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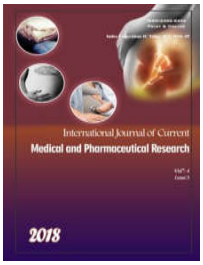

AN OVERVIEW OF BIOMATERIALS IN ENDODONTICS

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ABSTRACT

Mimicry in the field of science involves reproducing or copying a model, a reference. If we as dentists want to replace what has been lost, we need to agree on what is the correct reference. The accepted frame of reference must be the same for the entire profession, and it should be timeless and unchanging success.

In Dentistry there is no one Biomaterial that has the same, mechanical, physical and optical properties as tooth structure (i.e., dentin, enamel, and cementum) and possesses the physiological characteristics of intact teeth in function. By using Biomimetic therapeutic approaches, Dental professionals can improve and become closer to natural biological structures and their function.

This article is an overview of literature on Biomimetic and Bioactive materials and Biomimetic techniques applicable in Endodontics.

INTRODUCTION

Definition

Biomimetics is defined as the study of the formation, structure, or function of biologically produced substances and materials and biological mechanisms and processes especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones.[1]

A Biomimetic material should match the part of the tooth that it's replacing in several ways, including the modulus of elasticity and function of the respective areas (e.g., pulp, dentin, enamel, dentoenamel junction).[1]

The practice of endodontics has grown by leap and bounds in the past few decades. Replacement of diseased or lost tooth structure with biocompatible restorative materials is currently the order of today.[2]

Various Biomimetic materials used in endodontics are Calcium Hydroxide, MTA, Biodentine, Bioaggregate, Endo sequence root repair material, iRoot BP, CEM etc.

Calcium hydroxide

Since the introduction of calcium hydroxide to dentistry by Hermann in 1920, this medication has been indicated to promote healing in many clinical situations. Various biological properties have been attributed to this substance, such as antimicrobial activity (Bystrom *et al* 1985) and tissue dissolving ability (Hasselgren *et al* 1988, Anderson *et al* 1992). Inhibition of tooth resorption (Transtad 1988) and induction of repair by hard tissue formation (Foreman and Barnes 1990) was also seen with calcium hydroxide. Franck 1st reported the use of calcium hydroxide for apical closure by 1959.[3]

Calcium hydroxide dissociates into calcium and hydroxyl ions. These calcium ions reduce capillary permeability thus in turn reducing the serum flow and reducing the levels of inhibitory pyrophosphates that cause the mineralization. The hydroxyl ions neutralize acid produced by osteoclasts maintaining optimum pH for pyrophospahatase activity leading to increase level of calcium-dependent pyrophosphatase which reduced the levels of inhibitory pyrophosphate and causing mineralization.[4]

MTA

A mixture of Portland cement and bismuth oxide was marketed as MTA.[21] This is a material of choice for vital pulp therapy, apexification and apexogenesis, correcting procedural errors as well as for root-end filling material in apicoectomy procedures.[5]

Root-end filling materials have to set and develop their properties in a wet environment and should be radio-opaque. MTA exhibited desirable physical and mechanical properties, and has been shown to be bioactive when in contact with tissue fluids, and is radio-opaque due to presence of Bismuth oxide.[6]

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MTA cements have been clinically proposed as root-end materials and prospective studies have reported a failure of 9.8–16% at 1 year and 8% at 2 years. The biological behavior and the apatite-forming ability (i.e. bioactivity) of MTA cements have been recently adequately documented. Bioactivity of MTA (mineral trioxide aggregate) is due to its ability to form biologically active bone like apatite layer on its surface in a biological environment. MTA reacts chemically with body fluids in a manner compatible with repair processes of the tissue.[7]

The main clinical limitation of MTA cements is the long setting time and the consequent risk for a fast dissolution and removal of the cement and wash-out of the fresh (not set) cement from the surgical site of root-end obturation due to the blood and fluid contamination at the apical region of root canal. [7]

lc-MTA was tested for setting time, solubility, water absorption, calcium release, alkalinizing activity (pH of soaking water), bioactivity (apatite-forming ability) and cell growth-proliferation. lc-MTA proved the formation of bonelike apatite spherulites just after 1 day. Apatite precipitates completely filled the interface porosities and created a perfect marginal adaptation. lc-MTA allowed Saos-2 cell viability and growth and no compromising toxicity was exerted.[7]

Biodentine

Biodentine is a relatively new material introduced as a dentine substitute. Biodentine powder is mainly composed of highly pure tricalcium silicate, which regulates the setting reaction. Other components are calcium carbonate (filler) and zirconium dioxide (radiopacifier). The liquid contains calcium chloride (setting accelerator), water reducing agent (super-plasticizer) and water. The superplasticizer reduces the viscosity of the cement and improves handling.[8]

Biodentine was developed as a multipurpose dentin, and root replacement material. The other indications include restoration of deep and large coronal carious lesions, restoration of deep cervical and radicular lesions, pulp capping and pulpotomy, repair of root perforations, furcation perforations, perforating internal resorptions, external resorption, apexification, and root-end filling in endodontic surgery.[6]

Laurent P, Camps J, de Me´oM *et al*. investigated toxicity of Biodentin by the induction of specific cell responses to it and confirmed the lack of toxicity and genotoxicity. In addition to its lack of toxicity, Biodentine displayed bioactivity, i.e., activation of angiogenesis and activation of progenitor pulpal cells promoting healing and remineralization. Biodentine has potential for Ca and Si uptake by adjacent root canal dentine in the presence of phosphate-buffered saline (PBS). In this regard it is better than MTA.[9]

The primary clinical advantage of Biodentine is its fast setting (between 12 and 15 min). This is an a advantage when compared to the 170 min of MTA.[10]

Biodentine powder is mainly composed of tricalcium silicate, calcium carbonate and zirconium oxide as a radioopacifier, while Biodentine liquid contains calcium chloride as the setting accelerator and water-reducing agent. The interesting feature of Biodentine is the product packaging in a capsule: The mixing is achieved by using the capsule mixing device and the ratio powder/liquid is set by the manufacturer. This allows the practitioner to achieve a reproducible material with optimum properties every time.[10]

There are several drawbacks to the use of Biodentine as a root-end filling material. First, its handling is not as easy as claimed by the manufacturer. Another drawback, common to all silicate-based cements, is the impossibility to create small cones which would be easy to insert into the retro prepared cavity, as for ZOE or Super EBA cements. It is possible to use the Lee block but the use of a specific carrier like the MAP system makes the procedure easier. The primary clinical limitation of Biodentine is its low radiopacity. Despite the presence of a radio-opacifier (zirconium oxide).[10]

In conclusion, Biodentine is a promising material which is suitable for surgical endodontics, demonstrating excellent biological properties and fast clinical setting time, but with poor radiopacity.[10]

Bioaggregate

Bioaggregate (BA; Innovative BioCeramix, Vancouver, Canada), a calcium silicate-based material, is a modified type of MTA. BA is composed of calcium silicate oxides and calcium silicate. Also present are hydroxyapatite, calcium phosphate silicate, calcite, and tantalum oxide as a radiopacifier.[6] It is comprised of off whitish fine particles, and the powder is mixed with deionized sterile water.[11]

In contrast with Portland cement, MTA, and related products, BA is reported to be free of calcium aluminate. Furthermore, BA is also reported to contain the addition of higher levels of phosphate in contrast with the minimal phosphate levels found in Portland cement and MTA. Therefore, most of the constituents of BA are the same as that in WMTA except that BA is aluminum-free, uses a different metallic oxide as an opacifier, and has added phosphate constituents such as hydroxyapatite.[6]

The recommended clinical applications of BioAggregate include retrograde root filling, perforation repair, vital pulp therapy, etc.[11]

Studies have shown that BA exhibits cytocompatibility as MTA to primary human mesenchymal cells and was able to induce mineralization associated gene expression in osteoblast cells. Monobasic calcium phosphate in BA adjusts its hydrate setting.[12]

CEM

It is also known as NEC and was introduced by Asgary.[13] It consists of calcium oxide, whereas calcium oxide and silica in Portland cement and calcium oxide, silica, and bismuth oxide in MTA are the major ingredients.[11] This cement releases both calcium and phosphorus ions leading to hydroxyapatite production. It is also known as CEM. It is composed of calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, and calcium chloride.[5]

Although in vitro sealing ability and in vivo vital pulp therapies of CEM cement and MTA revealed similar results, CEM cement offers some benefits over MTA such as improved handling, shorter setting time, more flow and less film thickness, ability to form hydroxyapatite in normal saline solution, as well as an estimated lower cost.[14]

Saeed Asgary, Mohammad Jafar Eghbal *et al* investgated the sealing ability of CEM and hypothesized that the good sealing

property of CEM cement can be explained by its handling characteristics and chemical properties. In addition, some calcium compounds such as calcium sulfate and calcium silicate help to a slight expansion of the material through continuous hydration after initial setting of the material and further crystalline maturation.[13]

Studies have found that CEM cement promoted alkaline pH in a similar manner to MTA and released calcium and phosphate. These conditions can stimulate the calcification process and explain the basic physico-chemical mechanisms of hard tissue regeneration of CEM cement. [14]

Endosequence

Brasseler USA (Savannah, GA) has introduced the EndoSequence Root Repair Material (ERRM) and EndoSequence Root Repair Putty (ERRP), which use bioceramic technology to address some of the inconsistencies associated with conventional MTA. Bioceramics refers to the combination of calcium silicate and calcium phosphate that is applicable for biomedical or dental use.[15]

According to the manufacturer, it is composed of calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide, proprietary fillers, and thickening agents. The manufacture claims that the material is biocompatible and hydrophilic. According to the manufacturer, ERRM has a high pH, although no further details are given on pH. ERRM has strength of 70-90 MPa. The material also has excellent radiopacity. The working time of ERRM is 30 minutes. ERRM is available in a preloaded syringe with a moldable putty form. The preloaded syringe also has intracanal tips that can be bent to facilitate placement in clinical situations.[16]

This bioceramic material is produced with nanosphere (1×10^{-3} mm in its greatest diameter) particles that allow the material to enter into the dentinal tubules and interact with the moisture present in the dentin. This creates a mechanical bond on setting. The technology eliminates the potential for shrinkage of the root-end filling material, rendering the material with exceptional dimensional stability.[15] Studies have shown that ERRM is bioactive[17], it is not cytotoxic[16] and has good sealing ability[18]

iRoot root repair material

Novel bioceramic based materials were introduced in the form of root and perforation repair materials or sealers. Among these, iRoot FS has been developed by Innovative BioCeramix Inc. (Vancouver, British Columbia, Canada). According to the manufacturer, iRoot FS is a ready-to-use premixed putty developed for permanent root canal repair and surgical applications. iRoot FS sets in the moist environment and does not shrink during the setting process, while maintaining excellent physical properties. In an in vitro study, iRoot FS demonstrated negligible cytotoxicity, enhanced cell adhesion capacity and rapid setting. iRoot FS had similar apical sealing ability to MTA[19] and might be considered as a promising root-end filling material[20.]

CONCLUSION

The materials discussed here mainly concentrate on the bioinductive activity. The terms bioactive, bioinductive, biomaterial and biomimetic are different and have been defined separately. Bioactive material is defined as a material that has the effect on or eliciting a response from living tissue, organisms or cell such as inducing the formation of hydroxyapatite. The bioinductive property is defined as the capability of a material for inducing a response in a biological system.

These materials can be considered as boon to dentistry because of their regeneration potential. As Dentistry relies with great gusto on the technology, it will be affected profoundly. In short “Future is coming, it will be amazing”.

Future advances in this field will require materials and computer scientist, physicists, bioengineers, clinicians, biologist and industries working together towards a shared vision rather than pursuing their separate objectives.

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