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Recent advances in vital pulp therapy

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Abstract

Clinical management of teeth with pulp exposures due to extensive caries has become more common, particularly with the introduction of new restorative materials. The aim of the article is to summarize and discuss about the various and newer pulp capping therapies used for protection of the dentin-pulp complex.

Keywords: Bone Sialoprotein, Novel endodontic cement, Odontogenic ameloblast associated protein, Non-pharmacotherapeutic pulpotomy techniques.

Introduction

Pulpless teeth lose their ability to sense environmental changes, making the progression of caries unnoticeable by patients. Maintaining the vital pulp also helps reduce the occurrence of apical periodontitis by blocking bacterial infections.[1,2] Based on these issues and concerns, the ability to maintain or renew dental pulp vitality would be preferable to current endodontic treatments.[3]

There are two main strategies to achieve a successful vital pulp therapy, to reduce further damage of existing odontoblasts, and to induce the differentiation of new odontoblasts. A successful vital pulp treatment requires a good sealant against bacteria, no severe inflammatory reactions, and stable haemodynamic within the pulp.[4] The ideal prognosis also includes the formation of a continuous dentin bridge at the pulp-dentin border. This newly formed dentin helps to block stimuli from the outside and thus to protect the pulp vitality. However, the formation of osteodentin, dentin with an osteotypic appearance, and scar-like soft tissue is also regarded as successful healing, although osteotypic hard tissue cannot provide the necessary barrier effect to protect the pulp from exogenous destructive stimuli.[5]

The most commonly used restorative materials include calcium hydroxide, adhesive resin-based composites systems, glass-ionomer materials, and zinc oxide eugenol (ZOE). These inorganic restorative materials are unable to induce cell differentiation.

MTYA1-Ca: The powder composed of 89.0% microfiller, 10.0% calcium hydroxide and 1.0% benzoyl peroxide and was mixed with liquid (67.5% triethyleneglycol dimethacrylate, 30.0% glyceryl methacrylate, 1.0% o-methacryloyl tyrosine amide, 1.0% dimethylaminoethylmethacrylate and 0.5% camphorquinone). MTYA1-Ca developed dentine bridge formation without formation of a necrotic layer, revealed to have good physical properties, and was not inferior to Dycal histopathologically. Therefore, it is suggested that the newly developed material, MTYA1-Ca promises to be a good direct pulp capping material.[6]

Bone Sialoprotein: Bone sialoprotein (BSP) is the most efficient bioactive molecule, which induced homogeneous and well mineralized reparative dentin. Both BSP and BMP-7 were superior to calcium hydroxide in their mineralization inducing Properties.[7]

Stem cells: Dental pulp stem cells (DPSCs) and Stem cells from Human Exfoliated Deciduous Teeth (SHED) have been identified as a novel population of stem cells that have the capacity of self-renewal and multi lineage differentiation. Gene expression profile of DSPCs and SHED when analyzed using DNA microarray, it was reported that SHED had got significantly higher proliferation rate than that of DSPCs and BMMSCs and this could be a desirable option as a cell source for therapeutic applications.[8]

Novel endodontic cement (NEC): NEC consists of calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, and calcium chloride. NEC induces a thicker dentinal bridge with less pulp inflammation in human dental pulp as compared to MTA.[9]

Odontogenic Ameloblast Associated Protein (ODAM): ODAM is expressed in ameloblasts, odontoblasts, and pulpal cells. ODAM is involved in ameloblast maturation and enamel mineralization. ODAM accelerates reactionary dentin formation close to the pulp exposure area, thereby preserving normal odontoblasts in the remaining pulp.[10]

EndoSequence Root Repair Material: It consists of Calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide, proprietary fillers and thickening agents.[11] Cytotoxicity of MTA-Angelus, Brasseler Endosequence Root Repair Putty (ERRP), Dycal and Ultra-blend Plus (UBP)-(light curable $Ca(OH)_2$) was compared and it was found that ERRP and UBP are less cytotoxic.[12]

Castor Oil Bean (COB) Cement: The COB consists of 81-96% triglyceride of ricinoleic acid, and is considered a natural polyol containing three hydroxyl radicals. COB or RCP (Ricinus Communis Polyurethane) was originally developed as a biomaterial for bone repair and regeneration after local bone damage. Due to these positive characteristics, the material is considered to be an excellent candidate for use in pulp capping.[13]

Growth Factors: Growth factors are an extensive group of proteins which can induce cellular proliferation and differentiation by binding to receptors on the cell surface. A variety of growth factors have successfully been used for dentin-pulp complex regeneration, including Transforming Growth Factors (TGFs),[14] Bone morphogenetic proteins (BMPs),[15] Platelet-derived growth factor (PDGF),[16] Insulin-like growth factor (IGF),[17] and fibroblast growth factors (FGFs).[18]

Among those, BMP-2,[19] BMP-4,[20] BMP-7[21] have been shown to direct pulp progenitor/ stem cell differentiation into odontoblasts and result in dentin formation, making the BMP family the most likely candidate for dental clinic applications. Promising results include an autogenous transplantation of recombinant human BMP2-treated porcine dental pulp to the amputated pulp, resulting in the

formation of reparative dentin and odontoblast-like cells with long processes attached to newly formed osteodentin, as observed after 4 weeks.[22]

Some natural materials are used for pulp capping because they contain growth factors. The most commonly used one is dentin, because bioactive molecules released from dentin can promote dentinogenesis. It has been described that odontoblast-like cells and reparative dentin can be observed when EDTA-demineralized dentin was used as capping material.[23] Enamel matrix derivative is also capable of inducing dentin formation when applied to the dentin-pulp complex,[24] although the mechanism for this repair has not yet been clarified. However, growth factor delivery alone cannot work effectively in the cases exhibiting inflamed pulp tissue.[25]

Challenges and Future Direction: The pulp tissue repair/regeneration recapitulates tooth development. Despite the impressive progress in tissue engineering approaches to regenerative pulp therapy, numerous challenges remain. The associated broad spectrum of responses in pulp includes neural and vascular regeneration.

Nerve Regeneration: Pulpal nerves play a key role in regulation of blood flow, dentinal fluid flow, and pressure.[26] There is evidence for neural regulation of pulpal fibroblasts, inflammation and immunity.[26] The innervation of the pulp has a critical role in the homeostasis of the dental pulp. Invasion of immune and inflammatory cells into sites of injury in the pulp is stimulated by sensory nerves.[27] Sensory denervation results in rapid necrosis of the exposed pulp because of impaired blood flow, extravasation of immune cells.[27] Re-innervation leads to recovery in the coronal dentin.[27] Schwann cells appear to release neurotrophic growth factors and play a role in recruitment of sensory and sympathetic nerves during re-innervation. Thus, the pulpal nerve fibers contribute to angiogenesis, extravasation of immune cells and regulate inflammation to minimize initial damage and strengthen pulpal defense mechanisms. The members of the BMP family have pronounced effects on neurogenesis.[28] Thus, it is likely that BMPs can be used for regenerative pulpal therapy and dentinogenesis.

The increasing interest in tissue engineering of tooth must take into account neuro-pulpal interactions and nerve regeneration. Thus, the life of teeth can be possibly prolonged by preservation of pulp and odontoblasts and promoting repair and regeneration by the study of neuropulpal interactions[29] The recent progress in dental stem/progenitor cells[30] and mechanisms of neurotrophism of dental pulp cells[31] assures advances in regeneration of nerves based on neuropulpal interactions.

Vascular Regeneration: The vascular system in the dental pulp plays a role in nutrition and oxygen supply and as a conduit for removal of metabolic waste. The cellular elements of the blood vessels such as endothelial cells, pericytes, and associated cells contribute to pulpal homeostasis along with the nerves. Thus, the vascular contribution to regeneration of dentin-pulp complex is immense. Vascular endothelial growth factor (VEGF) is an excellent regulator of angiogenesis and is known to increase vascular permeability. VEGF induced chemotaxis, proliferation and differentiation of human dental pulp cells.[32] Human dentin matrix contains VEGF.[33] The presence of VEGF in dentin and response of dental pulp cells to VEGF raises the possibility of the presence of endothelial progenitor cells in dental pulp alongside progenitors for odontoblasts and neuronal cells.[34] In view of the role of endothelial progenitor cells in vascularization during tissue regeneration, it is likely VEGF and vascular endothelial cells are critical for dentin regeneration. The utility of gene therapy in stimulation of vascular growth permits local stimulation of

vascularization during regeneration. Thus, the recent advances in vascular biology and VEGF and techniques of gene transfer and gene therapy will be of potential clinical utility in dentistry especially in endodontics.

Nonpharmacotherapeutic Pulpotomy Techniques

Controlled Energy: Controlled energy in the form of electrosurgical and laser heat application to the pulp stumps at the canal orifice site has been proposed as an alternative to the more traditional pharmacotherapeutic techniques, particularly those using formocresol. Advantages of electrosurgical pulpotomy that can be applied to the controlled energy category includes: quick and efficient, self-limiting, good hemostasis, good visibility of the field, no systemic effects and sterilization at the site of application.[35]

Electrosurgery: Comparison between electrosurgery with formocresol in pulpotomy techniques for primate primary and young permanent teeth revealed that histological appearance for both groups was similar, with no evidence of pulp necrosis or abscess formation. In the electrosurgery group, secondary dentin was deposited along the lateral canal walls, and the apical two-thirds of the pulp revealed a slightly fibrotic to normal appearance.[35]

Six monthly histological comparison of electrosurgery with formocresol on the radicular pulp showed similar success rates of 80% for the formocresol and 84% for the electrosurgical groups. This concluded that neither of the technique was superior.[36]

Conversely, histological comparison between electrosurgery, formocresol, and electrosurgery plus formocresol in primate pulpotomies denoted that combining the two techniques of electrosurgery and formocresol produced no better results. Both electrosurgical groups were inferior to the formocresol group.[37]

A form of electrosurgery, known as electrofulguration, has been suggested for pulpotomies in primary teeth.[38] It involves establishing an electrical arc to the targeted tissue without direct contact of the probe, which ideally confines heat to the superficial tissue level.

Electrofulguration pulpotomy technique was investigated in 164 primary molars.[38] After a 26-month post-treatment period, 99.4% clinical and radiographic success rate was found. Conversely, calcium hydroxide was compared with ZOE when used as a base over electrofulgurated pulp tissue. Although the overall clinical success rate for the entire sample was 77 to 81%, the radiographic success was 57.3% for the electrofulguration plus calcium hydroxide group and 54.6% for the electrofulguration plus ZOE group.[39]

Lasers: Application of laser irradiation in vital pulp therapy has been proposed as another alternative to pharmacotherapeutic techniques. It was reported that irradiation of the buccal tooth surface with the Nd:YAG laser produced less pulp damage than the ruby laser with less histologic evidence of coagulation and focal necrosis.[40] Histological study noted that the least amount of pulp tissue injury occurred with defocused irradiation with lower power settings and shorter application of carbon-dioxide laser in the pulpotomy procedure. More tissue destruction occurred in the defocused mode with higher irradiation power settings.[41]

Studies on controlled-energy pulpotomy techniques are equivocal as to their effectiveness in reducing post-treatment inflammation when compared to conventional pharmacotherapeutic techniques. Although clinical reports of success exist, more controlled clinical and histologic investigations are needed to address the variables of power settings, application times, continuous versus pulsed modes of application, and degree of heat dissipation in the radicular pulp and surrounding hard tissues.

Conclusion

Although reparative dentin provides a physical barrier and protects the pulp, it has some limitations in the integrity. Pulpal exposure by caries can lead to acute localized inflammation and liquefaction necrosis under the exposure site. It has been postulated that to preserve the remaining healthy pulp, this infected, necrotic, and disintegrated pulp tissue need to be removed. The complete restoration of the physiologic, structural, and mechanical integrity of the native dentin-pulp complex is the ultimate goal of endodontic treatment.

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