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REVIEW ARTICLE

CALCIUM HYDROXIDE AS A REPERATIVE BIOMIMETIC MATERIAL: A REVIEW

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ABSTRACT

Mimicking can be done by using either by natural substitutes or Synthetic substitutes. 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. A material fabricated by biomimetic technique based on natural process found in biological systems is called a biomimetic material. Why synthetic materials are preferred? Age, disease and traditional restorations can cause further problems to the existing tooth structure. As teeth have no natural method of repair, biomimetic principles should be used to artificially repair the tooth to its natural functions and aesthetics. Biomimetics is an emerging inter disciplinary field that combines information from the study of biological structures and their function with physics mathematics chemistry and engineering in the development of principles that are important for the generation of novel synthetic materials and organs. Calcium hydroxide is one of the biomimetic material in dentistry.

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INTRODUCTION

Starting from prehistoric era man behaved similarly to animals in hunting and making shelter for survival. In the legend of Icarus & his father Daedalus, inspired by birds, made wings from feathers and wax for them to escape from prison. Biomimetics literally means to mimic life. It is considered the study of natural structural processes to try to mimic or replicate it artificially in an attempt to restore the same function or aesthetics. It is synonomous with biomimicry, biomechanics and biomimesis. Biomimetics is the field of scientific endeavor which attempts to design system and synthesize materials through biomimicry (Ram Chandra roa biomimetics, 2003). Although the subdivision of science has given us numerous discoveries and a wealth of knowledge to understand the biological system, the importance of the boundaries between biology and other research fields was pointed out in the middle of the last century. Material scientists view biomimetics as a tool for learning lo synthesize materials under ambient conditions and with least pollution to the environment. Chemists have always sundered at the case with which ammonia is produced in biological nitrogen fixation. They learn the synthesis of polymers that can perform the role of enzymes in such processes. Histological study of biological process but also to trace the evolution of various classes of organisms. Biochemist have interest in the field due to the complexities associated with the interaction of biopolymers with ions of metals leading to the mineralization in living organisms. Engineers attempt to explore the relationship between structure and function in natural systems, with a view to achieve analogous synthetic design and manufacture (Graham, 2000). On the whole, the field of biomimetics addresses more than one issue. Those engaged in activity try to mimic natural methods of manufacture at chemicals in order to create new ones, learn new principles from phenomena observed m nature, reproduce mechanisms found and copy the: principles of synthesizing materials under these conditions with easily available raw material (Paul Maanc, 1999; National Institute of Denial and Craniofacial Research Biomimetks and Tissue Engineering- National Institutes of Health, 2002). In the field of dental medicine, the foundation of this broad new field has ancient roots, replacing body parts got back at least 2500 years where the Etnicals learned to substitute missing teeth bridges made from artificial teeth carved from the bones of oxen. Evidence of date hack lo the Roman populations of the First or second century A.D. The foundation of this broad new field has ancient roots.

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Biomimetics is a term coined by Otto Schmitt in the 1950's, while studying the nerves in a squid. He attempted to copy and design an artificial device that could replicate the same process of synaptic impulse. The term bionics coined by Jack E. Steele in 1960 at continence in Dayton. Evidence of crude dental implants dates back to roman population of the first or second century AD and to pre-Columbian cultures of central and south America. The first use of dental amalgam to repair decayed teeth was recorded in the Chinese literature in the year 659. The middle of 20th century same sophisticated inventions in the heart pacemaker the artificial heart valve and hip and knee joint replacement historically organ and tissue loss have been treated by surgical reconstruction and more recently the use of mechanical devices such as kidney dialyzers and the transplantations of organs from one individual to another. Magne argues that porcelain bonded to metal and other substances like amalgam (Butki, 2001), which do not follow biomimetic principles and do not attempt to restore the tooth natural properties. He also argues that gold is excessively stiff, thereby also not following biomimetic principles. As these materials also are not bonded with the existing tooth structure there is a higher likelihood of cracks, leakage and bacterial invasion causing further deterioration (Wilson).

Biomimetic materials used in Biomedical Science

- PMMA (acrylic), Silicone- Intra ocular lens Breast implant
- Titanium & its alloys, Polyether ether ketone (PEEK)-
- Artificial hipjoints, Dental implants

Biomimetic Dentistry

The use of dental materials and technologies that mimic tooth structure and function:

- Maintaining as much natural tooth structure as possible.
- Materials should absorb and distribute stress like tooth structure and should bond with natural structure.
- Enamel like materials.
- Dentin like materials

Natural hard tooth structure once lost for any reason is not ever reproduced by the body system, hence dependence on simulating materials becomes essential for restoring it to form and function. Biomimetic materials are of two types:

1. Repairative Biomimetic Materials
2. Restorative Biomimetic Materials

The first use of dental amalgams to repair decayed teeth was recorded in Chinese literature in the year 659 B.C. Biomedical engineers trace the origins of biomimetic materials to ancient times when Muyjtn, Roman and Chinese civilizations had learnt to use dental implants made of natural materials. More recently in the 20th century material sciences have blossomed into a remarkable approach to nanotechnology. Using chemical molecules to fabricate sub-microscopic structures with unique relevance to novel biomimetics. In clinical dentistry these are challenged to design and fabricate new biomaterials that can mimic the tooth in both form and function. The lost or missing dental tissue is restored, leading to the full return of function and aesthetics to the tooth, or the material used can regenerate, replicate or mimic the missing dental tissue closely (Harold). This approach is conservative and biologically sound and in sharp contrast to the porcelain fused- to-metal technique in which the metal casting with its high elastic modulus makes the underlying dentin hypo functional.1 The main disadvantage with traditional biomaterials used in the medical field is that they lack the ability to integrate with biological systems through a cellular pathway which can lead to failure of the material. However, biomimetic materials transcend the regular biomaterial in utility and will suitably perform the functions of the biological molecule that needs to be replaced. A biomimetic approach to restore tooth structure is based on regenerative endodontic procedures by application of tissue engineering which opens up a whole new arena for the practioner. The key elements of tissue engineering are stem cells, morphogen, and a scaffold of extracellular matrix. Biomimetics is an emerging inter disciplinary field that combines information from the study of biological structures and their function with physics mathematics chemistry and engineering in the development of principles that are important for the generation of novel synthetic materials and organs. A bioactive material is one that elicits a specific biological response at the interface of the material which results in the formation of a bond between the tissues and the material.

The important points of biomimetic materials are

- Should be synthetic in origin
- Should mimic biology
- Should bond with natural structure
- Should not elicit any biological response

Repairative Biomimetic Materials

Calcium Hydroxide: Hermann's (1920) introduction of a material so eminent, which marked a new era in pulp therapy, when he demonstrated that a Calcium hydroxide formula called Calyx induced dentinal bridging of the exposed pulpal surface. Since then the emphasis has shifted from the "doomed organ" concept of an exposed pulp to one of hope and recovery. Calcium hydroxide is a strong alkali, which can be formed by the reaction of calcium oxide with water process called as slaking. If the oxide is treated with only sufficient water to make it crumble to a fine, white, dry powder slaked lime is produced. Calcium hydroxide has been included within several materials and antimicrobial formulations that are used in a number of treatment modalities in endodontics. These include, inter-appointment intracanal medicaments, pulp-capping agents and root canal sealers. Calcium hydroxide formulations are also used during treatment of root perforations, root fractures and root resorption and have a role in dental traumatology, for example, following tooth avulsion and luxation injuries. In its pure form, this substance has a high pH and use dental which relates chiefly to its ability to stimulate mineralisation and also its antimicrobial properties. Further advantage, include easy population a favorable influence on the local environment, raising the acidic pH to alkalinity (Horeman).

Composition

1 Acidic paste

- Alkyl salicylate (iso-butyl salicylatc or I-methyl triethylene salicylate)
- Inert fillers : Titanium oxide 12-14%

- Radiopacifer : Barium sulphate 32-35%
- Calcium tungstate or calcium sulphate 14-15%

2. Basic paste

- Calcium hydroxide 50-60%
- Zinc oxide 10%
- Zinc acetate 0.5%
- Ethylene toluene and paraffin oil 39.5%

Mechanism of Action

It seems (that calcium hydroxide has the unique potential to induce mineralization even in tissues which have not been programmed to mineralize. Rasussem and Major could not verify that calcium hydroxide induce mature bone formation but found that, when the material was placed in direct contact with host tissue, it induced the formation of fibrous tissue with occasional formal ion of area of immature bone. Calcium ions present in the applied calcium hydroxide do not borne incorporated in the mineralized repair tissue, which derives its mineral content solely from the dental pulp via blood supply. These observations indicate that calcium hydroxide is an major rather than a substrate for repair. A rise in pH as a result of the free hydroxyl ions may initiate or favour mineralization (Horeman). Calcium hydroxide may act as a buffer against the acidic reaction produced by the inflammatory process. The alkaline pH also neutralizes the lactic acid secreted by osteoclast and this may help to prevent further destruction of mineralized tissue. The material exerts a mitogenic and osteogenic effect, the high pH combined with the availability of calcium and hydroxyl ions having an effect of enzymatic pathways and hence mineralization. The high pH may also activate alkaline phosphatase activity which is postulated to play an important role in hard tissue formation. The optimum pH for alkaline phosphatase activity is 10.2 a level of alkinity such is produced by many Ca(OH)2 preparations. Initially the wound surface proliferate, migrate and elaborate collagen along. The superficial necrotic zone, the pulpal surface of capping material. The necrotic zone and the new collagen layer vinyl mineral salts becoming calcified materials. The layer of odontoblasts like cells is formed in association with fibrodentin and reparative dentin is secreted.

Advantage

- Its readily availability
- Its simplicity of preparation
- Its comparative easily removal
- It is the advantage of causing no difficulty if excess is expressed into the periapical area since it can reasorb.
- Ca(OH)2; ability to denture proteins (the root canal) rendering them less toxic.
- Calcium hydroxide has anti-bacterial effects.

Classification

- Setting materials
- Non setting materials

Ca(OH)2 pastes can be classified according to whether they are setting or non-setting materials. The former is used for lining or sub-lining of cavities. Later is used for root canal dressing. In nonCalcium Hydroxide setting type materials vehicles are distilled water, methycellulose, local anesthetic solution, camphorated monochlorophenol, ledermix and radiopacifiers.

Chemical Characteristics of Calcium Hydroxide: Lime stone is a natural lock composed of calcium carbonate (CaCO3) which forms when Hit' calcium carbonate solution existing in mountain and sea water becomes crystallized. The combustion of limestone between 900-1200" C causes the following chemical reaction

CaCO3 CaO + CO3

The calcium oxide formed (CaO) is called 'quicklime and has a strong corrosive ability. When calcium oxide contacts water, the following reaction occurs

CaO +CaO Ca (Co3)

Calcium hydroxide is while odourless powder with the formula Ca(OH)2 and a molecular weight of 74.08. It has a low solubility in water [about 1.2g at 250 C] which decreases in the temperature rises, it has high pH 12.5-12.8 . It is insoluble in alcohol. This low solubility is in turn a good clinical characteristic because a long period is necessary before it becomes soluble; in fluids when in direct contact with vital tissues The material is chemically classified ; as strong base. A chemical analysis of OH" ionic liberation from calcium hydroxide allows percentages of. Ca and OH ions that are released to be determined.

USES OF Ca(OH)2

Indirect pulp capping: There is evidence that calcium hydroxide stimulates an increase in mineralization within the dentin that remains at the base of the cavity (Stephen Cohen, 2002 and Donald, 1990).

Direct pulp capping: It is undertaken in an attempt to maintain the health of an exposed vital pulp.

Pulpotomy: In pulpotomy surgical removal of part of coronal pulp *is* undertaken. The healing process is similar to that of direct pulp capping.

Apexification: It is a method of inducing apical closure through the formation of mineralized tissue in the apical region of a non-vital tooth with incompletely roots. Calcium hydroxide is the material most commonly used for inducting of apical barrier formation (Acinechi Numd Rsimli, 2002 and Richard, 1991)

Pulpectomy: Calcium hydroxide is frequently used as a dressing for the treatment of both internal and external inflammatory root resorption, in order to halt the process (Horeman, 2002).

Conclusion

In the real world, Leonardo da Vinci in the 15th century dreamed of fabulous flying machines based on birds, although it was not until the 20th century that the Wright brothers successfully created a prototype that led to the modern aircraft of today. So these revolution from flying birds to todays aircraft reflects the human’s nature of mimicking the Nature’s

secrets. Thus Nature acts as a motivation factor which lead to development of new era of science. A favorable influence on the local environment, raising the acidic pH to alkalinity. So calcium hydroxide is considered to be one of the biocompatible reperative biomimetic material in dentistry.

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