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A Review on Biosmart Dental Materials in Dentistry

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Abstract: *A major change and production of materials in dentistry has occurred in recent years. The use of smart materials promises increased durability and long-term efficiency because of their ability to intelligently select and execute specific functions in response to various local environmental changes, thereby significantly enhancing the quality of dental care, because the field of dentistry relies on the use of different materials.*
Keywords: *Smart materials, Classification of smart materials, Properties, Applications of smart materials in dentistry*

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I. Introduction

Smart materials are often characterized as planned materials that have one or more properties which will be essentially changed during a controlled design by external stimuli, like stress, temperature, moisture, pH, and electric or magnetic fields .[1]

These materials also are mentioned as responsive materials. Smart materials are around for several years and that they have found an outsized number of applications. The use of the terms “smart” and “intelligent” to explain materials and systems came from the USA and began within the 1980s despite the very fact that a number of these so-called smart materials had been around for many years. Early smart material applications started with magnetostrictive technologies. This involved the utilization of nickel as a sonar source during war I to seek out German U-boats by Allied forces. Smart behavior happens when a material can sense and respond to any stimulus from its environment in a helpful, effective, reproducible, and typically reversible way. To initiate or actuate an active response, a really smart material will use its reaction to the external stimulus. Smart materials can happen by accident, or they can be built to integrate smartness into them. This paper aims to identify the different materials that exhibit some kind of smart conduct in dentistry. [2]

The latest dental products have been improvised, making them smarter. The use of those smart materials has revolutionized dentistry, including the utilization of restorative materials like smart composites, smart ceramics, compomers, resin-modified glass ionomers, pit and fissure sealants releasing amorphous calcium phosphate, etc., and other materials such as orthodontic form memory alloys, smart impression material, smart suture, smart burs, etc. This paper aims to identify the different materials that exhibit some kind of smart conduct in dentistry. [3]

CLASSIFICATION OF SMART MATERIALS [4]

The concept of smart materials has changed from a standard “passive” elastic systems are to an “active” or adaptive (lifelike) multifunctional structural and electronic system with inherent capabilities for self-sensing, diagnosis, and control capabilities.

1. Active smart materials: they sense and adapt to a shift in the environment. Fairweather (1998) identified active smart materials as those materials which, under the application of electric, thermal or magnetic fields, have the ability to change their geometric or material properties, thus acquiring an inherent ability to transduce energy.
2. Passive smart materials can act as sensors, but not as transducers or actuators. For example, fiber optic material is used.

ACTIVE SMART MATERIALS IN DENTISTRY ACCORDING TO THEIR USE [5]

1. Restorative dentistry
   - Smart glass ionomer cement (GIC)
   - Smart composites
   - Smart seal obturation system

- o Self‐ healing composites.
- 2. Prosthetic dentistry
- o Smart ceramics
- o Smart impression materials.
- 3. Orthodontics
- a. Smart Memory Alloy (SMA)
- 4. Preventive dentistry
- a. Amorphous calcium phosphate (ACP) releasing pit and fissure sealants.
- 5. Periodontics
- b. Smart antimicrobial peptide.
- 6. Endodontics
- c. NiTi rotary instruments.
- 7. Oral and maxillofacial surgery
- d. Smart sutures.
- 8. Smart fibers for laser dentistry
- a. Hollow core photonic‐ fibers.

Passive Smart Restorative Materials: Without external influence, they sense and react to external change. They have self-repairing features as well. [6-7]

- GIC
- Resin Modified GIC
- Compomer
- Dental Composites

PROPERTIES [8-13]

In the world around them, smart materials sense changes and react in a predictable way. These properties, in general, are:

- Piezoelectric **-** an electric current is produced when a mechanical stress is applied.
- Shape memory - can change the shape whenever appropriate and can return to the original shape once removed from the force / pressure applied.
- Thermochromic **-** In response to temperature changes, these materials change color.
- Photochromic **-** In reaction to changes in light conditions, these materials change color.
- Magnetorheological **-** fluid objects, when put in a magnetic field, become solid.
- PH sensitive **-**When the pH of the atmosphere is changed, the form can change.
- Formation of biofilm**-** The presence of biofilm on the material surface affects the contact of the surface with the environment.

APPLICATIONS OF SMART MATERIALS IN DENTISTRY

SMART GIC: Davidson first noticed GIC's intelligent behavioural property. GlCs have a thermal expansion coefficient similar to that of hard dental tissues. [14] In the presence of moisture/heat, GIC suggests no/minimum dimensional changes. But when it is heated at 500 C in dry conditions, it shows marked contraction. This is due to the flow of water that is similar to the behaviour of human dentin in or out of the structures. This property transforms GIC into an intelligent dental material. GlC's will provide a strong marginal adaptation to the restorations due to this action. Fluoride release is GIC's additional smart action.

In 2007, Mahmud GA et al. suggested that the use of cement releasing fluoride will reduce demineralization around orthodontic brackets, and demineralization does not depend on the amount of fluoride produced. Using Quantitative Light-induced Fluorescence, this was confirmed (QLF). These smart features are also seen by resin modified Glass Ionomer Cement, compomer or giomer.[13] Ex: GC Fuji IX GP EXTRA (Zahnfabrik Bad Säckingen, Germany).

Fig. 1: GC Fuji IX GP EXTRA – fastest setting glass ionomer, which provides improved stability against water, an important feature in challenging oral environments

AMORPHOUS CALCIUM PHOSPHATE (ACP): In 1963, Aaron S.Posner defined ACP for the first time. ACP transforms into crystalline hydroxyapatite (HAP) at or below 5.8 (critical pH), replacing the HAP crystal lost to the acid. These free ions are combined in seconds, creating a gel-like structure. This gel-like form releases calcium and phosphate ions within 2 minutes. Such ions of calcium and phosphate neutralize and buffer pH. Accessible as Provarnish Enamel. [15-16]

CASEIN PHOSPHOPEPTIDE (CPP), a milk derivative, is used for the remineralization of incipient white spot lesions in some dentifrices (under the name ReCaldent) in combination with ACP. It is sold as GC tooth mousse plus®- (The University of Melbourne, Victoria, Australia). [17]

SMART COMPOSITES: They are and are activated by alkaline, nano-filled glass restorative content. Calcium, fluoride and hydroxyl ions are released when intra-oral Ph fall below 5.5. These released ions aid in remineralization. This content can be used in deciduous and permanent teeth up to 4 mm deep in class 1 and class 2 cavities. Ex: Ariston pH control **-** introduced by Ivoclar –Vivadent (Liechtenstein) Company. [17-18]

Fig 2: Ariston pH control – introduced by Ivoclar – Vivadent (Liechtenstein) Company

SELF HEALING COMPOSITES: Due to various physical, chemical, and/or biological stimuli, materials typically have a short lifetime and degrade. This may involve static or dynamic external forces, states of internal stress, decay, breakdown, erosion or biodegradation. This gradually leads to a degradation of the structure of the materials and material failure.Developing newer bioinspired material structures is a primary subject of current scientific research. One of the first synthetic materials documented for self-repairing or self-healing shows some similarities to dental materials based on resin. As this is an epoxy system containing microcapsules filled with resin, if a crack occurs in the composite material of the epoxy, some of the microcapsules disintegrate near the crack and release the resin. The resin then fills the crack and responds with a Grubbs catalyst that is spread in the composite of the epoxy, resulting in the resin being polymerized and the crack fixed. There may be a promising future for the self-repair mechanism based on microcapsule disintegration, and composites repaired in this way may perform better than those repaired with macroscopic repair approaches. [19]

SMART CERAMICS: The first all-ceramic teeth bridge was produced at ETH Zurich in 1995, based on a process that allowed ceramic teeth and bridges to be directly machined. The method and the materials have since been tested and released on the market as CERCON. CERCON's strength and technology allow the bridge to be constructed without stainless steel or metal. All ceramic material based on zirconia is not baked on the metal in layers but is made from one unit with no metal. Metal-free, biocompatible lifelike restoration with strength that helps resist crack formation is the overall product. With CERCON, unsightly dark margins and the underlying metal's artificial grey shadows are no longer a problem. It is used widely in implants and other non-metal applications because they are bioresponsive. [20]

SMART IMPRESSION MATERIAL: They are hydrophilic to get a void-free impression and have shape memory so that it resists distortion during elastic recovery for more precise impression and resistance to toughness. They have a snap-set behavior that results in precise fitting restorations without distortion and decreases working and setting times with low viscosity and thus high flow by at least 33 percent. Eg: Imprint TM 3 VPS, ImpregimTM, Aquasil ultra (Dentsply). [21]

Fig 3: Aquasil

SMARTSEAL OBTURATION SYSTEM: Root canal obturation can avoid root canal space re-infection and potentially prevent periapical disease. The three-dimensional filling of the fitted canal and the accessory canals will accomplish this. Although various canal filling techniques are currently available to achieve this objective, there is continuing interest in the creation of simpler obturating materials/techniques for irregularly formed canal filling and in minimizing voids produced during obturation processes, which can act as nidi for residual biofilm growth. A point-and-paste root canal filling technique consisting of premade hydrophilic endodontic points and an accompanying sealer is the smart seal obturation system, the C Point system (EndoTechnologies, LLC, Shrewsbury, MA, USA). C Point's inner core consists of a mixture of two patented polymers of nylon: Trogamid T and Trogamid CX.The polymer coating is an acrylonitrile and vinyl pyrrole cross-linked copolymer, which is polymerized and cross-linked using allyl methacrylate and a thermal initiator. C Point's lateral expansion is non-uniform, with the expandability depending on the degree to which the hydrophilic polymer is pre-stressed (i.e., contact with a canal wall will reduce the rate or extent of polymer expansion). This non-isotropic lateral expansion increases the sealing capability of the filling of the root canal, thereby reducing the risk of reinfection.[22]

SMART COATINGS FOR DENTAL IMPLANTS: Researchers from North Carolina State University have created a "smart coating" that allows surgical implants to bind more tightly with bone and avoid infection. This has contributed to a road for safer hip, knee, and dental implants as they are at risk of implant rejection. A crystalline layer next to the implant and an amorphous outer layer covering the bone are formed by the coating. Over time, the amorphous layer dissolves and releases calcium and phosphate, which stimulates the growth of bones. The bone develops into the coating, resulting in enhanced osseointegration of the bond. As the bonding allows the bone and the implant to share the load, this bonding also makes the implant more functional. The researchers have also integrated silver nanoparticles to decrease infections in the coating. Silver embedded into the coating is released as the amorphous layer dissolves, acting as an antimicrobial agent. This will restrict the number of patients with antibiotics that will require the subsequent surgery and provide protection for the life of the implant from infection at the implant site. In addition, where there is a greater chance of infection, the silver is released more rapidly after surgery due to the quicker dissolution of the amorphous layer of the coating. As the patient is recovering, the silver release can slow down, so it is called a smart coating.[23]

SMART FIBRES FOR LASER DENTISTRY: For the delivery of high-fluence laser radiation capable of ablating tooth enamel, hollow core photonic crystal fibers (PCFs) were grown. Nd: YAG laser radiation sequences of picosecond pulses are transmitted via a hollow-core photonic crystal fiber with a core diameter of approximately 14 micrometers and centered on a tooth surface to ablate dental tissue. The hollow core PCF supports the 1.06 micrometer laser radiation single fundamental mode regime. The same fiber is also used to transmit emissions from plasmas, generated for detection and optical diagnostics by laser pulses on the tooth surface in the backward direction. [24]

SMART SUTURES: Thermoplastic polymers that have both shape memory and biodegradable properties are made up of these sutures. In their temporary form, they are applied loosely and the ends of the suture are fixed. The suture shrinks and tightens the knot as the temperature is increased above the thermal transition temperature, applying the optimal power. The temperature of the thermal change is similar to the temperature of the human body and this is of clinical importance when tying a knot with sufficient tension in surgery (Fig 9). Smart sutures are made of temperature sensors and microheaters covered with plastic or silk threads that can detect infections. Eg: MIT Polymer Novel (Aachen, Germany). [25]

Fig 4: Smart sutures use ultrathin silicon sensors to measure temperature at wound site

PHEROMONE GUIDED SMART ANTIMICROBIAL PEPTIDE: A new class of pathogen selective molecule named specifically (or selectively) Targeted Antimicrobial Peptides (STAMP) was formed on the basis of the fusion of a species-specific targeting peptide domain with a broad spectrum domain of antimicrobial peptides. Streptococcus mutans, the key microorganism responsible for dental caries, is targeted against the killing of this pheromone-guided "smart" material peptide. Streptococcus mutans, a pheromone developed by S.mutans, can be extracted from multi-species biofilm without affecting the nation's cariogenic microorganisms by using Competence Stimulating Peptide (CSP). Their molecules have the potential to be produced into "probiotic" antibiotics that remove pathogens selectively while maintaining the healthy oral flora's protective benefits. Ex: The "smart" antimicrobial peptide driven by pheromones. [26]

SMART PREP BURS: These are polymer burs with only contaminated dentin removed. The dentin affected, which has the capacity to remineralize, stays intact. The use of these smart preparation burs will prevent overcutting of the tooth structure, which is commonly seen with traditional burs. Carious dentin is selectively extracted by Smart Burs, leaving the good dentin intact. On coming into contact with tougher materials, such as good dentin, the polymer cutting edges break down and become blunt . Eg: SS White Preparation Kit for Diamonds and Carbides. [27]

Fig 5: Smart burs

II. Conclusion

Advances in the form of these biosmart dental materials pave the way for dentistry's future. In the near future, the most advanced type of smart materials would be the kind that can imitate biological systems. In order to respond to changes in the local environment, this class of multi-functional materials would have the capacity to pick and execute complex functions intelligently. Such materials may be capable of predicting difficulties based on the ability to identify, interpret and differentiate. These material science advances have thus marked the beginning of an age of bio-smart dentistry, a step into the future!!

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