Smart Materials in Prosthodontics: A Review

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Abstract

Dental materials are stable and have greater durability if they do not react with the environment and remain passive. At the same time, it is hoped that the materials will be well accepted and will cause neither harm nor injury. This is an entirely negative approach to material tolerance and biocompatibility. This outlook hides the possibility through which positive gains can be achieved by using materials that behave in a more dynamic fashion in the environment in which they are placed. The current dental materials are improvised. The use of smart materials has made a great revolution in 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 and other materials, such as orthodontic shape memory alloys, smart burs, etc.

Keywords: Smart Materials; Prosthodontics; Impression Materials; Ceramics; Implants

Introduction

In dentistry, there is no single material that is ideal in nature and fulfils all the requirements of an ideal material. So, the search for an "ideal restorative material" continues, leading to introduction of newer generation of materials. These are termed as "smart materials".[1] Smart materials can be defined as, designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, and electric or magnetic fields.[2] These materials are also referred to as Responsive materials. Now Material science is not what it used to be before. Traditionally materials used in dentistry were designed to be passive and inert, that is, to exhibit little or no interaction with body tissues and fluids. Materials used in the oral cavity were often judged on their ability to survive without interacting with the oral environment. The present scenario has changed. Many of the advanced materials at the forefront of materials science are functional. They are required to perform things and to undergo purposeful change. They play an active part in the way the structure or device works.[3] They have the intrinsic and extrinsic capabilities, first, to respond to stimuli and environmental changes and, second, to activate their functions according to these changes. The stimuli could originate internally or externally. Since its beginnings, materials science has undergone a distinct evolution: from the use of inert structural materials to materials built for a particular function, to active or adaptive materials, and finally to smart materials with more acute recognition, discrimination and reaction capabilities.[4] Perhaps the first inclination that an "active" rather than "passive" material could be attractive in dentistry was the realization of the benefit of fluoride release from materials. This both reflects and permits a change in material philosophy. Materials used in dentistry can be classified as bio-inert (passive), bioactive, and bio-responsive or smart materials based on their interactions with the environment. Smart behaviour occurs when a material can sense some stimulus from its environment and react to it in a useful, reliable, reproducible, and usually reversible manner. A really smart material will use its reaction to the external stimulus to initiate or actuate an active response. Smart materials can happen by chance or they can be designed to incorporate smartness in them.[3] These smart materials not only have the traditional structural material functions, but also have functions such as actuation, sensibility and micro-processing capability. These can be used directly to make smart systems or structures or embedded in structures whose inherent properties can be changed to meet high value-added performance needs.[2] Disadvantages of smart material include limited strain outputs, limited blocking forces, high cost, and sensitivity to harsh environmental conditions.[5] Some researchers insist that no material by itself is truly smart, as opposed to being simply responsive. They insist that being smart is not just a matter of producing a response in proportion to a stimulus, but includes principles such as adaptation and feedback. Others draw a distinction between merely smart and truly intelligent, in the sense of being able to do things like make decisions or repair oneself. No artificial materials are yet intelligent in this sense.[3] Traditionally, materials designed for long term use in the body or more specifically in the mouth are thought to survive longer if they are 'passive' and have no interaction with their environment. Materials such as amalgam, composites and cements are often judged on their ability to survive without interacting with the oralenvironment.[6]

Requirements of Smart Materials

According to Williams,[7] "smart" materials can respond to an external stimulus in a specific, controlled way. Conventional filling materials fail because of the formation of secondary caries, fracture of restoration, fracture of tooth, marginal discrepancies, or wear. Materials developed are smart to reduce failures by adding additives to the materials.

Smart materials respond by:

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

Classification of Smart Materials

Followings are the various types of smart materials in the different branches of the dentistry:-

Restorative Dentistry- Smart GIC, Smart composite, Self-healing composite Smart Prep Burs, Smart bonding system

Endodontics - NiTi Rotary Instruments. Smartseal obturation system

Prosthetic Dentistry- Smart ceramics, Smart impression materials

Orthodontics - Shape memory alloys. Smart orthodontic adhesive

Laser Dentistry- Smart Fibers

Periodontics - Smart antimicrobial peptide

Implant Dentistry - Smart coatings on implant

Oral surgery- Smart sutures

SMART MATERIALS CAN BE CLASSIFIED AS

- Passive smart materials
- Active smart materials

Application of Smart Materials

Smart Impression Material

This new formulated material is designed with reduced contact angle, more hydrophilic to get void free impression (smart wetting). It maintains a low viscosity during working time, shape memory during elastic recovery resists distortion for more accurate impression and toughness resisting tearing of impressions. Its Snap set behavior results in precise fitting restorations without distortion and also brings down working and setting time by at least 33%. And the viscosity of these materials is very low with high flow.[8,9]

Ex: Imprint™ 3 VPS, Impregim™, Aquasil ultra.

Smart Ceramic

Zirconia is a polycrystalline ceramic that do not contain glass. All of its atoms are packed into regular crystalline arrays through which it is much more difficult to drive a crack than it is through atoms in the less dense and irregular network found in glasses. Hence, polycrystalline ceramics generally are much tougher and stronger than glass based ceramics. Well-fitting prosthesis made from polycrystalline ceramics were not practical before the availability of computer-aided manufacturing. In 1995, the first ―all ceramic teeth bridge‖ was fabricated at ETH Zurich based on a process that enabled direct machining of bridges. Pure zirconia at room temperature has a monoclinic crystalline structure and at firing temperature zirconia has a tetragonal crystalline structure. On cooling from firing temperature, it results in 4.4% increase in volume than at firing temperature (tetragonalcrystalline structure).

Smart GIC

Smart behavior was seen for the first time in GIC by Davidson. On intake of hot or cold food and fluids, these restorative materials may show thermal expansion or contraction in response to thermal stimuli. The mismatch of thermal expansion and contraction between a restoration and the tooth structure may result in stresses at the interface, and this may lead to microleakage. In dry condition, these materials showed a marked contraction when heated above 500c. The explanation for this behavior is that the expected expansion on heating is compensated by fluid flow to the surface of the material to cause a balancing of the dimensional changes. On cooling, this process is reversed. In dry condition, the rapid loss of water on heating results in the observed contraction. This behavior is similar to that of human dentin where very little dimensional change is observed on heating in wet conditions and a marked contraction is noted in dry conditions. Both results can be explained by flow of fluids in the dentinal tubules. Hence glass ionomer materials can be said to be mimicking the behavior of human dentin through a type of smart behavior. Hence, GICs are described as ―smart materials‖ with respect to their thermal behaviour.[10]

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 Hydroxyapatite and precipitates, thus replacing the hydroxyapatite 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. Ariston pH control - introduced by Ivoclar-Vivadent. The material can be adequately cured in bulk thickness up to 4 mm. It is recommended for the restoration of class 1 and class 2 lesions in both primary and permanent teeth.Ariston is a light-cured filling material indicated for posterior restoration. 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 remineralisation.[11]

Smart Antimicrobial Peptide

Amongst the antibiotics available, the majority affect a broad range of microorganisms, including the normal flora. The ecological disruption due to antibiotic treatment frequently results in secondary infections, super infections or other negative clinical consequences. To address this problem, recent advances has lead to the development of a new class of pathogen-selective molecules, called specific or selective targeted antimicrobial peptides (STAMPs). Example like pheromone produced by streptococcus mutans, named competence stimulating peptide (CSP) which is potent against S mutans, a cavity-causing bacterium that resides in a multispecies microbial community without affecting closely related noncariogenic oral streptococci, indicating the potential of these molecules to be developed in to ―probiotic antibiotic which could selectively eliminate pathogens while preserving the protective benefits of a healthy normal flora. Specifically targeted antimicrobial peptides (STAMPs) could be delivered in current oral care products such as mouthwash, toothpaste, or dental floss and could help with the suppression of cariogenic bacteria.[12,13]

Smart Coatings for Dental Implants

Researchers at North Carolina State University have developed a ―smart coating‖ that helps surgical implants bond more closely with bone and ward off infection. When patients have hip, knee, or dental replacement surgery, they run the risk of having their bodies reject the implant. But the smart coating developed at NC State mitigates that risk by fostering bone growth into the implant. The coating creates a crystalline layer next to the implant and an amorphous outer layer that touches the surrounding bone. Dissolution of the amorphous layer takes place over a period of time, liberating calcium and phosphate, thus encouraging growth of the bone. ―Bone grows into the coating as the amorphous layer dissolves, resulting in improved bonding, or osseointegration. Such bonding makes the implant more functional, because the bonding helps to ensure that the bone and the implant do a better job of sharing the load. Further development leads to incorporation of silver nanoparticles throughout the coating. These silver particles will act as antimicrobial agents and provide protection from infection at the implant site for the life of the implant. Moreover, the silver is released more quickly right after surgery, when there is more risk of infection, due to the faster dissolution of the amorphous layer of the coating. Silver release will slow down during the healing phase of the patient. That is another reason why the authors call it Smart Coating.[14]

Conclusion

Researches in the field of smart materials have created new opportunities for application in dentistry which will make dental treatment much more comfortable for the patient and convenient for the operator. In the near future there is a possibility that more sophisticated types of smart materials which will emulates biological system will be developed and will mark the beginning of a new era in dentistry, biosmart dentistry.

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