

SMART MATERIALS – A REVIEW

Bhatnagar A,¹ Wagh S,² Singh B,³ Agarwal RR,⁴ Khan F⁵

1. Post Graduate Student, Department of Pedodontics & Preventive Dentistry, Kothiwal Dental College & Research Center, Moradabad, Uttar Pradesh.

2. Post Graduate Student, Department of Pedodontics & Preventive Dentistry, Kothiwal Dental College & Research Center, Moradabad, Uttar Pradesh.

3. Post Graduate Student, Department of Pedodontics & Preventive Dentistry, Kothiwal Dental College & Research Center, Moradabad, Uttar Pradesh.

4. Post Graduate Student, Department of Periodontics, Kothiwal Dental College & Research Center, Moradabad, Uttar Pradesh.

5. Senior Lecturer, Department of Prosthodontics, Career Post Graduate Institute of Dental Sciences & Hospital, Lucknow, Uttar Pradesh.

Abstract

The most promising technologies for life time efficiency and improved reliability include the use of smart materials and structures. Smart materials are being used, and are continually being developed, for medical, defensive and industrial purposes. There is no single material in dentistry that is ideal in nature and fulfils all the requirements of an ideal material. As the quest for an “ideal restorative material” continues, a newer generation of materials was introduced. These are termed as “smart” as these materials support the remaining tooth structure to the extent that more conservative cavity preparation can be carried out. 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.

Key words – Biomimetic, Ideal Restorative Materials, Smart Materials.

Introduction

A material is said to be “smart” if it can support the remaining tooth structure to the extent that cavity preparation can be carried out in the most conservative way. 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 derived from temperature, pH, moisture, stress, electricity, chemical or biomedical agents and magnetic fields. Due to the interesting behaviour of smart materials, scientists have been encouraged to apply them in various fields, mostly in biomedical science and dentistry. A key feature of smart behaviour includes an ability to return to the original state after the stimulus has been removed. Smart materials are highly responsive and have a great capacity to sense and respond to any environmental change. Hence these materials are also known as “Responsive Materials”.

Classification:

I. Passive Smart Restorative Materials: Respond to external change without external control.

- GIC
- Resin Modified GIC
- Compomer
- Dental Composites

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

1. Restorative Dentistry

- Smart GIC
- Smart composites
- Ariston Phc

2. Prosthetic Dentistry

- Smart ceramics
- Smart impression materials

3. Orthodontics

- Shape memory alloys.

4. Pediatric and 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:

Smart Glass Ionomer Cement (RMGIC)

The smart behaviour of GIC was first suggested by Davidson. It is related to the ability of a gel structure to absorb or release solvent rapidly in response to a stimulus such as temperature, change in pH etc. The number and size of pores with the cement can be controlled by the method of mixing conveniently measuring using micro-computed tomography scanning. These smart ionomer mimic the behaviour of human dentin. Resin modified glass ionomer cement, compomer or giomer also exhibit these smart characteristics.² Ex: GC Fuji IX GP EXTRA (Zahnfabrik Bad Säckingen, Germany)

Smart Composites

It is a light-activated alkaline, nano filled glass restorative material. It releases calcium, fluoride and hydroxyl ions when intraoral pH values drop below the critical pH of 5.5 and counteracts the demineralization of the tooth surface and also aids in remineralization. The material can be adequately cured in bulk thicknesses of up to 4 mm. It is recommended for the restoration of class 1 and class 2 lesions in both primary and permanent teeth.³ Ex: Ariston pH control — introduced by Ivoclar — Vivadent

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. The carious attack is usually the

result of exposure to low pH conditions (acid attack) either from bacteria, other biological organisms releasing acid, food (carbohydrate decomposition products) or acidic beverages. ACP at neutral or high pH remains ACP. When low pH values i.e., at or below 5.8 occurs during a carious attack, ACP converts in to HAP and precipitates, thus replacing the HAP lost to the acid. So when the pH level in the mouth drops below 5, these ions merge within seconds to form a gel. In less than 2 minutes, the gel becomes amorphous crystals, resulting in calcium and phosphate ions.⁴

Smart Ceramics

These are metal — free biocompatible life like restorations that allows them to blend well with the surrounding natural dentition. They made the process of restoring teeth to natural form easy and predictable. The Zirconia-based all ceramic material is not baked in layers on the metal, but is created from one unit with no metal. The overall product is metal-free biocompatible life like restoration with strength that helps resist crack formation. With Cercon unsightly dark margins and artificial grey shadows from the underlying metal are no longer a problem. Whether for "front" or "back" teeth, single unit or multi-unit bridges, Cercon Smart Ceramics deliver outstanding aesthetics without reservations or compromise.⁵ Ex: Cercon Zirconium Smart Ceramic System

Smart Impression Material

These materials exhibit more hydrophilic 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 cut of working and setting times by at least 33%. The viscosity of these materials is low with high flow.⁶ Ex: Imprint™ 3 VPS, Impregim™, Aquasil ultra

SMAs

These alloys have exceptional properties such as super elasticity, shape memory, good resistance to fatigue and wear and relatively good biocompatibility. Ni-Tinol was introduced in orthodontics in 1970s and is used in fabrication of brackets. Wires exhibiting shape memory behaviour at mouth temperature normally contain copper and or chromium in addition to nickel and titanium.⁷ Ex: Ni-Ti alloy

Nickel-Titanium (Ni-Ti) Rotary Instruments

The introduction of Ni-Ti in rotary endodontic has made instrumentation easier and faster than conventional hand instrumentation during biomechanical preparation of root canal treatment. The advantage of using rotary Ni-Ti files are less chances of file breakage within the canal during instrumentation, less fatigue to the operator, less transportation, decreased incidence of canal aberration and minimal post-operative pain to the patient.⁷ Ex: Ni-Ti rotary files

Smart Burs

These are polymer burs that cuts only infected dentin. The affected dentin which has the ability to remineralize is left intact. Over cutting of tooth structure that usually occurs with conventional burs can be avoided by the use of these smart preparation burs.⁸ Ex: SS White

Smart Sutures

These sutures are made up of thermoplastic polymers that have both shape memory and biodegradable properties. 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. This thermal transition temperature is close to human body temperature and this is of clinical significance in tying a knot with proper stress in surgery. Smart sutures made of plastic or silk threads covered with temperature sensors and micro-heaters can detect infections.⁹ Ex: Novel MIT Polymer (Aachen, Germany)

Smart Fibres for Laser

Laser radiation of high- fluency can be easily delivered by Hollow-core Photonic-Fibers (PCFs) i.e., the laser radiations can easily be snaked through the body using this Hollow-core Photonic-Fibers which are capable of ablating tooth enamel been developed. These photonic fibers are known as smart fibres.¹⁰

Conclusion

The recent advances in the design of smart materials have created novel opportunities for their applications in biomedical fields. These numerous applications of "Stimuli-Responsive or Smart Materials", no wonder tells us that these materials hold a real good promise for the future. The most sophisticated class of smart materials in the foreseeable future will be that which emulates biological systems.

References

1. McCabe JF, Yan Z, Al Naimi OT, Mahmoud G, Rolland SL. Smart materials in dentistry – Future prospects. *Dent Mater J* 2009;28(1):37-43.
2. Nomoto R, Komoriyama M, McCabe JF, Hirano S. Effect of mixing method on the porosity of encapsulated glass ionomer cement. *Dent Mater* 2004;20(10):972-8.
3. Rolland SL, McCabe JF, Robinson C, Walls AW. *In vitro* biofilm formation on the surface of resin-based dentine adhesives. *Eur J Oral Sci* 2006;114(3):243-9.
4. Xu HHK, Weir MD, Sun L, Takagi S, Chow LC. Effects of calcium phosphate nanoparticles on Ca-PO₄ composite. *J Dent Res* 2007;86(4):378-383.
5. Dube M, Ponnappa KC. Smart ART!! *J Int Oral Health* 2009;1(1):52-7.

6. Terry DA, Leinfelder KF, Lee EA, James A. The impression: A blue print to restorative success. *Int Dent SA* 2006;8(5):12-21.
7. Crumpton BJ, McClanahan S. Endodontic rotary nickel-titanium instrument systems. *Clin Update* 2003;25(8):15-6.
8. Dammaschke T, Rodenberg TN, Schäfer E, Ott KH. Efficiency of the polymer bur SmartPrep compared with conventional tungsten carbide bur in dentin caries excavation. *Oper Dent* 2006;31(2):256-60.
9. Patel P. Smart sutures that detect infections. *Bio Med News* 2012.
10. Konorov SO, Mitrokhin VP, Fedotov AB, Sidorov-Biryikov DA, Beloglazov VI, Skibina NB *et al*. Hollow-core photonic-crystal fibres for laser dentistry. *Phys Med Biol* 2004;49(7):1359- 1368.

Corresponding Author

Dr. Akash Bhatnagar
Post Graduate Student
Department of Pedodontics & Preventive Dentistry,
Kothiwal Dental College & Research Centre,
Moradabad, Uttar Pradesh, INDIA.
E mail: - raghuraghavagarwal@rediffmail.com