Review Article

Smart materials in dentistry: Think smart!

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ABSTRACT

There is no single material in dentistry that is ideal in nature and fulfills all the requirements of an ideal material. As the quest for an "ideal restorative material" continues, a newer generation of materials was introduced. These are termed as "smart'' as these materials support the remaining tooth structure to the extent that more conservative cavity preparation can be carried out. These materials may be altered in a controlled fashion by stimulus such as stress, temperature, moisture, pH, electric or magnetic field. Some of these are "biomimetic" in nature as their properties mimic natural tooth substance such as enamel or dentin. The current dental materials were improvised in order to make them smarter. 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 paper attempts to highlights the use of "smart materials" to achieve maximum advantage by conventional restorative techniques in dentistry.

Key words: Biodegradable, Biomimetic, Smart materials

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INTRODUCTION

Traditionally 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 reacting to the oral environment. Today the most promising technologies for life time efficiency and improved reliability include the use of "bio-active" smart materials.

A material is said to be "smart" if it can support the remaining tooth structure to the extent that cavity preparation can be carried out in the most conservative way. These materials have properties which may be altered in a controlled fashion by stimulus such as stress, temperature, moisture and pH, electric or magnetic field.[1] A key feature of smart behavior includes its ability to return to the original state even after the stimulus has been removed.

PROPERTIES OF SMART MATERIAL

Smart materials sense changes in the environment around them and respond in a predictable manner.[2] In general, these properties are:

- Piezoelectric[3] — when a mechanical stress is applied, an electric current is generated.
- Shape memory[4,5] — 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.[6]
- Bio film formation[7] — presence of bio film on the surface of material alters the interaction of the surface with the environment.

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CLASSIFICATION OF SMART MATERIALS

Smart materials have the capability to sense and react according to the environment. An important aspect of smart materials used in various areas of dentistry is their excellent biocompatibility.

Smart materials can be mainly classified into passive and active materials.[8] Passive materials respond to external change without external control. They also possess self-repairing characteristics. Active materials sense a change in the environment and respond to them.

The smart materials used in dentistry are further categorized as follows [Table 1].

AMORPHOUS CALCIUM PHOSPHATE (ACP)

ACP is an antecedent in the biological formation of hydroxyapatite (HAP). It has both preventive and restorative properties, which justify its use in dental cements and adhesives, pit and fissure sealants and composites.[8]

Mechanism of action

At neutral or high pH, ACP remains in its original form in the oral environment. But when the surrounding pH drops to a level where it can demineralize the tooth surface, i.e., at or below 5.8 (critical pH), ACP converts into crystalline HAP, thus replacing the HAP crystal lost to the acid. These released ions will merge within seconds and form a gel. In less than 2 min this gel becomes amorphous crystals, resulting in calcium and phosphate ions. Crystalline HAP is the final stable product in the precipitation of calcium and phosphate ions from neutral or basic and it neutralizes the acid and buffer the pH.

Table 1: Showing smart materials used in dentistry

Restorative materials	Types
Passive materials	Glass ionomer cements
	Resin-modified glass ionomer
	Compomer
	Dental composites
Active materials	
Dental materials	Smart composites
	Smart ceramics
Prosthodontics	Smart impression material
Orthodontics	Shape memory alloys
Pediatric and preventive dentistry	Fluoride releasing pit and fissure sealants
	ACP releasing pit and fissure sealants
Conservative dentistry and endodontics	Ni-Ti rotary instruments
	Smart prep burs
Oral surgery	Smart suture
Periodontics	Smart antimicrobial peptide

ACP: Amorphous calcium phosphate, Ni-Ti: Nickel-titanium

Advantages

1. It acts as a reinforcement of the natural defense mechanism of the tooth only when needed.
2. It has long life and there is no wash out.
3. Patient compliance is not required.

Casein phosphopeptide (CPP), a milk derivative is complexes with ACP and this CPP — ACP complex is used in dentifrices as a remineralizing agent in the reversal of incipient white spot lesions under the name ReCaldent. It is commercially available as GC tooth mousse plus® (The University of Melbourne, Victoria, Australia).

Smart composites

It is a light-activated alkaline, nano filled glass restorative material. It releases calcium, fluoride and hydroxyl ions when intraoral pH values drop below the critical pH of 5.5 and counteracts the demineralization of the tooth surface and also aids in remineralization.[9] The material can be adequately cured in bulk thicknesses of up to 4 mm. It is recommended for the restoration of class I and class 2 lesions in both primary and permanent teeth.

Ex: Ariston pH control — introduced by Ivoclar — Vivadent (Liechtenstein) Company.

Smart ceramics

These are metal — free biocompatible life like restorations that allows them to blend well with the surrounding natural dentition.[10] They made the process of restoring teeth to natural form easy and predictable.[11]

Ex: Cercon Zirconium Smart Ceramic System.

Smart impression material

These materials exhibit more:

- Hydrophilic to get void free impression.
- Shape memory during elastic recovery resists distortion for more accurate impression, toughness resists tearing.
- Snap — set behavior results in precise fitting restorations without distortion.
- Cut of working and setting times by at least 33%.
- Viscosity[12] — materials with low viscosity have high flow.

Ex: Imprint™ 3 VPS, Impregim™, Aquasil ultra (3M ESPE Dental Products, USA).

Smart glass ionomer cement (RMGIs)

The smart behavior of GIC was first suggested by Davidson.[13] It is related to the ability of a gel structure to absorb or release solvent rapidly in response to a stimulus such as temperature, change in pH etc. The number and size of pores with the cement can be controlled by the method of mixing conveniently measuring using micro-computed tomography scanning.[14] These smart ionomer mimic the behavior of human dentin. Resin modified glass ionomer cement, compomer or giomer also exhibit these smart characteristics.

Ex: GC Fuji IX GP EXTRA (Zahnfabrik Bad Säckingen, Germany).

SMAs

These alloys have exceptional properties such as super elasticity, shape memory, good resistance to fatigue and wear and relatively good biocompatibility.[1,5] Ni-Tinol was introduced in orthodontics in 1970s and is used in fabrication of brackets. Wires exhibiting shape memory behavior at mouth temperature normally contain copper and or chromium in addition to nickel and titanium.[15]

Ex: Ni-Ti alloy.

Nickel-titanium (Ni-Ti) rotary instruments

The introduction of Ni-Ti in rotary endodontic has made instrumentation easier and faster than conventional hand instrumentation during biomechanical preparation of root canal treatment. The advantage of using rotary Ni-Ti[16] files are less chances of file breakage within the canal during instrumentation, less fatigue to the operator, less transportation, decreased incidence of canal aberration and minimal post-operative pain to the patient.

Ex: Ni-Ti rotary files.

Smart prep burs

These are polymer burs that cuts only infected dentin.[17] The affected dentin which has the ability to remineralize is left intact [Figure 1]. Over cutting of tooth structure that usually occurs with conventional burs can be avoided by the use of these smart preparation burs.

Ex: SS White (145 Towbin Avenue, Lakewood, Newjersey, 08701, USA) diamond and carbide preparation kit.

Smart sutures

These sutures are made up of thermoplastic polymers that have both shape memory and biodegradable properties.[18] They are applied loosely in its temporary shape and the ends of the suture were fixed. When the temperature is raised above the thermal transition temperature, the suture would shrink and tighten the knot, applying the optimum force. This thermal transition temperature is close to human body temperature and this is of clinical significance in tying a knot with proper stress in surgery [Figure 2]. Smart sutures made of plastic or silk threads covered with temperature sensors and micro-heaters can detect infections.[19]

Ex: Novel MIT Polymer (Aachen, Germany).

Smart antimicrobial peptide

A pheromone-guided "smart" antimicrobial peptide is targeted against killing of *Streptococcus mutans* which is the principal microorganism responsible for the cause of dental caries.[20] The concept of tissue regeneration wherein the tissues can be re grown in the oral cavity is an emerging new technology.[21] The BRAX-I gene[22] has been isolated along these lines has been isolated that is thought to be responsible for control on enamel growth.

Ex: Pheromone guided "smart" antimicrobial peptide.

These smart materials are used to achieve maximum advantage by conventional restorative techniques in dentistry. The use of computer-aided design/computer-aided manufacturing[23] technology in designing of cavity preparation is much easier and more adaptable to each tooth, rather than the conventional approach.

Figure 1: Use of smart prep bur in cavity preparation

Figure 2: Tightening of smart suture after raise preparation in thermal temperature

CONCLUSION

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. These innovations in the material science have marked the beginning of an era of bio-smart dentistry, a step into the future!! So it's time to think "smart" and apply bio-smart dentistry in our day-to-day clinical practice.

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