REVIEW ARTICLE

SMART MATERIALS IN PEDIATRIC DENTISTRY - A REVIEW

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ABSTRACT

Till date there is no single material in dentistry that fulfills all the requirements of an ideal material Hence there has been continous search for newer materials which has led to the discovery of smart materials in the field of dentistry. Smart materials are called so as they can be altered in a controlled fashion by different stimulus like temperature, moisture, pH, stress and also with the use of smart materials conservative cavity preparation can be carried out and hence stepping into minimum invasive dentistry. Some of them are biomimetics and can mimic the natural tooth structures such as enamel and dentin. These materials hold a promising future in terms of improved efficiency and reliability and mark the beginning of a new era that is Smart Dentistry. This paper showcases different smart materials and its use to achieve minimum invasive dentistry.

Key Words: Smart Composites, Glass Ionomer Cement, Resin Sealant, Ceramic, Impant, Laser

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INTRODUCTION

Traditionally inert or passive materials which have no interaction with their environment were considered ideal for long-term use in the mouth. Materials such as amalgams, composites and cements were considered highly successful because of their ability to survive without interacting with the oral environment.[1] This is actually a different approach to material tolerance and biocompatibility and with smart materials there possibility that some positive gains can be achieved by using materials which behave in a more dynamic fashion in the environment in which they are placed. With increased knowledge of benefit of fluoride release from materials the idea of use of an active rather than passive material came in. This lead to the invention of smart materials. A key feature of smart behaviour includes an ability to return to the original state after the stimulus has been removed.[2]

CLASSIFICATION OF SMART MATERIALS[3]

• The materials which respond to external change without external control were considered Passive materials They also possess self repairing characteristics.

Ex: Resin-modified glass ionomer, Compomer, Dental composites,

• The materials which sense a change in the environment and respond to these changes were considered Active materials.

Ex: Smart composites, Smart ceramics

Smart materials

SELF REPAIRING /SELF HEALING COMPOSITES

Self-healing composite are inspired by biological system such as bone. After the fracture of the bone, for the bone to heal, nutrients and undifferentiated stem cells must be delivered to the fracture site and sufficient healing time must elapse. In recent research, White et al. have developed a self-healing polymer. It is first self-healing synthetic 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, resulting in opening metathesis polymerization (ROMP) reaction and repair the crack. Different studies showed that dental composites with this technology have a significantly longer duty cycle and enhanced clinical performance. The main problems may occur from the potential toxicity of the resins in the microcapsules and from the catalyst. However, seem to be rather small, and may well be below the toxicity threshold.[4,5]

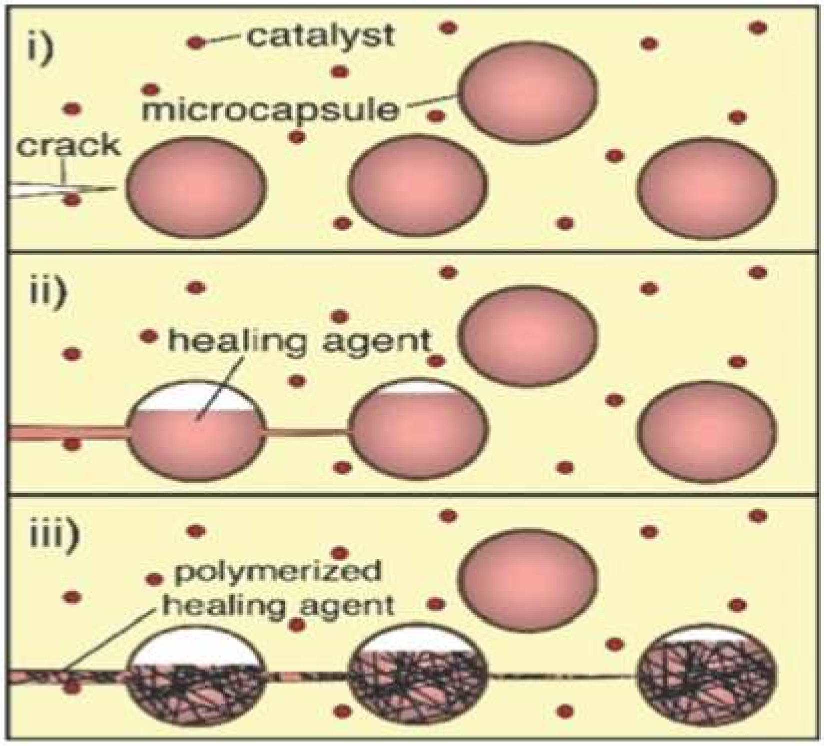
Smart composites

Smart composites have the property of RELEASE ON COMMAND. They release antimicrobial compounds or fluoride to fight microbes or secondary caries respectively when needed.

Smart composites contain Amorphous Calcium Phosphate (ACP), one of the most soluble of the biologically important calcium phosphates. When pH values falls below 5.8 ACP converts in to hydroxyapatite crystals and precipitates, thus replacing the hydroxyapatite crystals lost to the acid. Within seconds of pH fall below critical value these ions merge to form a gel. In less than 2 minutes, the gel becomes amorphous crystals, resulting in calcium and phosphate ions.[6,7]

Smart GIC

Glass Ionomer Cements (GIC) have shown a potential thermo-responsive smart behavior .The main advantage of GICs is that it has a coefficient of thermal expansion close to that of dental hard tissues. It was seen that there was not much of dimensional changes in GICs



in terms of heating (expansions) and cooling (contractions) in wet conditions but the materials demonstrated a marked contraction when heated at 50° C in dry conditions.

This action was due to the movement of water in or out of the structures which mimic the behavior of human dentin and indirectly shows the behavior of smart features.

The smart behavior of materials containing GIC is due its salt phases. There is evidence that the fluoride released from salt phases can be replaced when the material is bathed in a high concentration of fluoride. In the long term, the fluoride re-released after recharging may be much more important than the initial 'burst' which is sustained only for a short time.

With the depletion of inherent fluoride there is spikes of fluoride in the 24h period after recharging which was seen to increase slightly with age. This implies that the more inherent fluoride lost the greater capacity for uptake through re-charging. The levels of fluoride release maintained can be increased by beginning the recharging process as soon as possible after setting.

Mahmoud GA et al 2007 concluded that the use of fluoride releasing cements can minimise the demineralisation around orthodontic brackets and that this effect is not simply dependent upon the extent of the initial fluoride release.

BIOMIMETIC ENDODONTICS

Smartseal Obturation System

The main objective endodontics is three-dimensional filling of the instrumented canal, accessory canals, and dead spaces.

The main reason behind the failure of treatment using Gutta-percha was the leakage between sealer and dentin and gutta-percha and sealer and presence of voids. To overcome these problems and improve the treatment outcome, a root canal obturating system called Smartseal TM (known as Prosmart TM outside UK) was developed.[8]

It is hydrophilic endodontic point and an accompanying sealer. It has two components

1) propoint

2) smart paste/smart paste bio.

They are available in different tip sizes and tapers. The main advantage is the with a single propoint all the tip sizes are covered.

Propoint is called as C points have two parts:

Central Core: Provides the flexibility and hence

very advantageous in case of curved canals.

It is formed by the combination of Trogamid T and TrogamidCX which are two proprietary nylon polymers.

Outer Polymer Layer: Polymer acrylonitrile and vinylpyrrolidone has been cross-linked using allyl methacrylate and a thermal initiator. This hydrophilic, hydrogel layer allows the point to swell and adapt the canal wall and expand laterally without expanding axially by absorbing residual water from instrumented canal space and from naturally occurring intraradicularmoisture .

The lateral expansion of C Point is claimed to occur nonuniformly, with the expandability depending on the extent to which the hydrophilic polymer is prestressed. Eventhough C Point can achieve a relative good fit of an irregular canal space, gaps may still remain between the walls of the canal and the expanded point hence a sealer must be used to seal those areas.[5]

Smartpaste Bio

Smartpaste bio is a resin based sealant designed to swell through the addition of ground polymer. The addition of bioceramics, increases the dimensional stability of the sealer exceptionally and makes it non-resorbable inside the root canal.

Smartpaste bio produces calcium hydroxide and hydroxyapatite as byproducts of the setting reaction, rendering the material both anti-bacterial while setting and very biocompatible once set. The setting time ranges from 4-10 hr and because of the hydrophilic nature, the propoint hydrate and swell to fill any voids.

The sealant is delivered in a pre-mixed syringe and does not require mixing as it can be applied directly into the canal using an intra-canal tip minimising wastage of material. The cement absorbs water from within the canal and once set smartpaste bio produces a radiopaque biocompatible cement. Lesser formation of voids and improved efficiency in lateral canals fillings and homogeneity of obturation made using Smart Seal system comparable over Gutta-percha.

Eidet al. (2013) evaluated the biocompatibility of C Point and commercially available gutta-percha points using a rat odontoblast-like cell line (MDPC-23) by measuring cell viability and mineralization potential o fMDPC-23 cells. The study showed that the biocompatibility of C Point is comparable to gutta-percha with minimal adverse effects on osteogenesis after elution of potentially toxic components .

The single cone technique utilizing matched taper Propoint PT combined with Smartpastebio showed the lowest amount of glucose leakage.[5,8,9]

Smart Ceramics

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. Since then the process and the materials were tested and introduced in the market as CERCON – Smart Ceramics. The strength and technology of Cercon allows bridges to be produced without stainless steel or metal and deliver outstanding aesthetics.

Zirconium oxide (ZrO2) is a highly stable ceramic oxide, typically used in industrial applications requiring high strength and stability, and has a history as a biomaterial dating back to the1970s.

Zirconia have significantly high fracture toughness and flexural strengthand is much higher than that of alumina or any other currently available all ceramic.

The Cercon system offers a comprehensive solution to these needs by taking advantage of the strength, toughness, reliability, and biocompatibility of zirconium oxide. So the Cercon ceramics are said to be smart material as they are bioresponsive.[10,11,12]

Smart Prep Burs

These were designed keeping in mind minimally invasive dentistry. They are made of polymers. They cut only the infected dentin and hence keeping the tooth loss to minimal and also the affected dentin which has the ability to remineralize is left intact. Removal of tooth structure is minimal by the use of these smart preparation burs when compared to the conventional burs.

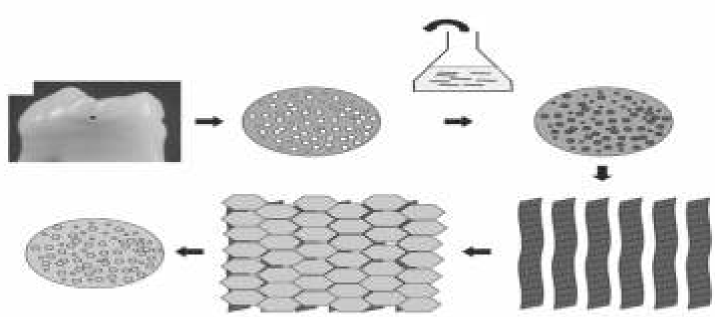
Ex: SS White (145 Towbin Avenue, Lakewood, Newjersey, 08701, USA) diamond and carbide preparation kit.[13]

Smart Sutures

The property that makes these suture materials smart is its shape memory and biodegradable properties. They are thermoplastic polymers These polymers are broken down in the body hydrolytically to produce lactic acid and glycolic acid. They are applied loosely in its temporary shape and the ends of the suture were fixed. When the temperature is raised above the thermal transition temperature, the suture would shrink and tighten the knot, applying the optimum force. Smart sutures made of plastic or silk threads covered with temperature sensors and micro-heaters can detect infections. Ex: Novel MIT Polymer (Aachen, Germany.[14]

Biomimetic Self-assembling Peptides:

P11-4 is a rationally-designed self-assembling



peptide. Self-assembling peptides undergo well-characterized hierarchical self-assembly into three-dimensional fibrillar scaffolds in response to specific environmental triggers, offering a new generation of well-defined biopolymers with a range of potential applications.

P11-4 switches from a low viscosity isotropic liquid to an elastomeric pneumatic gel at pH <7.4 and in the presence of cations, conditions assumed to be found within a caries lesion. In a number of in vivo and in vitro experiments, the assembled P11-4 fibers were shown to be highly biocompatible with low immunogenicity. Following P11-4 self-assembly, the anionic groups of other P11-4 side chains would attract Ca++ ions, inducing de novo precipitation of hydroxyapatite.

White spot is considered to be the first clinical sign of dental caries. At this stage, clinicians generally lesion appearance is monitored and topical fluorides application is done. The case is reviewed to determine whether the lesion will progress or not, in which case restoration would then be placed. Non-surgical intervention promoting defect biomineralization or regeneration at the white spot lesion stage would remove the need to 'wait and see' and avoid the ultimate excavation of the tooth to place a restoration.

Infiltration of early ('white spot') caries lesions using low viscosity monomeric P11-4 would result in triggered self-assembly within the lesion, generating a subsurface bioactive scaffold capable of recapitulating normal histogenesis by inducing mineral deposition in situ.

Peptide treatment significantly increased net mineral gain due to a combined effect of increased mineral gain and inhibition of mineral loss.[14,15]

Biomimetic Principles In Dental Implant

Biomimetic dental implants may be the next development in the field. There are various biomimetic coatings that may prove helpful for application in individual patients.

Development of SMART COATING by the researchers at North Carolina State University has proven to be helpful in bonding the surgical implants to the bone more closely thus warding off infection. This has provided with harmless hip, knee, and dental implants.

This coating alleviates the hazard by promoting bone growth into the implant. The coating produces a crystalline layer beside the implant and frequently an amorphous outer layer that touches the surrounding bone. Calcium phosphate hydroxyappatite and various types of aluminum oxides are proved to be bio compatible and they are coated to implant which increases osteointegration.[16,17]

Smart Fibres For Laser Dentistry

Transmission of high- energy laser pulses capable of ablating dental tissues is a crucial issue in laser dentistry. Flexible and convenient circuits for the delivery of laser radiation are needed to make the solution technologically attractive.

Through Hollow-core Photonic-Fibers (PCFs) high fluency laser radiations are delivered which can easily pass through the body using this Hollow-core Photonic fibres. These photonic fibers are known as SMART FIBRES.

Laser radiation which are transmitted through the Hollow-core PCF are focused upon the surface of a dry carious human tooth (in-vitro) induces an optical breakdown, resulting in plasma formation and dental tissue ablation. The laser breakdown was visualized as optical characterization of the ablated enamel surface. Emission from laser produced plasmas transmitted through the Hollow core PCF in the backward direction and analysed with a Monochromator and a CCD camera. Thus, Photonic Crystal Fibre are not only to transport the high power laser pulse to a tooth surface, but also to transmit plasma emission to the system for detection and optical diagnosis. While using these fibers we ought to be very careful because there is a risk factor that in some cases the fiber walls fail and the laser light may escape and harm the healthy tissue.[18]

Smart Toothbrush

This toothbrush offers a multitude of brush-head options for daily brushing and for specific dental considerations (e.g. sensitivity, orthodontics, implants). A red light illuminates at the backside of the toothbrush when pressure exceeds the needed. This red light is visible while brushing to remind the brusher to adjust the pressure applied to the tooth.

The smart toothbrush has inbuilt Bluetooth and various applications with multiple features:

Timer: The brushing time can be monitored. The time required for each quadrant is shown and reminds the user to brush longer if the set time is not reached. Longer brushing time can also be s set. Various instructional videos about proper usage of the brush is included. While brushing, the user can focus on the diagram of the section of the mouth to be brushed or read a newsfeed or oral care tips. These features encourage longer brushing times

Professional Guidance: The user's dental professional can set up Focused Care. Focused Care reminds the user to focus on a specific area in the mouth. The user may be reminded to spend more time brushing in a specific area, and the dental professional can add notes to further educate the patient. Product recommendations and appointment reminders can be set here.

Activity: This portion of the app is a report of the user's history of brushing times and frequency.

Dental Care Journeys: This section of the app guides the user to a desired outcome with proper brushing, flossing, rinsing, and tongue-brushing habits.

Achievements: This portion of the app encourages the user to develop optimal brushing habits by recording the user's personal bests.[19,20]

CONCLUSION

Our field of dentistry is completely dependent on the use of different materials, the use of smart materials promises improved reliability and long-term efficiency because of their potential to select and execute specific functions intelligently in response to various local changes in the environment, thereby significantly improving the quality of dental treatment. The numerous applications of smart materials have revolutionized many areas of dentistry and there is no doubt that "smart materials" hold a real good promise for the future.

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