



Bio-Smart Materials in Dentistry: A Review

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Abstract

There hasn't yet been a dental material that is perfect in every way and meets all the criteria for a superb material. Newer groups of materials have been introduced as the hunt for a "ideal restorative material" goes on. These "Smart Materials" hold the remaining tooth structure to the same level as the cavity so that more cautious cavity preparation can be done. These materials can be precisely improved by stimuli like stress, temperature, moisture, pH, electric field, or magnetic field. Some of these mimics the characteristics of natural tooth components like enamel or dentin and are referred to as "biomimetic" materials. To make them more intelligent, the currently used dental materials were modified. Dentists now use restorative materials like Smart composites, Smart ceramics, Composers, Resin Modified Glass Ionomer, Amorphous Calcium Phosphate Releasing Pit and Fissure Sealants, etc. in addition to other materials like Shape Memory Alloys, Smart Impression Material, Smart Suture, Smart Burs, etc. that have been made possible using Smart materials. This article emphasizes how conventional dental restoration methods can benefit from the usage of Smart materials.

Introduction

According to McCabe Zrinyi, "smart materials" are "materials that can change in response to stimuli and then transform back into the original state" after the removal of stimulus." Temperature, pH, moisture, stress, electricity, chemical or biological agents, and magnetic fields are only a few examples of the stimuli that can be produced. Researchers have used smart materials in the field of medicine and dentistry because of the distinctive behaviour they display. Smart materials stand out because they may return to their original state when the stimulus has been removed. The ability to sense and respond to environmental changes is built into smart materials, which are incredibly responsive. They are known as responsive materials as a result.[1, 2]

Even though just a handful of them were referred to as "smart materials," the phrases "smart" and "intelligent" were used to describe materials and systems in the 1980s. Applications for smart materials previously began with magneto-strictive technologies. This included the employment of nickel as a sonar source by Allied forces to search German U-boats during World War I.[3]

If dental materials are passive and do not respond to their surroundings, they are more stable and durable. Meanwhile, it is hoped that the items would be favorably received and won't harm or hurt anyone. This strategy for material tolerance and biocompatibility is wholly unfavorable. This perspective conceals the possibility that using materials that behave more dynamically in their surroundings will lead to favorable outcomes. The materials used in dentistry today are improvised. Dentistry has undergone a significant transformation thanks to the use of smart materials, which also include orthodontic shape memory alloys, smart burs, and restorative materials like smart composites, smart ceramics, compomers, resin-modified glass ionomer, and amorphous calcium phosphate-releasing pit and fissure sealants.[4-8]

Ideal Properties of Smart Material: Williams asserts that "smart" materials can react to an outside stimulus in a predetermined, controlled manner. The failure of conventional filling materials can be attributed to the development of secondary cavities, restoration or tooth fracture, marginal inconsistencies, or wear. By incorporating additives, newly created materials are intelligently designed to lower failure rates.[9] Ideal Properties of Smart Material are as follow:

- Preventing secondary caries
- Preventing fracture of restoration
- Preventing fracture of tooth
- Providing a good marginal integrity
- Reducing wear
- Preventing marginal discrepancies
- Preventing wear

Table no. 1 Classification of Smart Dental Material^[10,11]	
Smart materials are of two types namely passive and active materials	
Passive Smart Materials: They are materials that sense external change and react to it without external control. Example: Composites, GIC, Resin-modified GIC and Compomers.	Active Smart Materials: They are materials that sense change in the environment and respond to them. Example: Smart GIC, Smart composites, Smart Prep Burs.

Table no. 2 General Properties of Smart Material ^[12-16]

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 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.

Bio - Smart Dental Materials

Smart GIC: For the first time, GICs exhibited intelligent behavior. The materials used in restorative procedures may exhibit thermal expansion or contraction in response to thermal stimuli when ingested along with hot or cold meals and liquids.[7] Stresses at the contact may be caused by the incompatibility of thermal expansion and contraction between a restoration and the tooth structure, which may result in microleakage.[17] The materials demonstrated a noticeable contraction in dry conditions when heated over 50°C. This behavior can be explained by the fact that fluid flow to the material's surface balances the dimensional changes by compensating for the expected expansion upon heating. The procedure was reversed as it cooled. The contraction that is seen in dry conditions is caused by the water quickly evaporating when heated. This behavior is comparable to that of human dentin, which exhibits a considerable shrinkage when heated in dry settings but very little dimensional change when heated in moist conditions.[18]

The fluid flow in the dentinal tubules can be used to explain both results. As a result, it can be argued that glass ionomer materials exhibit a smart behavior that mimics the behavior of human dentin. As a result, GICs are referred to as "smart materials" in terms of their thermal behaviour.[19]

Smart Antimicrobial Peptide: The main bacterium responsible for dental caries, Streptococcus mutants, are targeted by a pheromone-guided "smart" antimicrobial peptide. Tissue regrowth in the mouth cavity is conceptualized by the emerging technology known as "tissue engineering".[20] Accordingly, the BRAX-I gene has been isolated and is thought to be in charge of regulating enamel growth.[21]

Smart Pressure Bandages: Polyethylene glycols reveal traits like temperature adaptability and reversible shrinkage when they are linked to various fiber materials like cotton and polyester. Such shrinking entails imbuing the material with a fundamental memory and causing it to contract when exposed to fluids. When in contact with blood, these materials can be used as pressure bandages to apply pressure to wounds.

Smart Ceramic: Crowns have been made using ceramics, which have been around for a while. Ceramics are now used more and more in dentistry due to its improved aesthetic qualities, biocompatibility, color stability, wear resistance, and low thermal conductivity. Zirconia, a polymorphic material that appears in three temperature-dependent forms in its pure form, is the most recent development in the dental ceramics' family. Crystal structure that is monoclinic between ambient temperature and 950 °C. Zirconia changes to a tetragonal crystal structure above 950 °C. This change is accompanied by a shrinkage of more than 1% when heated and a nearly equal expansion when cooled. The zirconia transforms from a tetragonal to a cubic structure at higher temperatures. It is possible to create a microstructure during cooling that includes lens-shaped "precipitates" of tetragonal zirconia in cubic grains of zirconia with carefully controlled chemical additives and heat treatments. Normally, the tetragonal material would change to the monoclinic form during cooling, but expansion is required. The surrounding cubic zirconia's great strength inhibits this expansion, therefore the zirconia maintains its tetragonal shape even at room temperature. Each tetragonal zirconia precipitate is therefore under stress and brimming with energy that needs to be released. If a crack attempts to form, each tetragonal precipitate will enlarge, breaking the ceramic. Tetragonal precipitates next to the crack are now able to expand and transform back to their stable monoclinic form. This expansion adjacent to the crack presses against the crack and stops it. This is the mechanism of transformation toughening. This property of ceramic makes it a smart material.[21,22]

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.[10,23]

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.[24,25]

Smart NiTi: The phrase "smart material" or "smart behaviour" was originally used in the context of NiTi alloys, also known as shape memory alloys (SMAs), which are utilised as orthodontic wires. Buehler et al. created nickel-titanium 50 years ago at the Naval Ordnance Laboratory (NOL) in Silver Springs, Maryland. Due to their "superelasticity" and "shape memory," these alloys are regarded as smart materials. This "smart" characteristic is the outcome of the substance's capacity for phase shift. In essence, nitinol has two phases. In a body-centered cubic lattice, the low-temperature phase is known as the martensitic or daughter phase, and the high-temperature phase is known as the austenitic or parent phase.

Stress or temperature can change the way the lattice is organized. In endodontics, stress is applied to NiTi files during root canal therapy, and this stress-induced martensitic change takes place within the speed of sound from the austenitic to the martensitic phase. Along with changes in volume and density, a form shift also takes place. Super elasticity is the ability to withstand stress without experiencing irreversible deformation and return to the original lattice shape. The NiTi file's ability to return to its original straight form without displaying any indication of persistent distortion is known as the "shape memory effect." An SMA has an extremely low yield strength when cold, or below its transformation temperature, and may be easily bent into any new shape with little loss of integrity.[26-28]

Conclusion

Smart materials have characteristics that can change depending on the surrounding conditions, including pressure, temperature, moisture, pH, and electric or magnetic fields. Smart behavior has the capacity to revert to its initial state even after the stimulus has been taken away. There is little doubt that "smart materials" have a great deal of potential for the future given the multiple uses that they have in dentistry. These advances in material science have ushered in a new era of bio smart dentistry and taken dentistry one step further into the future.

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