ORIGINAL RESEARCH PAPER

Volume - 9 | Issue - 6 | June - 2020 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

DIRECT SMART RESTORATIVE MATERIALS. A LITERATURE REVIEW

Dental Science

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ABSTRACT

Smart materials have been around for many years and they have found wide range of applications. The use of the terms smart and intelligent is being used recently anyhow these so-called smart materials had been around for many years.

Smart behaviour occurs when a material detect 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.

These properties have a beneficial application in various fields including dentistry. Shape memory alloys, zirconia, and smartseal are examples of materials exhibiting a smart behavior in dentistry. There is a strong trend in material science to develop and apply these intelligent materials. These materials would potentially allow new and groundbreaking dental therapies with a significantly enhanced clinical outcome of treatments. There is a strong trend in material science to develop and apply these intelligent materials. These materials would potentially allow new and groundbreaking dental therapies with a significantly enhanced clinical outcome of treatments.

KEYWORDS

INTRODUCTION

Conventionally materials used in dentistry were designed to be inactive and inert, that is, to exhibit little or no interface with body tissues and fluids. Materials used in the oral cavity were judged on their ability to survive without interacting with the oral environmentanf at the same time it lacked the ablity to provide complete function and good esthetic.

The present situation 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.

The first and foremost realisation of material activity otherthan being inert in the environment comes with the release of active flourides from the cements and created the term active rather than passive. This both reflects and permits a change in material philosophy.

Materials used in dentistry can be classified as bioinert (passive) like guttapercha, amalgam, bioactive like MTA, Calcium hydrocide, Glass ionomer Cement, and bioresponsive or smart materials based on their interactions with the environment.(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 [1]. These materials are also referred to as responsive materials.

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This paper aims at describing various materials in dentistry that exhibit some sort of smart behaviour.(2)

Smart Composites

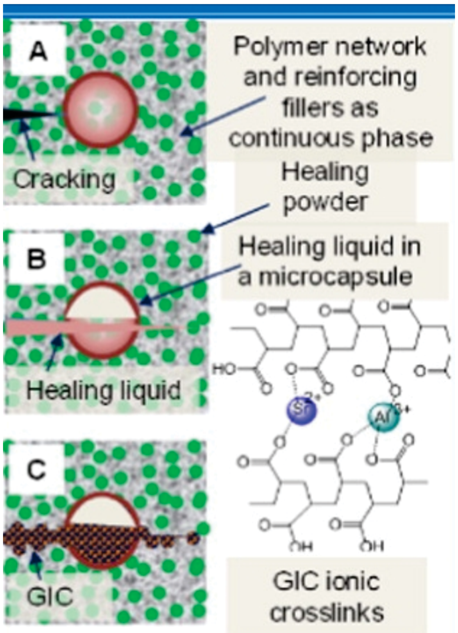
Amorphous calcium phosphate (ACP) was obtained as an amorphous precipitate by accident when mixing high concentrations (30 mM) of calcium chloride and sodium acid phosphate (20 mM) in buffer. ACP based materials have been developedand utilised for a wide range of applications and along with, like bases/liners, orthodontic adhesives, endodontic sealers [8], and as pit and fissure sealants.

ACP in composite is defined and incorporated in the cspsular forms. The aim of incorporation is to repair the enamel surface adjacent to the composite material. The Calcium and phosphates relrased from the material replace the lost hydroxyapatite crystals by actively taking part in the formation, this process usually starts when the PH of the oral environment reduces below 5.8. Usually the precipitated calcium and phosphate released from the composite may result into the formation of gel like structure that immediately converts into the hydroxyapatite crystals and replaces the lost structure. By this mechanism this composite acts as smart material to modify the changes occured because of some kind of insult. There is still question as the continous release of these ions may result into the formation of nanogaps in the material which ultimately effects the overall strength of the composite material. Firthr required some modification and research to strengthen the composite as a hole.(3)

Smart composites can be created by embedding the shape memory alloy fiber into a metal matrix. The purpose of incorporation of the SMA fiber is to create compressive stresses in the host matrix. It is well established that the compressive stress in the matrix is beneficial to mechanical properties of the composite such as yield stress and fracture toughness. Thus, metal matrix composites reinforced with SMA fibers have increased tensile properties (yield stress) as well as fatigue resistance/crack growth retardation of the composite. This is one of important component and obtained material to beat the polymerisation shrinkage and Coefficient of thermal changes. Need of the hour is to utilise these nano materials into dental composites.(4)

Self-Healing Composites

Materials usually have a limited shelf life and degrade due to different physical, chemical, and/or biological stimuli. These may include external static (creep) or dynamic (fatigue) forces, internal stress states, corrosion, dissolution, erosion, or biodegradation. This eventually leads to a deterioration of the materials structure and finally failure of the material [5].



Nature has encouraged scientists and researchers to develop materials which can repair on their own. A great many natural materials are themselves self-healing composite materials. An example for this is natural bone which is permanently remodelled and which can self-repair (heal) even after a major fracture has occurred. A key focus of current scientific research is the development of bioinspired materials systems [6].

The material which has shown as self repair capability is the resin materials. The epoxy resin in small microcapsule has been added into the main composite resin component, whenever there is a crack in the composite these small capsule breaks in the line of fracture and releases the epoxy resin content. The resin subsequently fills the crack and reacts with a Grubbs catalyst dispersed in the epoxy composite, resulting in a polymerization of the resin and a repair of the crack.These are the self repaired materials. The studies are required to check thd reliability of this system in further strengthening the already cracked and repaired composite.Insch approach Wertzberger et al. [7] conducted a study to determine the effectiveness of self-healing of a highly filled composite and to explore the physical properties of a model dental compound formulated to automatically heal cracks. A visible light cured model resin consisting of Triethylene Glycol Dimethacrylate (TEGMA) : Urethane Dimethacrylate (UDMA) : Bisphenol A Glycidyl Methacrylate (BisGMA) (1 : 1 : 1) at 45% w/w with silane 0.7 µ glass was formulated with a self-healing system consisting of encapsulated dicyclopentadiene and Grubbs catalyst. The base resin was also formulated and characterized with the microcapsules alone, Grubbs catalyst alone, and no healing additives. Fracture toughness (KIc) was assessed using single edge notch specimens in three-point bend. The fracture toughness of the self-healing material was statistically similar to the control. The modulus decreased in the composites with encapsulated dicyclopentadiene. (5,7)

Basic method of the microcapsule approach (White et al., 2001) Source:

It can be expected that dental composites using this technology would have a significantly longer shelf life and enhanced clinical performance. Problems may arise from the likely toxicity of the resins in the microcapsules and from the catalyst, which needs to be present in the composite. The amounts of these agents necessary to repair microcracks in the dental composite, however, seem to be rather small, and may well be below the toxicity threshold [4-5)].

The self-repairing mechanism based on microcapsules may be more promising, and composites repaired in that way may perform better than those repaired with macroscopic repair approaches, some of which [6] have been shown not to lead to satisfactory mechanical properties of the repaired composite with an aesthetically pleasing result. These conventional composites, however, have little in common with natural tooth structure and do not support any kind of tissue regeneration or repair.(7)

6. Glass Ionomer Cement as a Smart Material

Extensive temperature fluctuations may occur in the oral cavity due to the intake of hot or cold food and fluids. Hence, the restorative materials placed in this environment may show thermal expansion or contraction in response to thermal stimuli. The coefficient of thermal expansion (CTE) is normally used to describe the dimensional changes of a substance in response to thermal change [8].

The CTE is an inherent characteristic of each material at a specific temperature. When dealing with thermally induced volumetric changes, comparison of CTE values of the restorative material and the tooth substance is more important than the CTE value of the material itself. When two materials expand or contract at a similar rate, gap formation at the interface is almost a nonissue; thus, microleakage is negligible

The mismatch of thermal expansion and contraction between a restoration and the tooth structure may cause stresses to develop at the interface and this may have unfavourable effects on the margins and finally lead to microleakage [8,10).

In dry conditions, the materials showed a marked contraction when heated above 50°C. The explanation for this behaviour 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, the process was reversed. In dry conditions, the rapid loss of water on heating results in the observed contraction. This behaviour is of the same kind to that of human dentine 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, the glass-ionomer materials can be said to be mimicking the behaviour of human dentine through a type of smart behaviour [9-10)

Fluoride release ability of glass ionomer cements is well documented. Anti-caries property is established by increasing enamel resistance to demineralization and enhancing remineralization of the early carious lesion.It is thought that, this fluoride release drop over time restricts the ability of the materials to inhibit secondary caries around restorations.The exposure of dental materials to topical fluoride creates a fluoride recharge potential.[8] The ability of a restoration to act as a fluoride reservoir is mainly dependent on the kind and permeability of filling material, the frequency of fluoride exposure and the kind and concentration of fluoride agent(11)

With increasing of exposure time, the rechargability was increased. As the same methodology was used after immersing of the glass ionomers in the tooth paste at all time intervals, it seems the exposure time and the nature of tooth paste specially containing higher amount of fluoride influence the recharge pattern of glass ionomers with tooth paste rather than its sticky nature.(12-13) This suggests, if possible, the use of higher concentrations of fluoride in mouth wash or more regular application to brushing with tooth paste.If high fluoride uptake and release is expected for prevention of caries in a long period of time, a time tabled schedule of application of fluoride-containing materials could help to achieve high fluoride release. (12-14)

GICs are described as smart materials with respect to their thermal behaviour and flouride recharging activity, since it is a desired feature, when restorative materials undergo thermally induced volumetric changes close to those of the tooth substance and release of floiride to prevent initial caries and getting recharge with flouride. [8, 13, 15].

CONCLUSION

Smart materials have been around for many years and they have found wide range of applications. The use of the terms smart and intelligent is being used recently. There is trending and smart evolution of materials in restorative Dentistry. However the self healing property of fractured material and release of Flourides in prevention of caries and again regaining lost flouride without hampering the further other properties make it smart. Still further research required in this field of smart material dentistry to utilise it in restorative dentistry.

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