rise to new odontoblasts influenced by HERS, allowing new root dentine to form and root maturation to proceed to completion. The surviving dental pulp stem cells may rebuild the lost pulp tissue and can differentiate into the replacement odontoblasts to substitute the damaged primary odontoblasts. Thus, the odontoblasts differentiated from the stem cells from apical papilla leads to dentine formation in the apical region leading to elongation of the root and those differentiated from the DPSC lay down dentine on the dentinal walls, leading to increase in the thickness of the root. Continued root development has been reported in human immature permanent teeth with apical periodontitis/abcess after revascularization procedures. However the precise nature of hard tissue formed inside the canal space and continued root development of immature teeth with apical periodontitis/abcess following revascularization procedures in humans is not known, because no histological studies are available. It has been assumed that periodontal ligament tissue might grow in canal space and deposit cementum on the canal walls after revascularization procedure. Using autoradiographic examination, showed that PDL cells could migrate into apical root canal after pulpectomy in immature dog’s teeth. Stem cells in periodontal ligament are capable of differentiating into cementoblast and osteoblast -like cells upon simulation by appropriate inductive signal. It was also speculated that there might be direct in-growth of cementum and bone from periapical tissues into the canal space. In studying Pulpal changes in replanted and autotransplanted immature dog’s teeth, showed that osteoid tissue formed inside the root canal space was continuous with the bone of alveolar socket through open apical foramina. The same finding was also demonstrated in dog’s immature teeth with apical periodontitis after revascularization procedures. Similar observations of hard tissue formation in the canal space were reported in rhesus monkeys when their teeth were artificially infected for 1 week. The pulps were removed and canals were chemomechanically debrided and filled with collagen/calcium phosphate gel as a scaffold. The tissues present inside the canal space of immature teeth with apical periodontitis after revascularization procedures in dog studies were described as cementum or bone-like tissue and periodontal ligament –like fibrous connective tissue. No pulp like tissue was present regardless of intracanal medication used. Histologically, Cvek et al showed the presence of vital pulp tissue in apical portion of canal space in reimplanted immature incisors despite the presence of intraradicular and periapical abscesses. Accordingly, it has been speculated that pulp tissue regeneration might occur after revascularization procedures. Further, Heitthersay and Dominguez et al reported observations of continued root development in apexification cases with calcium hydroxide treatment. They assumed that HERS survived in apical periodontitis. Whereas, no pulp-like tissue was present in apical portion of canal space of immature teeth with apical periodontitis.
periodontitis/abscess after revascularization procedures in animal studies. 19,16 This indicates that the apical papilla did not survive. In addition, no evidence of dentin formation was observed inside the canal space or on the canal walls in those animal survived in apical periodontitis. When the entire or half of the HERS was removed from immature teeth of monkeys before autotransplantation, total or partial arrest of root formation occurred. In contrast, when HERS was not injured before autotransplantation ,normal physiological root development took place. 24 Increased root length can also occur by excessive deposition of cementum around the apex caused by aging abnormal occlusion trauma, Pulpal or periapical inflammation in adult mature teeth without the presence of HERS cells. 25 It has been demonstrated that extracellular matrix of cementum and growth factors released from cemental matrix are capable of signaling PDL stem cells to differentiate to cementoblasts and produce cementum. Regeneration implies regrowth of lost or damaged part of original tissue or organ caused by trauma or disease an example of this is the regeneration of liver when it is partially resected. 25 The incompletely developed roots of immature permanent teeth with infected necrotic pulp and apical periodontitis are not attributable to the inhibition or damage of HERS cells. Therefore continued root development of human immature permanent teeth with infected necrotic pulp and apical periodontitis/abscess after revascularization procedures does not appear to be a regenerative process. It could be considered a physiological process if both apical papilla and HERS survive in apical periodontitis/abscess after periapical wound healing. If the tissue is present inside the canal space in human immature permanent teeth with apical periodontitis/abscess after revascularization procedure are similar to that observed in animals, then revascularization is a reparative process with the loss of pulp biological function. Cementoid and osteoid tissues are not normally present as a part of pulp tissue. These tissues inside the canal space may function like periodontal tissues. 26 Histological studies are necessary to verify whether repair or regeneration of the pulp tissue occurs inside the root canal space following revascularization procedures in humans.

REFERENCES


