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Smart Material - Making Dentistry Smarter

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Abstract

Conventionally, materials designed for long-term use in the mouth are thought to survive longer if they are ‘passive’ and have no interaction with their environment. Materials such as amalgams, composites and cements are often judged on their ability to survive without interacting with the oral environment. 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. The use of smart materials has revolutionized dentistry which includes the use of restorative materials such as smart composites, smart ceramics, compomers, resin modified glass ionomer, amorphous calcium phosphate releasing pit and fissure sealants, etc. and other materials such as orthodontic shape memory alloys, smart impression material, smart suture, smart burs, etc. This review of literature attempts to highlight some of the currently available “smart materials” in dentistry which

may over the course of years help us move toward a new era of smart dentistry.

Keywords: Smart material, Dental material, Smart composite, Smart GIC

Introduction

In dentistry, there is no single material, i.e., ideal in nature and fulfils all the requirements of an ideal material. So, the quest for an "ideal restorative material" continues, leading to introduction of newer generation of materials.[1]

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. 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.[2]

The use of smart materials has revolutionized dentistry which includes the use of restorative materials such as smart composites, smart ceramics, compomers, resin modified glass ionomer, amorphous calcium phosphate releasing pit and fissure sealants, etc. and other materials such as orthodontic shape memory alloys, smart impression material, smart suture, smart burs, etc.[3] This view of literature attempts to highlight some of the currently available ―smart materials‖ in dentistry to achieve maximum advantage over conventional dental materials.

Table 1: Classification of Smart materials[1]

Passive smart restorative materials: Respond to external change without external control	Glass ionomer cement (GIC) Resin-modified GIC Compomer Dental composites
Active smart restorative materials: Utilize a feedback loop to enable them to function like a cognitive response through an actuator circuit.	1 **Restorative dentistry** • Smart GIC • Smart composites • Smart prep burs 2 **Prosthetic dentistry** • Smart ceramics • Smart impression materials 3 **Orthodontics** • Shape memory alloys (SMAs) 4 **Pediatric and preventive dentistry** • Fluoride-releasing pit and fissure sealants • ACP-releasing pits and fissure sealants 5 **Endodontics** • Nickel-titanium (NiTi) rotary instruments 6 **Oral surgery** • Smart suture 7 **Smart fibers for laser dentistry** 8 **Smart antimicrobial peptide**

Applications of Smart Materials in Dentistry

Smart GIC: Davidson first observed the smart behavioural property of GIC. GlC have a coefficient of thermal expansion close to that of dental hard tissues.[4]

Through observation, there were minimal or no dimensional changes in GlC in terms of heating (expansions) and cooling (contractions) in wet conditions but the materials demonstrated a marked contraction when heated at 50° C in dry conditions. This action was due to the movement of water in or out of the structures which mimic the behavior of human dentin and indirectly shows the behavior of smart features. Due to this behavior, GlC can provide a good marginal adaptation to the restorations.[5]

Additional smart behavior of GIC is Fluoride release. Mahmoud GA et al. concluded that the use of fluoride releasing cements can minimise the demineralisation around orthodontic brackets and that this effect is not simply dependent upon the extent of the initial fluoride release.[6]

Self Healing Composite: Self-healing composites are composite materials capable of automatic recovery when damaged. They are inspired by biological systems such as the human skin which are naturally able to heal themselves.[7]

The first self-healing resin based synthetic material has been developed by White et al. The material was an epoxy system which contained resin filled microcapsule dicyclopentadiene, a highly stable monomer with excellent shelf life, encapsulated in thin shell made of urea formaldehyde. In response to environmental stimuli, some of the microcapsules rupture and release resin, which further reacts with Grubbs catalyst in epoxy composite, causing a polymerization reaction to take place and repair the crack. The main concern is the potential toxicity of the resins in the microcapsules and from the catalyst. However, their amount is relatively small, and the concentration may well be below the toxicity threshold.[8]

Smart Composite: Smart composite contains Amorphous Calcium Phosphate. ACP at neutral or high pH remains ACP. When low pH values i.e., at or below 5.8 occurs during a carious attack, ACP converts in to HAP and precipitates, thus replacing the HAP lost to the acid. So when the pH level in the mouth drops below 5.8, these ions merge within seconds to form a gel. In less than 2 minutes, the gel becomes amorphous crystals, resulting in calcium and phosphate ions.[9]

Smart pit and fissure sealants

Colour Changing Pit and Fissure Sealant: In March 1977, the first coloured sealant (3M's Concise White Sealant) was introduced to the market. It is easier to see the sealant during application, and it is faster and easier to assess with a white sealant than with a clear sealant at later time intervals. While a Helioseal material, which changes colour from clear to green when exposed to a visible light, has some clinical utility, particularly on subsequent follow-up examinations.[11]

ACP Releasing Pit and Fissure Sealant: Amorphous calcium phosphate is referred to as a "smart material" because it releases calcium and phosphate ions when the surrounding pH drops (5.9) to a level where it could start to dissolve the tooth. Once calcium phosphate is released, it will act to neutralize the acid and buffer the pH. ACP acts as reinforcement to the tooth's natural defence system only when it's needed. Recent decade has introduced sealants that contain fluoride and ACP.[12]

Smart Bur: One of the goals of conservative dentistry is to develop a method to remove caries infected dentin while preserving caries affected dentin. The smart prep bur appears to be the instrument to offer straight forward and efficient means of achieving this goal. Smart prep instrument is a medical grade polymer that safely and

effectively removes decayed dentin leaving healthy dentin intact.

Polymer bur is a unique rotary instrument which is constructed from a medical-grade polyether-ketone-ketone, and it selectively removes decayed dentine without cutting the healthy dentine. This property is based on the hardness of the instrument being lower than the hardness of the healthy dentine. In addition, this minimally invasive excavation has the advantage of fewer dentin tubules being cut and thereby, less pain sensations being triggered compared to using conventional burs. Freedman and Goldstep found that polymer burs remove carious dentin selectively, whereas healthy dentin is not affected. The polymer cutting edges will wear down in contact with harder materials (such as healthy dentin) and will go blunt.[13,14]

Smart Bonding Agent System: Now studies are trying to impart smart to dental adhesives by adding ACP, Dimethylaminododecyl methacrylate and silver nano particles, which make them antibacterial and self repairable. Studies have found that ACP releases calcium and phosphate ions which can demineralise tooth lesions. DMADDM and silver nano particles substantially decrease the biofilm and their metabolic activities and hence preventing secondary caries.[14,15]

Smart Seal Obuturation System: Obturation of root canals should prevent reinfection of the canal space and ultimately prevent periradicular disease. This objective may be achieved by three-dimensional filling of the instrumented canal, accessory canals, and dead spaces.

Newly introduced root canal obturating system “SmartSeal” is established on the polymeric technology. The hydrophilic nature of the obturating points can absorb surrounding moisture and expand, resulting in filling of voids and spaces, onto which the principle of this system depends.

This product is considered to exhibit smart behavior and incorporates developments in hydrophilic polymer plastics. Smartseal is a two-part system consisting of:

1. Propoint
2. Smart paste/Smart paste Bio

Pro-point: Also known as C points, these obturation points are constructed in two parts:

a) **Central Core:** It consists of a combination of two proprietary nylon polymers, Trogamid T and Trogamid CX. It is considered to provide the point with the flexibility to allow it to easily pass around any curves in the prepared canal, while being rigid enough to pass easily to length in narrower canals.

b) **Outer Polymer Layer:** It consists of a cross-linked copolymer of acrylonitrile and vinylpyrrolidone, which has been cross-linked using alkyl methacrylate and a thermal initiator. This hydrophilic, hydrogel layer allows the point to swell in order to adapt to the ramifications of the root canal. This coating is designed to swell laterally, thereby self-sealing the canal. It does not swell axially so there is no length change and radial swelling stops once a seal is created.

Smart paste: Smartpaste is a resin based sealer containing an active polymer that swells to fill any voids or cavities in the root canal. The degree of swelling is controlled by the amount of active polymer used. The polymer can also swell at a later date to fill any voids that might develop.

The development of materials such as Smartseal may prove to be a game changer in the field of endodontics. One of the main advantages of this obturating system is the versatility of the product allows the creation of points to match most file systems present today. The use of

Smartseal in conjunction with the latest equipment and techniques available in endodontics will further enhance the root canal treatment outcomes.[16]

Smart Sutures: These are thermoplastic polymers that have both shape memory and biodegradable properties. When temperature rises above thermal transition temperature the suture shrinks and tightens the knot, applying the optimum force. Smart sutures are covered with silk or plastic threads covered with temperature sensors and micro heaters, which can detect infection. The nanomaterials used to coat the thread serves required purpose. The threads are coated with different nanomaterials to detect different environmental conditions. Smart sutures in the future will allow 'multimodal sensing, wireless data transfer, UV sterilization, drug release and thermal therapy' according to Rogers. There will be no need for follow up visits.[10]

Smart Impression Materials: This new formula of Aquasil (Aquasil Ultra Smart Wetting® Impression Material) is an addition to the silicone impression material designed with a reduced contact angle, an increase in tear strength, and maintenance of a low viscosity during the working time. The material is available as a regular- and fast-set rigid (light green), heavy (light green), monophase (maroon), low (teal), and extra-low (orange) viscosities.[1]

Nickel-Titanium Smart Alloy: The term "smart material" or "smart behaviour" in the field of dentistry was probably first used in connection with Nickel Titanium (NiTi) alloys, or shape memory alloys (SMAs), which are used as orthodontic wires. The smart behavior of NiTi alloys is because of two salient features called "super elasticity" and "shape memory." This "smart" property is the result of the substance's ability to undergo a phase change- a kind of atomic ballet in which atoms in the solid subtly shift their positions in response to a stimulus like a change in temperature or application of mechanical stress.

The super elasticity of NiTi rotary instruments provides improved access to curved root canals during the chemicomechanical preparation, with less lateral force exerted. It allows more centered canal preparations with less canal transportation and a decreased incidence of canal aberrations.

In orthodontics, NiTi arch wires are used instead of stainless steel owing to their limited flexibility and tensile properties. NiTi wires, because of their super elasticity and shape memory, apply continuous gentle forces on the teeth, which are in physiologic range over a longer period of time.[17,18]

Smart Fibers for Laser Dentistry: Laser radiation of high fluency can be easily delivered by Hollow-core Photonic Fibers (PCFs) i.e. the laser radiations can easily be snaked through the body Using this Hollow-core Photonic-Fibers which are capable of ablating tooth enamel. These photonic fibers are known as Smart Fibers. Photonic Crystal fiber are not only to transport the high power laser pulse to a tooth surface, but can be used for detection and optical diagnosis through transmitted plasma emission. While using these fibers we ought to be very careful because there is a risk factor that in some cases the fiber walls fail and the laser light may escape and harm the healthy tissue. [18,19]

Discussion

In the 21st century, science and technology relies heavily on the development of new materials that are expected to respond to the environmental changes and manifest their own functions according to the optimum conditions. Smart materials are an answer to this requirement of environment- friendly and responsive materials, which alter their properties to perform specific functions.

Smart material has encompassed all the fields of science and engineering. The future of smart materials is wide open. The use of smart materials in a product and the type of smart structures that one can design is only limited to one's talents, capabilities and ability to think out of box. Great deal of researches for smart materials are going on which is having its effect in the field of dentistry. Newer materials are coming in with unique smart properties. Soon, the word 'smart' would become the integral part of dentistry and dentistry could become "smart dentistry"

Smart materials are designed materials that have one or more properties that can be changed in a controlled fashion by external stimuli; such as stress, temperature, moisture, pH, electric or magnetic fields. In dentistry, smart materials would potentially allow new and ground-breaking dental therapies with a significantly enhanced clinical outcome of treatments. On the other hand, bioactive materials are defined as materials which have an effect on or elicit a response from a living tissue, organisms or cells as inducing the formation of hydroxyapatite. As the saying goes, "Every tooth in a man's head is more valuable than a diamond." Thereby in the interest of all the dentists the introduction of smart materials have been made, which would help them to be more conservative and efficient with their treatment plans.[20,21]

Conclusion

There is no doubt that the demand of dental biomaterials on a rapid rise and there are no available dental materials with ideal properties for dental applications, which imitate biological systems. The recent advances in the "Smart Materials" have created novel opportunities for their applications in dentistry. Smart materials are a new generation of materials which hold a good promise for the future in the field of bio-smart dentistry. They are in their initial stages of development, and considerable research is required in this field of material science. The numerous applications of smart materials have revolutionized many areas of dentistry and there is no doubt that "smart materials" hold a real good promise for the future.

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