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Advancement of Materials in Dentistry!

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ABSTRACT

No material is said to be an ideal material for restoration in dentistry. As the search for "ideal material" was in progress, a newer generation of materials were introduced. Those materials were termed as smart materials. A material is said to be "smart" if it has the capacity to support the remaining tooth structure to the extent that cavity preparation can be carried out in the most conservative way. These materials possess altering property by stimulus such as stress, pH, temperature and moisture. Such smart materials include smart composite, smart ceramics, compomers, resin modified glass ionomer, pit and fissure sealants etc. This paper attempts to highlight the use of "smart materials" to get maximum advantage by restorations in dentistry.

INTRODUCTION

Materials science is not what it used to be. There are various materials present in the field of dentistry, but there is no single material which can fulfil all the basic requirements of an ideal material. As the debate for an ideal dental material continues, new generation materials get introduced. In the early half of the 20th century, new materials started getting introduced in the dental field. Dental materials were designed to be inert and passive such that it doesn't get interacted with the oral environment. In the beginning of the 1960's materials were manufactured such that they are bioactive. In recent times, materials used in dentistry can be grouped as bio-inert, bioactive and bio-responsive or smart materials on the basis of their interactions with the environment [1]. Hence, smart materials have been around for many years.

Smart materials are materials which possess altering properties by stimulus such as pH, temperature, stress, moisture, electric or magnetic fields [2]. A material is said to be "smart" if it has the ability to support the remaining tooth structure such that cavity preparation can be done in the most conservative way. McCabe Zrinyi [2] defined smart materials as "Materials that are able to be altered by stimuli and transform back into the original state after removing the stimuli".

The first thought that an “active” rather than “passive” material could be advantageous in dentistry was the realisation of the benefit of fluoride release from materials which permitted and reflected a change in material philosophy [2]. Since then dentistry in addition with the material science is undergoing great evolution and the quest for newer smart materials with more recognition, discrimination and reaction capabilities is heading to the goals [3].

Nature of Smart Materials

The usage of smart materials were started earlier by the technologies where nickel was used as a sonar source during World War I to find German boats by the Allied forces [4,5]. Smart materials which are used recently takes advantages of a variety of properties including thermal responses, piezoelectricity, pH sensitivity etc.

Piezoelectric materials-produces voltage when a stress is applied. So these materials can be made to change shape or dimensions when voltage is applied [6].

Thermo-responsive materials- shape memory alloys or shape memory polymers has the ability to adopt different shapes at different temperatures because of its marked and controlled changes in structure [7].

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Magnetic shape memory alloys- these materials can change their shape in response to a change in magnetic field [8]. pH-sensitive polymers- materials which collapse or swell when pH of the surrounding media changes [9]. Photo chromic material- these materials changes it color in response to changes in light condition [10]. Bio film formation- when a bio film is present on the surface of a material, it alters the interaction of the surface with the environment [11].

CLASSIFICATION OF SMART MATERIALS

Smart materials can be majorly classified into passive and active materials [10,12].

Passive smart materials: which respond to external changes without any external control?

- GIC
- Resin modified GIC
- Compomer
- Dental composite

Active smart materials: that takes help of a feedback loop to enable them to function through an activator circuit.

Restorative dentistry

- Smart GIC
- Smart composite
- Ariston Phc

Prosthetic dentistry

- Smart ceramics
- Smart impression compounds

Orthodontics

- Shape memory alloys

Paediatric and preventive dentistry

- Fluoride releasing pit and fissure sealants
- ACP releasing pit and fissure sealants

Endodontics

- NiTi rotary instruments

Smart fibers for laser dentistry

- Hollow-core photonic-fibers

SMART MATERIALS IN DENTISTRY

Smart Glass Ionomers

A wide range of temperature fluctuations due to the consumption of hot and cold foods and fluids takes place in the oral cavity. Therefore, the restoration materials placed in the oral cavity are exposed to thermal changes. Thermal changes of a substance can be described by coefficient of thermal expansion (CTE). It is desirable and acceptable to have a CTE value for the restoration material which is comparable with that of the tooth structure to reduce the chances of stress concentration and micro-leakage [12-14].

The smart behaviour of GIC was first introduced in the field of dentistry by Davidson [15]. When heating and cooling between 20°C and 50°C in wet conditions, little or no dimensional change was observed by glass-ionomers. Material showed a marked contraction in dry conditions above 50°C. This behaviour is explained by the mechanism of fluid flow in the dentinal tubules. In wet conditions, heating expansion is compensated by the fluid flow to the surface of the material to produce a balancing dimensional change which is reversed on cooling. In dry conditions, loss of fluid flow from the material causes contraction on heating. Hence, the glass-ionomer materials is said to be mimicking the behaviour of human dentine through a type of smart behaviour [16].

The other smart behaviour of this material is the fluoride releasing property and recharging capacity. After the initial burst, glass Ionomers possesses rapid loss of fluoride releasing property and a solution to this was the introduction of smart glass ionomers as they showed the presence porosities. It is proved that the fluoride released can be recharged if it is baked in a

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solution containing higher concentration of fluoride as may occur in tooth paste or mouth rinse which allows sustained release of fluoride in mouth temperature. This recharging phenomenon is temperature dependent and more rapid recharging is obtained with the use of warm fluoride solutions [17].

The common disadvantages with the usage of glass ionomers are the limited longevity and durability due to their solubility and brittleness [18].

Smart Composite

Stimuli responsive-smart composites may be useful with various applications including the "release-on- command" of remineralising elements or antimicrobial products and fluorides to fight microorganisms or secondary caries [19,20]. Composites containing amorphous calcium phosphate (ACP) are usually considered as smart composites. Smart composites have the advantages of excellent sustained release of calcium and phosphate ions into the stimulated saliva and excellent biocompatibility. Due to its extended time release of calcium and phosphate and bio activity, they have high prophylactic value in preventing caries by highly reducing demineralisation and promoting remineralisation of tooth [3,10].

Microbes producing acids can decrease the pH resulting in the loss of hydroxyapatite from the tooth. ACP is stable at neutral and high pH, but at a low pH (5.8 or less) it gets converted into crystalline hydroxyapatite and later gets precipitated thus replacing the lost hydroxyapatite. Composites having alkaline glass fillers with calcium and fluoride release can prevent demineralisation contiguous to the restorations. They also reduce the growth of bacteria which is cariogenic by the neutralising and buffering action on the acid produced by the microbes [21].

Recently introduced product wherein nano DCPA (dicalcium phosphate anhydrous) and TTCP (tetra calcium phosphate) fillers have been introduced with increased strength of the material which doesn't compromise the Ca and PO_4 releasing property. These newer composites can increase the Ca and PO_4 release while the pH is reduced from neutral to a cariogenic pH of 4 [22,23].

Smart Impression Materials

A proper impression is considered to be the foundation and blueprint for the success of a restoration. A final impression is the result of an accurate and properly built multiple interrelated steps during the preparation and impression taking process. Selection of an appropriate impression material is equally important to that of impression making. The most significant physical characteristics in selecting impression materials are setting time, dimensional stability, viscosity, tear resistance, hydrophilicity and elastic recovery [24,25]. Smart impression materials exhibits various advantageous properties like increased hydrophilicity to get void free impressions, shape memory and snap- set behaviour to resist distortion, and low viscosity ensuring better flow of the material [26].

Smart Ceramics

It was introduced by Cercon "all ceramic teeth bridge" was materialised after the introduction of smart ceramics. Though ceramics were available for a long time to fabricate crowns and bridges, they were used with a metal substructure as porcelain fused metal crowns. These porcelain fused metal crowns reduce the aesthetic quality of the restoration. The introduction of high tech ceramic, zirconia has brought the fabrication of crowns and bridges without the metal substructure. Zirconia is a polycrystalline ceramic where all of the atoms are arranged in regularly crystalline arrays. This arrangement provides greater resistance to the development and propagation of crack through it compared to other forms of ceramics. Hence, zirconia are stronger and tougher than other ceramics [27,28].

Zirconia takes advantage of toughness, strength, biocompatibility and reliability and they have been used highly in all ceramic teeth frameworks, dental prosthesis, implant supported crowns, implant abutments and root canal posts [29,30].

Shape Memory Alloys

Nickel-titanium (NiTi) alloys have two unique features such as super-elasticity and shape memory and hence categorised as smart materials. Shape memory effect is the ability of the NiTi alloy to get back to its original form without showing any permanent deformation. When the NiTi alloy is cooled below a particular transformation temperature, yield strength decreases and it can be deformed easily into any new shape, which it will retain and when the material is heated above its transformation temperature, change in crystal structure occurs which causes it to return to its original shape [31].

In orthodontics, NiTinol wires are used in arch-wires for teeth alignment in the initial stages of treatment where large deflection is necessary. They also have a excellent spring-back capacity and low modulus of elasticity (E) on comparison with other alloys. They can be drawn into a resilient, rectangular wire which allows simultaneous levelling, rotation, tipping and torquing movements early in the treatments. They offer the main advantage of reduced treatment time and cost [32].

Nitinol endodontic files for root canal procedures offer superior durability torque-ability when compared to stainless steel files. Nitinol exists in an austenitic crystalline phase that gets converted into a martensitic structure on stress at constant temperature. In this martensitic phase, even a light force can be enough for bending. When the stress is released, the structure recovers to

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an austenitic phase and retains its original shape. This is called stress-induced thermo elastic transformation. This offers the advantage of ease of increased patient comfort. Super-elastic files allow more centred canal preparations and less chance of canal transportations [10].

Nitinol alloys are also used in implant dentistry for the fabrication of end-osseous blade type implants. In the field of oral surgery it is used for the construction of NiTi alloy bone plates in the treatment of transverse mandibular fractures and in prosthodontics for fabrication of dental prostheses like crowns, clasps, partial denture etc.

Smart Fibres for Laser Dentistry

Hollow-core photonic-crystal fibres (PCFs) are used for the delivery of high- fluence laser radiation capable of ablating tooth enamel. Sequences of picosecond pulses of Nd: YAG-laser radiation is passed through a hollow-core photonic-crystal fibre having a core diameter of approximately 14 µm which are then focused on a tooth surface to ablate dental tissue. The hollow-core PCF is shown to support 1.06 µm laser radiations, which serves as a spatial filter and allows the laser beam quality to be improved. The same fiber is used for detection and optical diagnostics.

CONCLUSION

Even-though various materials have been identified exhibiting smart characteristics, majority of this behaviour resulted by chance rather than by design. However, with the understanding of the potential benefits of smart behaviour researches are targeted in designing materials that can behave smart in the environment they are meant for. Introduction of smart materials have revolutionised the field of dentistry and undoubtedly “smart materials” hold a really good promise for the future.

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