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AN ELEVATION IN THE FIELD OF DENTISTRY-THE SMART MATERIALS: A REVIEW

Running title: Smart materials- a review

Balasubramaniam Anuradha[1], Alemete Suriyanarayanan Kamali., [2], Alagarsamy Venkatesh, [3], Arumugam Karthick, [4]

M.D.S, Reader [1], B.D.S., Postgraduate student [2], M.D.S, Professor [3], [4] Department of Conservative Dentistry and Endodontics,, Sree Balaji Dental College and Hospital, Bharath Institute of Higher Education and Research,, Narayanapuram , Pallikaranai,Chennai - 600100. Tamilnadu, India.

Corresponding Author:

Alemete Suriyanarayanan Kamali, B.D.S ,Postgraduate student

Address:

Department of Conservative Dentistry and Endodontics,
Sree Balaji dental college and hospital,
Bharath institute of Higher Education and Research,
Narayanapuram,Pallikaranai, Chennai-600 100
Tamilnadu,India.

ABSTRACT

Oral cavity is subjected to various types of diseases worldwide. Materials used to cure such diseases has to be bioactive, inert and in neutral zone, without harming the tooth structure. At present, numerous materials are available with much more capabilities of regeneration, strength and biocompatibility. Such newly emerging materials has the ability not only to restore lost tooth structure, but actively respond to stimuli of oral environment. Such as stress, temperature, moisture and ph. Such materials are called “smart materials”. They are known for their smart behavior such as shape memory, thermochromic, photochromic, magneto rheological,sensitive and biofilm formation. This review article throws light on benefits and application of smart materials in various fields of dentistry.

Keywords: Biomimetics, Bio-responsive, regeneration, tissue engineering, intelligent materials.

INTRODUCTION:

Material science is not what it was used to be. Traditional materials used in dentistry were designed to be passive and inert,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 oral environment.[1]The present scenario has changed. In the field of dentistry, there is a complete lack of materials which fulfills its ideal properties which leads to introduction of newer generation of materials. Such materials are termed as “smart materials’· The current advances within the design of smart materials have created golden opportunities for application within the bio medical fields· Preliminary smart materials applications initiated with Magnetostrictivetechnology. This involved use of nickel as a sonar source during world war 1 to find German U-boats by allied forces. These materials are termed as ‘smart’ as they support the remaining tooth structure to an extent as more conservative cavity preparation can be out· They

also referred to as biomimetics as they can mimic natural tooth structure such as enamel and dentin [2].

MECHANISM OF SMART MATERIALS

Biosmart materials works by two mechanisms:

(1) It possesses inductive and instructive on cells and tissues by responding to external and internal stimuli such as ph, temperature, magnetic and ionic strength to promote tissue repair and regeneration.

(2) It has intelligently altered individuals' properties and controlled functions to actively engage in tissue regeneration.

CRITERION FOR A SMART MATERIAL

(1) Asymmetrical nature
(2) Action of receiving and responding to stimuli
(3) Inclusion of at least one smart structure in the material [3]

CLASSIFICATION OF SMART MATERIALS

Smart materials are broadly classified into two types

(1) Passive- which responds to external change without external control.

i.	Glass ionomer cement
ii.	Resin modified Glass ionomer cement
iii.	Compomer
iv.	Composite resins

(2) Active- which sense changes in the environment and respond to them.

i.	Smart prep burs,
ii.	smart ceramics,
iii.	NiTi rotary endodontic instruments
iv.	Smart composites
v.	Smart seal obturation system
vi.	Smart fibers for laser
vii.	Shape memory alloys
viii.	Smart antimicrobial peptide
ix.	Smart impression materials
x.	Smart material coated dental implants

GIC AND RMGIC:

Glass ionomer cement(GIC) are used for wide range of applications in dentistry. A good example of modern dental materials is glass ionomer cement (GIC) that has transformed the restorative approaches especially in minimally invasive dentistry.GIC also carry number of drawbacks such as brittleness, poor wear resistance, prone to fracture, inadequate surfaceproperties, sensitive to moisture when newly placed in the oral cavity [5]. In order to overcome such disadvantages, certain modifications have been implicated in conventional GIC.Major modification includes combination of glass ionomer cement with photo cured or auto

cured resin systems to produce resin modified glass ionomer cement. nanotechnology involves use of systems, modifications or materials which is in size range of 1-100 nm. Nano modification of conventional GIC and RMGIC achieved by incorporation of nano sized fillers, reducing the size of glass particles, introducing nano sized Bioceramics to the glass powder. Incorporation of nano sized apatite crystals not only increases mechanical properties but also induces fluoride release and bioactivity.

Limitations: There is a possibility of failure of glass bioceramic interface which affects the mechanical properties of set cement.Very few studies focusing on the nano modification of GIC, more mechanical and biological studies and clinical trials are needed to ascertain the status of clinical application of nano GIC.More to be learned about effect of nano modification of powder component of GIC and on their fluoride release. None of the studies have investigating on this aspect till date [5]

SMART COMPOSITES:

Composite resins have become most popular direct restorative material in field of dentistry despite of its major disadvantages if polymerization shrinkage, microhardness and estrogenic potential. variation in curing distance and time gap in curing cycle can significantly reduce polymerization shrinkage of nanohybrid composite. Slow curing of nanohybrid composite z350 and waiting period of 3-5 mins can significantly reduce polymerization shrinkage in cavities due to stress relief[6].Incorporation of amorphous calcium phosphate into smart composites will rapidly convert into crystalline hydroxyapatite. ACP incorporation will extend the time release of calcium and phosphate benefits the prevention of dental caries.71% of lost mineral by ACP incorporated smart composites. [content of decalcified tooth was recovered [7].

Limitation: Research and development of smart composite is still in its initials stage. For shape memory material components, well bonded interface will constrain the martensitic transformations and sacrifice the shape memory effect and other performances [8].

NITI ROTARY INSTRUMENTS:

NiTi instruments superelastic behavior, shape memory effect, lower young's modulus are beneficial for preparation of anatomically complex root canal, reduces risk of Iatrogenic errors, limits apical transport and finally allows irritants to flow deeply towards apical constriction[9].In spite of their advantages NiTi instruments possess high risk of fracture in curved root canal due to the property of cyclic fatigue. Manufactures aim to improve the cyclic fatigue by changing the metallurgy, design and kinematic of the files and through various surface and thermal treatments applied to files. Neoendo files can be preferred in all types of canal curvatures including severely curved canal as it had the increased cyclic fatigue resistance in all angles of curvatures including 45 degree, 60 degree and 90 degree.

Limitations: Further studies to include effects of cyclic loading in performance of endodontic rotary files.Main disadvantage is mechanical properties of NiTi files affected by type of alloys used in manufacturing process which will not be revealed by manufactures [10].

SMART PREP BURS:

There are the polymer burs which are specially designed to cut infected dentin, leaving affected dentin intact which has the capability to remineralize. Over cutting of tooth structures by conventional burs can be avoided by using smart prep burs.

Limitations: Smartprep burs were not able to excavate more dentin, which clinically appeared to be in carious condition. IN case of small cavities, polymer-based burs easily touched the enamel

by chance and smartprepbur went blunt. Smartprep burs seem to be less effective in excavation of carious when compared to tungsten carbide bud burs [11].

SMART SUTURES:

These are thermoplastic polymers that has both shape memory and biodegradable properties. when temperature rises above thermal transition temperature the suture shrinks and tightens the knot, applying the optimum force. Smart sutures are covered with silk or plastic threads covered with temperature sensors and microheaters, which can detect infection [4]. The nanomaterials used to coat the thread serves required purpose. The threads are coated with different nanomaterials to detect different environmental conditions. Smart sutures in the future will allow 'multimodal sensing, wireless data transfer, UV sterilization, drug release and thermal therapy' according to Rogers. There will be no need for follow up visits.

Limitations: These threads have not been subjected to live animal testing for heating capabilities or sensing temperature variations.Mostly relevant for small molecule drugs as it is coated in certain classes of thermally – activated polymer matrix, where thermal triggers change the permeability of the coating, thus releasing the drug as required [12].

SMART FIBERS FOR LASER DENTISTRY:

Hollow- core- photonic- crystal fibers which delivers high-fluence laser radiation capable of ablating tooth enamel.Nd:yg laser radiation with total energy of 2 nJ are transmitted through a hollow core photonic crystal fiber are focused on tooth surface to ablate dental tissue [13].

Limitations: The high average power comes at the expense of lower pulse energies because the repetition rate is increased by more than thousand times, and efficient HGG is not possible is usual geometry [14].

SMART ANTIMICROBIAL PEPTIDE:

The specifically targeted antimicrobial peptide (STAMP) developed based on fusion of species-specific targeting peptide domain. This pheromone guided smart material peptide is targeted against killing of streptococcus mutans, which is the significant microorganism causing dental caries [15]. The probiotic property of stamp selectively eliminates pathogens while preserving protective benefits of healthy oral flora.

Limitations: It eliminates only the targeted bacteria.More rigorous studies and more medically relevant combination of pathogen targets are necessary to find out the true potential of STAMP [15].

SMART COATINGS OF DENTAL IMPLANTS:

Surgical implants with smart coating bonds close to the bone and ward off infection. The crystalline layer is created surrounding the implant and amorphous layer formed reaches the bone[.By dissolution of amorphous layer, bone growth is favored by release of calcium and phosphate which promotes osseointegration. The antimicrobial property of silver nano particles incorporated in implant minimizes the chances of infection [16].

Limitations: Important limitation of this coating is that it is designed to be short- acting and biodegradable so only be effective in preventing infection seeded during surgery or in immediate postoperative period [17].

SMART SEAL OBTURATION SYSTEM:

"Smart seal" is established on the polymeric technology. The hydrophilic nature of obturating points can absorb surrounding moisture and expand, which results in filling of voids and space.e.g. Propoints, best known as "c" points.

The **smartpaste** and **smartpastebio** also works by this mechanism. Accessories used in this system are **smart trim** and **smart gauge** [18]. one of the main benefits of this obturation system is the resourcefulness of the product, thus allowing the conception of points to equal most of the available different file system that are presently used in daily practice. Propoints demonstrates a greater filling ability than gutta percha in all thirds of the canal.
Limitations: Limited evidence on effectiveness [19].

CONCLUSION:

Advancement in the field of dentistry has always been appreciated by introduction of such sophisticated class of "Biosmart Materials". These valuable materials possess the capability to select and accomplish determined functions intelligently. Though these materials have certain limitations, they have proven to be much better than conventional techniques in many areas of dentistry. Such limitations can definitely be overcome by further clinical research and studies on these materials in the foreseeable future which will emulate the biological system.

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