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REVIEW ARTICLE

Biosmart Dentistry – A Revelation: A Review

Kapil Ahuja[1], Rohit Pannu[2], Neha Pal[3], Neetu Aggarwal[4], Vikas Berwal[5]

[1,3]M.D.S. Oral Surgery, M S Ramaiah Dental College and Hospital, Bangalore, Karnataka, India
[2]M.D.S. Conservative Dentistry and Endodontics, Private Practitioner, Bhiwani, Haryana, India
[4]MDS Oral and Maxillofacial Surgery, Goa Dental College and Hospital, Bambolim, Goa, India
[5]Department of Oral and maxillofacial Surgery, PGI Rohtak, Haryana, India

ABSTRACT:
Various biocompatible materials have been introduced and widely used in many aspects of dental treatment. The smart response of materials occurs when it senses some stimulus from surrounding environment and reacts to it in useful, reproducible and mostly reversible manner. These materials can be altered in a controlled manner by various stimuli such as stress, temperature, moisture, pH and electric or magnetic field. This group of multi-functional materials can possess the capability to select and execute specific functions intelligently in order to respond to changes in the local environment. It can be expected in future that the science of dental materials may change significantly with the introduction of new biosmart-materials which can mimic the biological systems.
Keywords: Smart materials, Stimulus, Responsive materials, Biomimetic.

Corresponding author: Dr. Rohit Pannu, H.No. 3037, New Housing Board, Sector – 13, Bhiwani (Haryana), India.

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INTRODUCTION

McCabe Zrinyi1 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 stimuli can be in the form of temperature, pH, moisture, stress, electricity, chemical or biomedical agents and magnetic fields. The different types of smart materials used in the field of dentistry are piezoelectric materials, shape memory alloys or shape memory polymers, pH sensitive polymers, polymer gels and others that have shown their own smart behaviour. These smart materials can easily sense the changes in the oral cavity and respond positively to these changes. These materials are also known as - Responsive Materials.[2]A key feature of smart behaviour includes an ability to return to the original state after the stimulus has been removed.[3]
Today, it is one of the challenging tasks to manufacture new multifunctional materials which possess intelligence at the material level. Material intelligence being classified in to three functions: sensing changes in environmental conditions, processing the sensed information and finally making judgment (actuating) by moving away from or to the stimulus.[4]

PROPERTIES

Smart materials sense changes in the environment around them and responds in a predictable manner.

1. Piezoelectric:[5]
   - when a mechanical stress is applied, an electric current is generated.
2. Shape memory:[6]
   - can change the shape whenever required and can return back to original shape once force / pressure applied is removed .
3. Thermochromic:[7]
   - these materials change color in response to changes in temperature.
4. Photochromic:[7]
   - these materials change color in response to changes in light conditions.
5. Magnetorheological:[7]
   - these are fluid materials, become solid when placed in a magnetic field.
6. pH sensitive:[8]
   - when pH of the surroundings gets altered they will change their shape.
7. Biofilm formation:[9]

- presence of biofilm on the surface of material alters the interaction of the surface with the environment.

Classification of Smart materials

Smart materials are of two types namely passive and active materials.[10]

Passive Smart Restorative Materials: They sense the external change and react to it without external control.

1. GIC.
2. Resin Modified GIC.
3. Compomer.
4. Dental Composites.

Active Smart Restorative Materials: Active materials sense change in the environment and respond to them. Utilize a feedback loop to enable them to function as a cognitive response through a controlled mechanism or system.

1. Restorative Dentistry:
   - Smart GIC.
   - Smart composites.
   - Ariston pHc.
   - Smart Prep Burs.
2. Prosthetic Dentistry:
   - Smart ceramics.
   - Smart impression materials.
3. Orthodontics:
   - Shape memory alloys.
4. Pediatric & Preventive Dentistry:
   - Fluoride releasing pit and fissure sealants.
   - ACP releasing pits and fissure sealants.
5. Endodontics:
   - Niti Rotary Instruments.
6. Smart Fibers for Laser Dentistry:
   - Hollow-core Photonic-Fibers.

Applications of smart materials in Dentistry

Smart GIC

Davidson first observed the smart behavioural property of GIC.[11]GlCs have a coefficient of thermalexpansion close to that of dental hard tissues. Throughobservation, there were minimal or no dimensionalchanges in GlCs in terms of heating (expansions) andcooling (contractions) in wet conditions but the materialsdemonstrated a marked contraction when heated at 50° Cin dry conditions. This action was due to the movement ofwater in or out of the structures which mimic the behaviorof human dentin and indirectly shows the behavior ofsmart features. Due to this behavior, GlCs can provide agood marginal adaptation to the restorations.[2]Additional smart behavior of GIC is Fluoride release. Mahmoud GA et. al.[12] concluded that the use of fluoride releasing cements can minimise thedemineralisation around orthodontic brackets and that this effect is not simply dependent upon the extent of the initialfluoride release. This has been studied using Quantitative Light-induced Fluorescence (QLF).

Smart composites

Smart composites contain Amorphous CalciumPhosphate (ACP), one of the most soluble of thebiologically important calcium phosphates. The basicbuilding block of tooth enamel is hydroxyapatite; it is alsoan inorganic component of dentin. In the case of cariousattack, hydroxyapatite is removed from the tooth resultingin cavities or white spots. The carious attack is usually theresult of exposure to low pH conditions (acid attack) eitherfrom bacteria, other biological organisms releasing acid,food (carbohydrate decomposition products) or acidicbeverages. ACP at neutral or high pH remains ACP. Whenlow pH values ie. at or below 5.8 during a cariousattack, ACP converts in to HAP and precipitates, thusreplacing the HAP lost to the acid. So when the pH level inthe mouth drops below 5.8, these ions merge withinseconds to form a gel. In less than 2 minutes, the gelbecomes amorphous crystals, resulting in calcium andphosphate ions.[13]

Self-Healing Composites

In recent research, White et al. have developed a self-healing polymer. It is first self-healing synthetic material. It is resin based material. This was an epoxy system which contain resin filled microcapsule Dicyclopentadiene (DCPD), a highly stable monomer with excellent shelf life, was encapsulated in thin shell made of urea formaldehyde. If crack occur in epoxy composite material, some of microcapsules rupture and release resin. These resin, fills the crack by reacting with Grubbs catalyst in epoxy composite, result in ring opening metathesis polymerization (ROMP) reaction take place and repair the crack.[14]

Ariston pHc

Ivoclar Vivadent (Liechenstein) introduced Ariston pHc (pH control) in 1998, which is claimed to release fluoride, hydroxide and calcium ions, when the pH in restorations of this material falls to the critical pH. This is said to neutralize acid and counteract the decalcification of enamel and dentin.[2]

Smart Prep Burs:

Smart Prep Burs are polymer burs which have ability to cut only infected dentin.[15]The affected dentin, which has the ability to remineralize is left intact. The cutting blades deflect and deform upon encountering normal or partially decalcified dentin, thereby enabling the reduction of cutting efficiency.[16]

Smart Ceramics

Smart Ceramics deliver outstanding aesthetics without reservations or compromise. These are metal-free and biocompatible.In 1995 the first "all ceramic teeth bridge" was invented at ETH Zurich based on a process that enabled the direct machining of ceramic teeth and bridges. The Cercon system offers advantages like strength, toughness, reliability, and biocompatibility of zirconium oxide.[2] It is an ultra-thin monolithic material, which provides maximum strength.[17]

Smart Impression Material

These materials exhibit more hydrophilic nature to get void free impression and shape memory during elastic recovery resists distortion for more accurate impression, toughness resists tearing. Its Snap set behaviour results in precise fitting restorations without distortion with reduction of working and setting times by at least 33%. The viscosity of these materials is low with high flow.[18]

Shape memory alloys (SMA)

Shape memory alloys (SMA) constitute a group of metallic materials with the ability to recover to a previously defined length or a shape when subjected to an appropriate thermo mechanical load. In 1962, Buehler and co-workers of the U.S. Naval Ordnance Laboratory, discovered the shape memory effect in an equiatomic Ni-Ti alloy which began to be known as Nitinol. SMAs have come into wide use because of their exceptional superelasticity, shape memory, good resistance to fatigue and wear, and relatively good biocompatibility. Owing to their elastic properties and extendibility, the level of discomfort can be reduced significantly as the SMA applies continuous, gentle forces which are in physiological range, over a longer period.[19]

Fluoride Releasing Pit & Fissure Sealants

Occlusal surfaces constituteonly 12% of the tooth surfaces, they are eight times asvulnerable as smooth surfaces to caries.[20]Fluoride releasemight occur from the insoluble sealant material as a resultof porosity. It might also occur because the fluoride ion orthe fluoride glass is not tightly bound to the polymerizedresin molecules. Release in fluoride glass containing sealants may also be due to fluoride glass grains depositing on the surface of the resin.[21]

Casein Phospho-peptide (CPP):

It is a milk derivative, in combination with ACP is used for the remineralisation of incipient white spot lesions in some dentifrices (under the name ReCaldent). It is marketed as GC tooth mousse plus®.[7]

Nickel Titanium Files

Nitinol endodontic files for root canal procedures offer superior flexibility, durability, and torqueability as compared to stainless steel files. This shape memory effect and super elasticity are useful in endodontics, which helps the superelastic files to benefit by maintaining close contour to the canal shape without concern of file breakage.[22]

Nitinol shows stress-induced thermoelastic transformation. An austenitic crystalline phase that gets converted to a martensitic structure on stressing at a constant temperature. In this martensitic phase, only a light force is sufficient for bending. If the stress is released, the structure recovers to an austenitic phase and its original shape.[23]

Smart Sutures:

They are made up of thermoplastic polymers that have both shape memory and biodegradable properties. Smart sutures made of plastic or silk threads covered with temperature sensors and micro-heaters can detect infections. Sutures are loosely tied, once the temperature is increased above the thermal transition temperature, sutures shrink & gets tightened.[7]

Smart Antimicrobial Peptide (AMP):

These are pheromone guided smart antimicrobial peptide, which are targeted against Streptococcus mutans, causative microorganism of dental caries.[24] The action of AMPs typically involves binding to the negatively charged functional groups of microbial membranes (e.g, lipopolysaccharides) and creating a disruption by inserting into the membranes. Specifically targeted antimicrobial peptides (STAMP‘s) could be delivered in current oral care products such as mouthwash, toothpaste, or dental floss and could help with the suppression of cariogenic bacteria.[25]

Smart Fibers for Laser Dentistry

Laser radiation of high fluency can be easily deliveredby Hollow-core Photonic Fibers (PCFs) i.e. the laserradiations can easily be snaked through the body usingthis Hollow-core Photonic-Fibers which are capable ofablating tooth enamel. These photonicfibers are known as SmartFibers.[26]Photonic Crystal Fiber are not only to transport the high power laser pulse to a tooth surface, but can be used for detection and optical diagnosis through transmitted plasma emission. While using these fibers we ought to be very carefulbecause there is a risk factor that in some cases the fiberwalls fail and the laser light may escape and harm thehealthy tissue.[27]

Smartseal Obturation System

It is hydrophilic endodontic point and an accompanying sealer. It consists of propoint and smart paste biosealer. It is available in different tip sizes and tapers. This hydrophilic, hydrogel layer allows the point to swell and adapt the canal wall[28]& expand laterally without expanding axially by absorbing residual water from instrumented canal space and from naturally occurring intra-radicular moisture. The lateral expansion of C Point is claimed to occur non-uniformly, with the expandability depending on the extent to which the hydrophilic polymer is pre-stressed (i.e. contact with a canal wall will reduce the rate or extent of polymer expansion).[29]

CONCLUSION

There is no doubt that the demand of dental biomaterials on a rapid rise and there are no available dental materials with ideal properties for dental applications, which imitate biological systems. The recent advances in the "Stimuli-Responsive or Smart Materials" have created novel opportunities for their applications in dentistry. 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. With the availability of these intelligent materials, which possess multifunctional capabilities, it will be easy and comfortable to muddle aong with dental therapy and execute specific function smartly to respond to changes in the local environment.

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