REVIEW ARTICLE

# Biosmart Dental Materials: A New Era in Dentistry

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## ABSTRACT

The need of the hour is to introduce dental materials that have biomimicking properties of natural tooth structure. Various biocompatible materials have been introduced and widely used in many areas of dentistry. The smart behaviour of materials occur when it senses some stimulus from surrounding environment and reacts to it in useful, reproducible and mostly reversible manner. These materials can be altered in a controlled manner by various stimuli such as stress, temperature, moisture, pH and electric or magnetic field. A key feature of smart behaviour includes its ability to return to the original state after the stimulus is removed. Some of these materials used are resin modified glass ionomers, amorphous calcium phosphate releasing pit and fissure sealants, smart composites, smart ceramics, compomers, orthodontic shape-memory alloys, smart impression materials, smart sutures, smart burs, smart endodontic files etc. These materials have revolutionized the dentistry and are the beginning of new chapter in Biosmart Dentistry.

**KEYWORDS: Dentistry, Bio- Smart, Dental Materials**

## INTRODUCTION

Most of the dental materials were thought to survive for the longer period in the oral cavity, allowing them to be used for longer period. They were designed in such a manner that no interaction will occur between the material and the oral cavity. (For this they were designed in such a way that they will not have any interaction with the oral environment). Materials such as amalgams and some cements have the ability to survive without reacting to the change in the oral environment. But some materials have the ability to sense change in oral environment and respond positively e.g, The ability of Glass Ionomer Cement or Pit and Fissure sealants to release Fluoride. But some materials were able to act in an 'positive' way for example ; the ability to release and absorb fluoride can positively react in an oral environment. Materials showing this type of behaviour are considered as “Smart materials”.[1,2] McCabe Zrinyi[2] defined smart materials as "Materials that are able to be altered by stimuli and transform back into the original state after removing the stimuli". A key feature of smart behaviour includes an ability to return to the original state after the stimulus has been removed.[2] The stimuli can be in the form of temperature, pH, moisture, stress, electricity, chemical or biomedical agents and magnetic fields. The different types of smart materials used in the field of dentistry are piezoelectric materials, shape memory alloys or shape memory polymers, pH sensitive polymers, polymer gels and others that have shown their own smart behaviour. These smart materials can easily sense the changes in the oral cavity and respond positively to these changes. (are highly responsive and have a great capacity to sense and respond to any environmental change.) Hence these materials are also known as “Responsive Materials”.[3]

## PROPERTIES

Smart materials sense changes in the environment around them and responds in a predictable manner. In general, these properties are:

- Piezoelectric[4]- when a mechanical stress is applied, an electric current is generated.
- Shape memory[5,6] - can change the shape whenever required and can return back to original shape once force / pressure applied is removed .
- Thermochromic[7]- these materials change color in response to changes in temperature.
- Photochromic[7]- these materials change color in response to changes in light conditions.
- Magnetorheological[7]- these are fluid materials become solid when placed in a magnetic field.
- pH sensitive[6]-when pH of the surroundings gets altered they will change their shape.
- Biofilm formation[8]- presence of biofilm on the surface of material alters the interaction of the surface with the environment.

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## CLASSIFICATION

Smart materials are of two types passive and active materials.[9] Passive materials respond to external change without external control.

**Passive Smart Restorative Materials**: They sense the external change and react to it without external control. They also possess self - repairing characteristics.

- GIC
- Resin Modified GIC
- Compomer
- Dental Composites

**Active Smart Restorative Materials**: Active materials sense change in the environment and respond to them. Utilize a feedback loop to enable them to functions as a cognitive response through a controlled mechanism or system.

Followings are the various types of smart materials in the different branches of the dentistry:-

**Restorative Dentistry**

- Smart GIC
- Smart composites
- Ariston pHC
- Smart Prep Burs

**Prosthetic Dentistry**

- Smart ceramics
- Smart impression materials

**Orthodontics**

- Shape memory alloys.

**Pediatric And Preventive Dentistry**

- Fluoride releasing pit and fissure sealants
- ACP releasing pits and fissure sealants.

**Endodontics**

- Niti Rotary Instruments.

**Smart Fibers For Laser Dentistry**

## APPLICATIONS OF SMART MATERIALS IN DENTISTRY

**Amorphous Calcium Phosphate (ACP):** Aaron S. Posner has described ACP for first time in 1963.[3] At or below 5.8 (critical pH), ACP converts into crystalline Hydroxyapatite (HAP), thus replacing the HAP crystal lost to the acid. These free ions gets merged in , forming gel-like structure within seconds. Within 2 minutes this gel-like structure releases calcium and phosphate ions. These calcium and phosphate ions neutralizes and buffers the pH[10] (Fig.1). Available as Enamel Provarnish (Fig.2).

**Casein Phosphopeptide (CPP)**, a milk derivative , in combination with ACP is used for the remineralisation of incipient white spot lesions in some dentifrices (under the name ReCaldent) Fig.3. It is marketed as GC tooth mousse plus®-Fig.4 (The University of Melbourne, Victoria, Australia)[7]

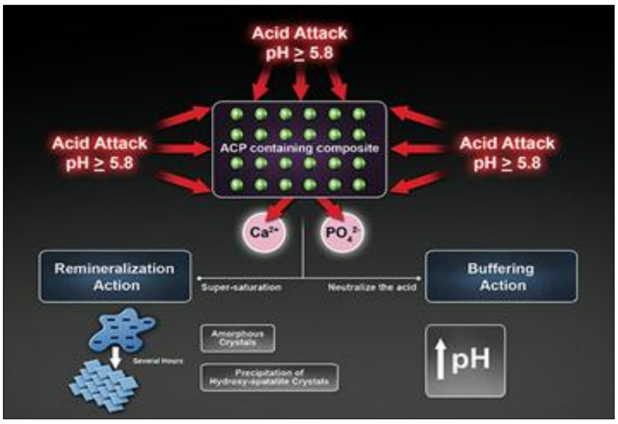


Fig.1 Mechanism of action of ACP


Fig. 2. Enamel Provarnish


Fig.3. Recaldent

Fig.4. G.C. Mousse Plus

**Smart Prep Burs:** Techniques used in caries removal include the mechanical rotary or non-rotary instruments, chemo-mechanical techniques and lasers. The non-invasive techniques include air abrasion, air polishing , ultrasonic and sonic abrasion.[11] Smart Prep Burs (Fig.5, 6) are polymer burs which have ability cuts only infected dentin.[12] The affected dentin which has the ability to remineralize is left intact. The cutting blades will deflect and deform upon encountering normal or partially decalcified dentin, thereby enabling the reduction of cutting efficiency. The time required for caries removal may be slightly longer, but when considered against the benefits they are awesome.[11]

Fig.5 Smart Prep Bur


Fig.6 Smart Prep Kit

**Smart GIC:** Davidson first observed the smart behavioural property of GIC. [13]. GICs have a coefficient of thermal expansion close to that of dental hard tissues.[3] GIC shows no / minimal dimensional changes in presence of moisture / heat. But when it is heated in dry condition at $50^0$ C, shows marked contraction. This is due to the movement of water in or out of the structures which is similar to the behaviour of human dentin.[3] This property makes GIC a smart dental material. Due to this behaviour, GIC's can provide a good marginal adaptation to the restorations. Additional smart behavior of GIC is Fluoride release.

Mahmud GA et al. 2007 stated that the use of fluoride releasing cement can minimize the demineralisation around orthodontic brackets and demineralisation does not dependent upon the amount of fluoride released. This has been confirmed by using Quantitative Light-induced Fluorescence (QLF).[3] Resin modified Glass Ionomer Cement, compomer or giomer also exhibit these smart characteristics. *Ex: GC Fuji IX GP EXTRA (Zahnfabrik Bad Säckingen, Germany).*(Fig. 7)

Fig.7 . GC Fuji IX GP EXTRA

**Smart Composites:** They are alkaline, nano-filled glass restorative material and are activated. When intra-oral pH drops below 5.5 , calcium, fluoride and hydroxyl ions are released.These released ions helps in remineralization.[14] This material can be used in class 1 and class 2 cavity in deciduous and permanent teeth till the depth of 4mm.[7] Ex: *Ariston pH control - introduced by Ivoclar -Vivadent (Liechtenstein)* Company (Fig. 8)

Fig.8 Ariston pH control composite

**Smart Ceramic:**Smart Ceramics deliver outstanding aesthetics without reservations or compromise. These are metal — free and biocompatible. The Cercon system offers advantages like strength, toughness, reliability, and biocompatibility of zirconium oxide [3]. It is the ultra-thin monolithic material, which provides maximum strength.[15] Ex: *Cercon Zirconium Smart Ceramic System*(Fig.9,10)

Fig.9 Preformed Pediatric Zirconia Crowns


Fig.10. Cercon Zirconium Smart Ceramic System

**Shape Memory Alloys (SMA):** Shape memory alloys (SMA) are the metals with the ability to recover the original shape/length when subjected to the thermo-mechanical load. These alloys show properties like super elasticity, shape memory, good resistance to fatigue and wear and relatively good biocompatibility.[16,17] Ex: Nickel -Titianium

**Nickel Titanium Alloy:**Greniger and Mooradian in 1938, first noticed shape memory property of copper-zinc and copper tin alloys.[3] Nickel-Titanium was developed 50 years ago by Buehler et al. in the Naval Ordinance Laboratory (NOL) in Silver Springs, Maryland. Nitinol basically exists in two phases. The low -temperature phase is called the martensitic or daughter phase (a body - centered cubic lattice) , and the high -temperature phase is called the austenitic or parent phase (hexagonal lattice).This lattice organisation can be altered either by stress or temperature.[8]

In endodontics, 55wt% Ni and 45 wt% Ti are commonly used, referred to as "55NiTiNOL." Walia et al. in 1988 introduced Ni- Ti to Endodontics.

The super-elasticity of NiTi rotary endodontic instruments (Fig.11,12) provide improved access to curved root canals during the chemomechanical preparation with a less lateral force exerted.[19] It allows more centered canal preparations with less canal transportation and a decreased incidence of canal aberrations.[18] Nitinol shows stress-induced thermoelastic transformation. Generally, it is in an austenitic crystalline

Fig.11 Ni-Ti Rotary Protaper Files

Fig.12 Ni-Ti Rotary Protaper Files

phase that gets converted to a martensitic structure on stressing at a constant temperature. In this martensitic phase, only a light force is sufficient for bending. If the stress is released, the structure recovers to an austenitic phase and its original shape.

In orthodontics, NiTi arch wires (Fig.13) are used instead of stainless steel owing to their limited flexibility and tensile properties. NiTi wires, because of their superelasticity and shape memory, apply continuous gentle forces on the teeth, which are in physiologic range over a longer period of time.[3]


Fig.13 NI-TI Arch wire

**Smart Fibres For Laser Dentistry**: Laser means Light Amplification by Stimulated Emission of Radiation.

Laser is a type of electromagnetic wave generator.[20] The emitted laser has three characteristic features [22] :

- Monochromatic: waves are of the same frequency and energy.
- Coherent: waves have certain phase and are relation to each other, in speed and time.
- Collimated: emitted waves are almost parallel and the beam divergence is very low.[21]

Laser radiation of high- fluency can be delivered by Hollow-core Photonic-Fibers (PCFs) which can ablate tooth enamel been developed. These photonic fibers are known as Smart Fibres.[3,23] Photonic Crystal Fibre are not only to transport the high power laser pulse to a tooth surface, but can be used for detection and optical diagnosis through transmit plasma emission . Care should be taken while using these fibers as laser light may escape and can harm healthy tissue.

**Smart Sutures:** They are made up of thermoplastic polymers that have both shape memory and biodegradable properties. Smart sutures made of plastic or silk threads covered with temperature sensors and micro-heaters can detect infections. Sutures are loosely tied , once the temperature is increased above the thermal transition temperature ; sutures gets shrinked and tightened.[7] (Fig.14). Ex: *Novel MIT Polymer* (Aachen, Germany).

Fig.14. Novel MIT Polymer smart sutures

**Smart Antimicrobial Peptide:** These are pheromone-guided "smart" antimicrobial peptide , which are targeted against Streptococcus mutans causative microorganism of dental caries.[23] The concept of tissue regeneration wherein the tissues can be re grown in the oral cavity is an emerging new technology. Antimicrobial peptides vary in their peptide sequence and posttranslational modifications, but the majority of AMPs are amphipathic mixtures of α– helical and β–sheet structures with a cationic charge. (Pazgier) The action of AMPs typically involves binding to the negatively charged functional groups of microbial membranes (e.g, lipopolysaccharides) and creating a disruption by inserting into the membranes, although it has been suggested that a number of AMPs translocate intra-cellularly and are lethal via a different mechanism. (Zasloff) Specifically targeted antimicrobial peptides (STAMP's) could be delivered in current oral care products such as mouthwash, toothpaste, or dental floss and could help with the suppression of cariogenic bacteria.[24]

## CONCLUSION

These smart materials have numerous applications and doing wonders in the field of dentistry. Advances in form of these biosmart dental materials are paving the future of dentistry. The most sophisticated class of smart materials in the foreseeable future will be that which can mimic the biological systems. This class of multi-functional materials will possess the capability to select and execute specific functions intelligently in order to respond to changes in the local environment. These materials could have the ability to anticipate challenges based on the ability to recognize, analyze, and discriminate. Thus these innovations in the material science have marked the beginning of an era of bio-smart dentistry, a step into the future!!

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