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Review Article

Smart Dentistry: Stepping into the Future

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Abstract: Till date, there has been no single material in dentistry that is idyllic in nature, which can satisfy all the necessities of a superlative material. As the search for an "ideal restorative material" continues, newer group of materials were introduced. These are "Smart Materials'', as they support the remaining tooth structure to the level, so that more conservative cavity preparation can be performed. These materials may be improved in a precise manner by stimulus such as stress, temperature, moisture, pH, electric or magnetic field. Some of these are "Biomimetic" in nature as their properties imitate the natural tooth constituent such as Enamel or Dentin. The existing dental materials were amended so as to make them smarter. Use of Smart materials has modernized dentistry which comprises the use of restorative materials such as Smart composites, Smart ceramics, Composers, Resin modified glass ionomer, Amorphous calcium phosphate releasing pit and fissure sealants, etc. and other materials such as Shape memory alloys, Smart impression material, Smart suture, Smart burs, etc., . This article highlights the use of Smart materials for achieving benefit by the conventional restorative procedures in dentistry.
Keywords: Biomimetic, Smart materials, Dentin

INTRODUCTION

Smart materials, as defined by McCabe Zrinyi[1], are "Materials that are capable of being altered by stimuli and converting back into the original state after removal of stimuli". The stimuli can be a resultant from temperature, pH, moisture, stress, electricity, chemical or biomedical agents and magnetic fields. Because of the unique behavior exhibited by the smart materials, researchers have applied them in medical and dental field. The ability of smart materials to transform into original state after stimulus removal makes them distinct. Smart materials are extremely receptive and have an inherent capacity for sensing and reacting to changes in the environment. For this reason, they are termed as Responsive Materials [1, 2]

In 1980's , terms "smart" and "intelligent" were used to define materials and systems ,irrespective of the fact that few of them were called as Smart Materials. Earlier, smart material applications started with magneto-strictive technologies. This encompassed the use of nickel as a sonar source during World War I to search the German U-boats by Allied forces.

Classification [1-3]

I. Passive Smart Materials: React to external change without external control.

- GIC.
- Resin Modified GIC.
- Compomer.
- Dental composites

II. Active Smart Materials: Utilize a feedback loop to enable them to function like a cognitive response through an actuator circuit.

- Smart GIC.
- Smart Composites.
- Ariston pHC
- Smart ceramics (e.g. CERCON)
- Smart impression materials
- Shape memory alloys.
- Fluoride releasing pit and fissure sealants.
- ACP releasing pits and fissure sealants.
- Niti Rotary Systems.
- Smart fibres for laser dentistry.
- Self-healing composites.
- Smart seal obturation system.
- Dental Implants with Smart Coating.
- Smart prep burs (Smart Preparation burs)
- Smart antimicrobial peptide.

Biomedical Applications:

- Smart Sutures.
- Smart Pressure Bandages
- Hydrogel.

- Smart Shirt
- In disputing radioactive rays

Smart Glass Ionomer Cement

Davidson first suggested the smart behavior of GIC. This behavior is thus associated with the capability of the gel structure to absorb or discharge solvent swiftly in response to stimulus such as temperature, change in pH etc. Behavior of the human dentin is well imitated by these smart ionomers. Resin modified glass ionomer cement, compomer or giomer exhibit such smart characteristics. Ex: GC Fuji IX GP EXTRA (Zahnfabrik Bad Säckingen, Germany) [2-4].

Smart Composites

Smart composites comprises of Amorphous Calcium Phosphate (ACP), one of the most soluble among the biologically significant calcium phosphates. Hydroxyapatite is the basic constituent of tooth enamel, andan inorganic component of dentin. Caries in a tooth is basically the outcome of introduction of oral cavity to low pH conditions (acid attack) either due to bacteria, other biological organisms liberating acid, food (carbohydrate decomposition products) or acidic beverages. ACP remains ACP at neutral or high.

Due to caries, there is decrease in the pH values ie. at or below 5.8, thus conversion of ACP into HAP and precipitates, followed by the replacement of HAP lost due to the acid. Intra-orally, when the pH level drops below 5.8, within seconds, these ions unite to form a gel. The gel becomes amorphous crystals, thus resulting in calcium and phosphate ions [5].

Ariston pHC

Introduced in the dental field by Ivoclar Vivadent (Liechtenstein) (pH control) in 1998. Restorations with Ariston pHC, when introduced to fall in pH to the critical pH, it is claimed release fluoride, hydroxide and calcium ions. Thus, it neutralizes acid and lessens the enamel and dentin decalcifications [5].

Smart Ceramics

ETH Zurich, in 1995 first invented" all ceramic teeth bridge", centered on a procedure that permitted the direct machining of ceramic teeth and bridges. Since then, the procedure and the materials were verified and introduced in the market as CERCON – Smart Ceramics. Whether for anterior or posterior teeth, single unit or multi-unit bridges, Cercon Smart Ceramics provides exceptional aesthetics without any compromise.

Fracture toughness and flexural strength of zirconia is considerably greater than that of alumina or any other presently available All ceramic. The Cercon system gives aninclusive solution to such requirements by taking benefit of the strength, toughness, dependability, and biocompatibility of zirconium oxide. So the Cercon ceramics are supposed to be smart material as they are bioresponsive [6].
Ex: Cercon Zirconium Smart Ceramic System.

Smart Impression Materials

These materials exhibit properties like Hydrophilic in nature, Shape memory, Snap — set behavior, reduction in working and setting times by almost 33%, Viscosity.
Ex: Imprint™ 3 VPS, Impregim™, Aquasil ultra (3M ESPED ental Products, USA) [7].

Shape memory alloys

Such alloys show unique properties such as super elasticity, shape memory, superior fatigue and wear resistance and relatively better biocompatibility. In 1970’s, Ni-Tinol was introduced in orthodontics for fabricating brackets. Wires revealing shape memory behavior at intra-oral temperature usually comprise of copper and or chromium in addition to nickel and titanium. Ex: Ni-Ti alloy [8].

Nickel-Titanium (Ni-Ti) Rotary Instruments

Introduction of Ni-Ti in rotary endodontics has simplified and fasten the instrumentation technique than conventional hand instrumentation during biomechanical preparation of the root canal. Use of rotary Ni-Ti files has contributed in reducing the probabilities offile breakage within the root canal during instrumentation, minimsing fatigue to the operator, less root canal transportation, reduced incidence of canal aberrations and least post-operative pain to the patient [8].

Smart Fibres

Hollow-core Photonic-Fibers (PCFs) can easily deliver lasers with greater ease i.e., the laser radiations can be twisted effortlessly through the body by utilizing these fibres, that have efficiency of ablating the developed tooth enamel. Such photonic fibers are known as Smart Fibres [9].

One should be very cautious while using these fibers because there are chances of fiber wall failure, there may be spurt of laser light, thus causing hazard for the healthy tissue [9].

Self-Healing Composites

These are epoxy system comprising of microcapsules filled with resin. Occurrence of crack in such epoxy composites destroys the microcapsules present near the crack, thus releasing the resin. The resin successively fills the crack and counters with a Grubbs catalyst, that is distributed in the epoxy composite, accordingly resulting in resin polymerization and repair of the crack. Analogous systems were established to have a meaningfully longer liability cycle under mechanical stress in situ equated to comparable systems with the self-repair ability.

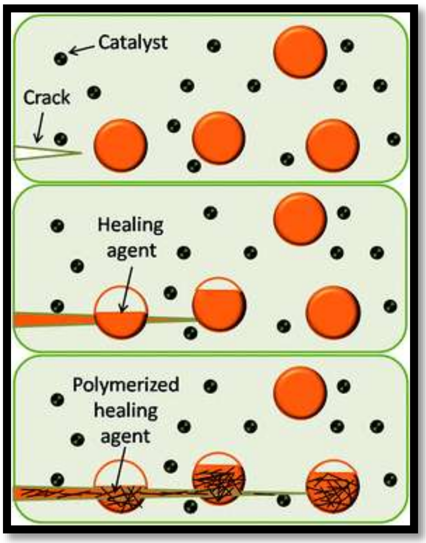

Fig-1: Mechanism of Self-Healing Composites

Self-repairing mechanism centered on microcapsules may be more hopeful, and composites repaired in that way may execute better than those repaired with macroscopic repair methods, few of these have shown not to lead to acceptable mechanical properties of the repaired composite with esthetically acceptable results [10, 11].

Smart Seal Obturation System

The C Point system (EndoTechnologies, LLC, Shrewsbury, MA, USA) is a point-and-paste root canal filling technique comprising of hydrophilic endodontic points and a sealer. C point having an inner core, combination of two proprietary nylon polymers: Trogamid T and Trogamid CX.Smartpaste bio is a resin-based sealant intended to swell through the addition of ground polymer [12].

Polymer coating is a cross-linked copolymer of acrylonitrile and vinylpyrroli, polymerised and cross-linked using allyl methacrylate and a thermal initiator. Lateral expansion of C Point is claimed to befall non-uniformly, with the expandability liable on the magnitude to which the hydrophilic polymer is pre-stressed (i.e., contact with a root canal wall will minimise the degree or range of polymer expansion). Manufacturer claims that when bioceramics are added, the sealer exhibits extraordinary dimensional stability thus making it non-resorbable inside the root canal [12].

Fig-2: C-points and Smart Seal paste

Economides *et al.* concluded that there was no difference in dentine adhesion between the Smart seal system and gutta-percha/AH-26 applied either by single cone or lateral condensation technique [13].

Dental Implants with Smart Coating

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. Dissolution of the amorphous layer takes place over a period of time, liberating calcium and phosphate, thus encouraging growth of the bone.

"Bone develops into the coating as the amorphous layer thaws, resulting in enhanced bonding, or osseointegration." Such bonding makes the implant more efficient, because the bonding aids in ensuring the bone and the implant to do animproved job of load [14].

Smart Prep-burs (Smart Preparation burs)

These are polymeric burs that remove only the infected dentin leaving the affected dentin untouched. The affected dentin had the ability to remineralize. Excessive and unwanted cutting of tooth structure usually happens with conventional burs. This can be avoided by the use of this smart prep-bur [15].

Fig-3: Smart Prep-Burs

Smart antimicrobial peptide

Pheromone-guided "smart" antimicrobial peptide is directed against carnage of Streptococcus mutants which is the key microorganism responsible for causing dental caries. The developing technology "tissue engineering" conceptualizes tissue re-growth in the oral cavity [16].

The BRAX-I gene has been quarantined along these lines, is assumed to be liable for having control on enamel growth [17].

BIOMEDICAL APPLICATIONS

Smart Sutures

Comprised of thermoplastic polymers, having shape memory and biodegradable properties. They are applied lightly in its provisional shape and suture ends are fixed. When the temperature rises above the thermal transition temperature, suture would contract, thus tightening the knot and applying the optimal force. This thermal transition temperature nears the human body temperature and is of clinical implication in tying a knot with appropriate pressure in surgery [18].

Smart sutures are made up of plastic or silk threads enclosed with temperature sensors and micro-heaters that can perceive infections [19].

Fig-4: Smart Sutures

Smart pressure Bandages

When polyethylene glycols are bonded to several fibrous materials like cotton and polyester, they unveil properties like thermal adaptableness and reversible shrinkage. Such shrinkage includes conveying of an elemental memory to the material, making it shrink when the material exposes to a liquid. These materials can be used for pressure bandages, dragging pressure on the wounds while in contact with the blood [20].

Hydrogel

With changes in temperature, pH, magnetic or electrical fields, the hydro gels reveal plastic contraction. These have applications in the field of biomedicine as soft actuators or for controlled release of drugs [2].

Smart Shirt

The Georgia Tech in collaboration with Sensa Tex, Inc., invented "Smart Shirt". It is a T-shirt that functions like a computer, a garment assimilated with optical and cohesive fibers. It screens heart rate, EKG, respiration, temperature, alerting the person wearing it or the doctor if any problem exists. This shirt can also monitor the important signs of law enforcement officers, fire men, astronauts, elder persons living alone, infants, athletes' military personnel and prolonged ill patients [2].

In disputing radioactive rays

Composite suppression structures can be utilized for disputing the radioactive or chemical waste materials. Radiation or chemical waste when sensed, fibers having chemical or radioactive subtle coatings can be provided which are revised for releasing the scavenger compounds [2].

CONCLUSION

Recent advances in the strategy of smart materials have produced innovative prospects for their uses in dentistry and bio-medical fields. These various applications of "Stimuli-Responsive or Smart Materials", nevertheless tells us that they hold potential promises for the future. Such advances have marked the commencement biosmart dentistry era, an imminent step into the future. So now, it is the time to think "smart" and apply smart materials in dentistry, in our routine clinical practice.

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