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Smart Dental Material: A Review

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Abstract

A single dental material that satisfies all the criteria for the ideal material has not yet been discovered. While the hunt for the "ideal material" is still on, newer types of materials have been launched. The term "smart" refers to materials with characteristics that are also present in living organisms, such as the ability to detect changes in their environments and respond to these changes in predetermined ways. Such stimuli as pressure, temperature, moisture, pH, and an electric or magnetic field can change these materials in a regulated way. These products come in a variety of "bio-responsive" and "bio-mimetic" varieties. These materials might enable innovative and novel dental therapies with greatly improved clinical outcomes of the treatment processes. In an effort to accelerate the transition to a new era of bio-smart dentistry, this paper aims to highlight some of the "smart materials" presently used in dentistry.

Keywords: Dental Material, Smart Dentistry, Smart Material

Introduction

According to McCabe et al., "Smart materials" are substances whose characteristics can be changed in a controlled way by factors like stress, temperature, moisture, pH, and electric or magnetic fields.[1,2] The capacity to revert to the initial state after the stimulus has been removed is one of the main characteristics of intelligent behaviour. These substances are also referred to as "responsive materials" because they react to ambient changes or outside influences. A change in shape, stiffness, viscosity, or damping could be one way the reaction manifests itself. They can compensate for flaws or cracks created when embedded in host materials and turned on; this phenomenon is known as the self-repairing effect and it aids in maintaining the material in a "safe condition."[3,4]

Many of the smart materials were developed by government agencies working on military and aerospace projects. This involved the use of nickel as a sonar source during World War I to find German U-boats by allied forces. Despite the fact that some of the so-called smart materials have been around for decades, the first use of the terms “smart” and “intelligent” materials started from the USA in 1980. Recently, there has been a surge in the requirement of an increasing safety margin of infrastructure, biomedical, and engineering (automotive, aerospace, and marine) elements. This has led to a rapid increase in the development of smart materials and structures, at the levels of micro- and nano-scale. The use of smart material has also been expanded into some everyday items, and the number of applications for them is growing steadily.[3,4] In an effort to accelerate the transition to a new era of bio-smart dentistry, this paper aims to highlight some of the "smart materials" presently used in dentistry.

Table 1: General Properties of Smart Material[5-9]

Properties of Smart Material	
Piezoelectric	When a mechanical stress is applied, an electric current is generated.
Shape memory	After deformation these materials can remember their original shape and return to it when heated.
Thermo chromic	These materials change color in response to changes in temperature.
Photo chromic	These materials change color in response to changes in light conditions.
Magneto rheological	These are fluid materials become solid when placed in a magnetic field.
Ph sensitive	Materials which swell/collapse when the pH of the surrounding media changes.
Bio film formation	Presence of bio film on the surface of material alters the interaction of the surface with the environment.

Table 2: Classification of Smart Dental Material[10,11]

Smart materials are of two types namely passive and active materials

Passive Smart Materials:	**Active Smart Materials:**
They are materials that sense the external change and react to it without external control. Example: Composites, GIC, Resin-modified GIC and Compomers.	They are materials that sense change in the environment and respond to them. Example: Smart GIC, Smart composites, Smart Prep Burs.

Smart Dental Materials

Smart Glass Ionomer Cement: Davidson was the first to propose the GIC's intelligent behaviour. Expansion and contraction of composite materials happened as anticipated regardless of dry or wet conditions when samples of restorative materials were heated to determine their coefficients of thermal expansion. When heating and cooling glass-ionomers between 20°C and 50°C in wet circumstances, however, little to no change in dimension was seen. Glass ionomers demonstrated a noticeable contraction in dry circumstances when heated above 50°C.[1,12]

Glass-ionomers and similar materials' intelligence is closely correlated with their water content and the capacity of that water to respond to environmental changes. The process underlying the observed contraction during heating is an increase in fluid flow to the surface and a quick loss of water. Comparable changes are observed as a result of fluid flow in the dentinal tubules in human dentine, which exhibits a behaviour comparable to this one. Thus, it can be said that the glass-ionomer materials mimic human dentine behaviour through a form of cunning behaviour. GIC offers excellent marginal adaptation to the restorations as a result of its smart behaviour.[13]

The fluoride release and recharge capability of GIC is another feature of its intelligent behaviour. The release of fluoride in products is typically observed as a high initial release followed by a gradual decline over time. The ability of materials with GIC salt phases to "recharge" when exposed to high concentrations of fluoride, such as those found in toothpaste or mouthrinses, is thought to be the cause of their clever behaviour.[1]

Commercially available as GC Fuji IX GP EXTRA (incorporates a “SmartGlass” filler).

Smart Composite: Composites are presently the most popular restorative material because of their properties and the fact that they are tooth-colored and strong, which is advantageous to both the clinician and the patient. Composites are modified by adding nanoparticles, ACP, and other elements to further enhance its capabilities. Smart Composite is an alkaline, nano-filled, glass-restorative material that responds to light, which will change its properties. When intraoral pH values fall below the crucial pH of 5.5, it improves the remineralization of the tooth surface when it becomes demineralized by releasing hydroxyl, calcium, and fluoride ions [16]. Recommended for fillings in class 1 and class 2 lesions and permanent teeth**.** Smart composites have also been changed to allow for bulk curing in thicknesses up to 4 mm. It is recommended for restorations in class 1 and class 2 lesions and can be used on both primary and permanent teeth.[14,15]

Smart Burs: Polymer burs in the shape of paddles, Smart Burs are composed of polyether-ketone-ketone. Smart Bur can cut the infected dentin while keeping the affected dentin intact because it has a harder surface than infected dentin (15–20KHN) and healthy dentin (68KHN).When a smart bur comes into touch with healthy, calcified tooth structure, it becomes dull and vibrates.[16,17]

Smart Obturation System: Obturation is the filling of instrumented canals, accessory canals, and dead areas in three dimensions. Obturating the substance will stop reinfection, which will stop periapical infection. Dentists use a variety of methods for filling canal. As a result of leakage between the sealer and the dentin, as well as between the gutta-percha and the sealer, as well as the existence of voids, treatment failure results. Gutta-percha is an impermeable substance. There has been an ongoing search for materials with superior sealing properties because numerous in vitro studies to test gutta-percha's sealing ability revealed high leak rates. One such material is the smart seal system. A recently released point-and-paste system with hydrophilic polymer-based technology is the C point system, also referred to as the clever seal system.[18,19] Hydrophilic obturation points and a sealer are the two primary parts of a smart seal. Obturation points come in a variety of tip diameters and taper shapes and are composed of polymorphs. The hydrophilic characteristic of the smart obturating material aids in absorbing moisture and lateral expansion of the material filling gaps; however, for proper sealing, a sealer should be used in conjunction with this endodontic material. Numerous tip diameters and tapers are offered for SmartSealTM.[19,20]

Smart Ceramic: The first "all ceramic teeth and bridge" was created in 1995 at ETH Zurich using a technique that allows for the direct machining of ceramic teeth and bridges. The procedure involved sintering after machining a premade ceramic blank made of zirconia ceramics with a nanocrystalline porous structure. The sintered material uniformly contracts to its ultimate dimensions in all spatial directions. During the final sintering, the substance acquires its high hardness, high strength, and toughness. The necessary aesthetic and wear features are then added by veneering the high strength ceramic framework. The method's benefits include high accuracy in a simple, quick, and completely automated manner. The dental supplier Degudent presented this invention to the market under the name CERCON ®-Smart Ceramics System. It subsequently ushered in a new age of dental ceramics. It displayed superior qualities in terms of aesthetics requirements, great biocompatibility, and lack of hypersensitivity reactions.[22,23]

Smart Sealer: Smartpaste Bio, a resin-based sealer with bioceramics, is another illustration. Calcium hydroxide and hydroxyapatite are produced as byproducts of the setting process in Smartpaste Bio, making the substance extremely biocompatible and antibacterial. It sets slowly, taking between 4 and 10 hours, and because it is hydrophilic, the propoints are encouraged to hydrate and expand, filling in all the gaps. The lateral pressures produced are less than the dentin's tensile strength and less than those produced by conventional methods. The Smartpaste Bio's bioceramics give the sealer dimensional integrity and prevent it from resorbing in the root canal.[11]

Self Healing Composite: Materials deteriorate over time as a result of various physical, chemical, and/or biological factors. This causes the material's properties to deteriorate, eventually resulting to failure. One of the most sought-after qualities in the creation of materials is self-healing. The healing of a broken bone in the presence of nutrients and a source of blood supply is the finest illustration of self-healing in the body. This biological paradigm is being continuously replicated in material science.

White et al. have created the first synthetic resin-based self-healing substance. The substance was an epoxy system that held resin-filled microcapsules of the highly stable monomer dicyclopentadiene that were protected by a thin layer of urea formaldehyde. When exposed to certain environmental triggers, some of the microcapsules burst, releasing resin that then interacts with the Grubbs catalyst in the epoxy composite to trigger a polymerization reaction that fills the crack. The primary issue is the catalyst's and the microcapsules' possible toxicity of the resins. The concentration may well be below the toxicity threshold, but their quantity is comparatively small.[24]

Smart Suture: Containing thermoplastic polymers with form memory and biodegradability. They are gently applied in its temporary shape, and the suture ends are secured. Suture would compress as the temperature rose above the thermal transition temperature, tightening the knot and exerting the ideal force. This thermal transition temperature is clinically relevant in tying a knot in operation with the proper pressure because it is close to the human body temperature. Smart sutures are made of silk or plastic strands that have temperature monitors and tiny heaters built in to detect infections.[25,26]

Conclusion

Recent developments in the use of smart materials have led to creative possibilities for their application in the areas of dentistry and biomedicine. Nevertheless, these numerous uses for "Stimuli-Responsive or Smart Materials" indicate that they may hold future promise. With these developments, the age of biosmart dentistry has officially begun and moved one step closer to reality. Therefore, it is now necessary to "think smart" and use smart materials in dentistry during routine clinical procedures.

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