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Smart materials in conservative dentistry and endodontics: An update

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Abstract

Many facets of dentistry have been modernized by smart materials. The search for the ideal restorative material spurs the development of a more modern class of dental materials known as smart materials. These substances are referred to as "smart" materials because they can be controlled to change in response to stimuli like stress, pH, moisture, temperature, electric field, or magnetic field. The use of smart materials in dentistry has benefited restorative products like resin-modified glass ionomer, smart burs, smart ceramics, smart composites, amorphous calcium phosphate (ACP)-releasing pit and fissure sealants.

Keywords: Dentistry, Restorative materials, Smart material

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1. Introduction

The primary requirement for dental materials is that they must be companionable with fluids found in the oral cavity, including saliva and gingival crevicular fluids. One of the most dependable and long-lasting materials is bioactive material. In order to find idyllic materials, smart materials are developed, which could lead to smart dentistry. There has never been a substance in dentistry that is perfect in nature and satisfies all of the criteria for a superlative material [1].In the 1980s, the United States pioneered the use of the terms "smart" and "intelligent" to describe products and systems. The first use of smart materials was for magnetostrictive technologies, which involved using nickel as a sonar source to help Allied forces locate German U-boats during World War I. A material generally exhibits intelligent behaviour when it detects an environmental stimulus and responds to it in a practical, trustworthy, repeatable, and typically reversible way [2]. Smart materials, by definition, are substances with properties that can be changed in a controlled way by stimuli like pressure, temperature, pH, moisture, and magnetic or electric fields. The ability of smart performance to revert to its initial state even after the stimulus has been eliminated is one of its most crucial key characteristics [2,3]. They are referred to as intelligent materials because, according to Takagi (1990), they respond to environmental changes under ideal circumstances and reveal their own functions as a result [4].

These are referred to as "smart" materials because they support the remaining tooth structure to allow for more conservative cavity preparation. Some of these are also "biomimetic" in nature, meaning that they have traits that can resemble enamel or dentin, two types of natural tooth structures. Dental restorations such as amorphous calcium phosphate-releasing pit and fissure sealants, smart composites, smart ceramics, resin-modified glass ionomer, etc. have all been made possible by the use of these smart materials [2].

2. History

In 1960, Richard P. Feynman made the first mention of nanotechnology. The Greek word "Nano" means "dwarf." Nanorobots were first proposed by James Clerk Maxwell in 1867. Nanomaterials are aggregate materials or unbound natural or artificial materials with particle sizes between 1 and 100 nanometers. Extremely small diameters, a high surface area to mass ratio, and improved chemical reactivity are just a few of the properties of nanomaterials. The ability of nanoparticles to interact with the human body at the molecular and subcellular levels is a benefit. It was developed for endodontic use to enhance dentin that was already compromised in terms of mechanical integrity, tissue regeneration, and antimicrobial efficacy [4].

3. Classification of smart materials

The following categories can be used to group smart materials:

1. Passive materials, such as resin-modified glass ionomers, compomer and dental composites.

2. Active materials, such as smart composites and smart ceramics

Without external control, passive materials react to alteration in the environment. They also have the ability to repair themselves [2,5].

4. Properties of smart materials

Smart materials react unsurprisingly to variations in their environment by sensing those changes. These characteristics are typically:[2]

a. Piezoelectric devices produce an electric current when mechanical stress is applied.
b. b. Shape memory: These materials can recall their original shape after deformation and take it back when heated. such as-NiTi alloys
c. Thermochromic materials, on the other hand, alter colour in response to temperature changes. Thermochromic brushes, for example.
d. d. Photochromic materials—these substances alter colour in response to variations in lighting. such as - ClinproTM Sealant (3M)
e. Magnetorheological materials are fluids that solidify when exposed to a magnetic field.
f. f. Materials that collapse or swell when the pH of the surrounding media varies are said to be pH-sensitive.amorphous calcium phosphate (ACP)-containing smart composites, for instance.
g. Biofilm formation — The presence of biofilm on a material's surface changes how that surface interacts with its surroundings.
h. Ion release and recharging - The beneficial outcome of fluoride release from dental materials has been the subject of extensive research over many years because the products have a tendency to lose their capability to release fluoride in considerable quantity even after a high initial fluoride release. The constant re-release of fluoride after initial recharging, which may be much more significant than the initial burst, is provided by the intelligent behaviour of materials containing GIC salt phases, however, and provides some long-term solutions.

5. Biomimetic paradigms

1. Maximum bond strength - Bond strength increases as polymerization stress to the developing hybrid layer is reduced. The biomimetically restored tooth can function and withstand functional stresses just like an unharmed natural tooth thanks to this sturdy bond.
2. Long-term marginal seal: Under conditions of functional stress, a long-term marginal seal can be established and maintained thanks to a strong and secure bond.
Enhance Pulp Vitality 3.
4. Reduced Residual Stress - Any biomimetic restorative technique's ultimate goal is to reduce residual stress while maintaining the highest possible bond strength [4].

6. Mechanism of smart materials

To encourage tissue repair and regeneration, biosmart materials have inductive and instructional effects on cells and tissues by responding to both internal and external stimuli like pH, magnetic field, temperature, and ionic strength.

It has controlled and intelligently altered the functions of individuals to actively engage in tissue regeneration [4].

7. Criteria for a smart material

- Asymmetrical nature
- Receiving and responding to stimuli
- Include at least one material with a smart structure [4].

8. Smart materials by design [5]

The following techniques can be used to incorporate and create intelligent behaviour in materials with a poly salt matrix:

• *Water's role*: The capability of a structure to quickly release or absorb solvent in reaction to a thermal stimulus is correlated with intelligent behaviour.

The dimensional stability of the structure may be decreased or increased based on the properties of the water and the strength of the bonds that are present.

• *Thermal behaviour*: A material's coefficient of thermal expansion largely determines how it will behave thermally. The issue with most dental materials is that they have different coefficients of thermal expansion than teeth, which causes them to expand and contract more than natural teeth do.

• *Radial pressure and expansion*: The durability and longevity of the material can be stabilised by adding resins to the salt and gel matrix.

8.1. Amorphous Calcium Phosphate (ACP)

Hydroxyapatite (HAP) is formed biologically from ACP as a precursor. Its application in adhesives and dental cements, composites and pit and fissure sealants is justified by the fact that it has both preventive and restorative properties. Casein phosphopeptide (CPP), a milk derivative, forms a complex with ACP and is used as a remineralizing agent in dentifrices [3].

8.2. Pheromone Guided Smart Antimicrobial Peptide

Based on the fusion of a species-specific targeting peptide domain with a wide spectrum antimicrobial peptide domain, a new class of pathogen selective molecules known as specifically (or selectively) Targeted Antimicrobial Peptides (STAMP) have been developed. The primary microorganism causing dental caries, Streptococcus mutans, is the target of this pheromone-guided "smart" material peptide [2]. Ex: A "smart" antimicrobial peptide that is pheromone guided. By utilising conventional restorative methods in dentistry, these smart materials are utilised to the fullest extent possible [1].

8.3. Fluoride Releasing Pit and Fissure Sealant

Pit-and-fissure sealants can be used successfully as a component of an all-encompassing caries prevention strategy. While sealants have historically been used to prevent primary caries, recent research shows that applying sealants to early, non-cavitated carious lesions can also be a successful secondary preventive strategy. Resin-based sealants and glass ionomer cements are the 2 main categories of pit-and-fissure sealant materials that are readily available. Available resin-based sealant materials can be polymerized through a combination of the two processes: autopolymerization, visible light photopolymerization, or autopolymerization. A patient's caries risk status needs to be periodically reevaluated as it plays a considerable role in the decision-making process. The recommendations cover when sealants should be used to prevent caries, how to apply sealants over early (noncavitated) lesions, when to use resin-based cement instead of glass ionomer cement, and how to enhance sealants' retention and caries prevention efficiency [5,6].

8.4. Smart prep burs

These polymer bursts only eliminate diseased dentin. Dentin in the affected area, which has the capacity to remineralize, is unharmed. By using these clever preparation burs, overcutting of the tooth structure, which is typically seen with conventional burs, can be prevented. Smart Burs selectively eliminate carious dentin while leaving healthy dentin unharmed. When the polymer cutting edges come into contact with harder substances like healthy dentin, they lose their sharpness and become blunt. As an example, consider the SS White diamond and carbide preparation kit [2,3].

8.5.Smart Glass Ionomer Cement (RMGIs)

Davidson was the one who first proposed GIC's wise actions. It has to do with how quickly a gel structure can absorb or release solvent in reaction to an external stimulus, such as a change in temperature or pH. The intelligent ionomer imitates the actions of human dentin. These clever qualities are also seen in glass ionomer cement, compomer, and giomer that have been resin-modified. Consider GC Fuji IX EXTRA [2].

The capacity of the gel structure to quickly absorb and discharge solvent in response to stimuli such as pH, temperature, and pressure variation is the basis for the similarity between the behaviour of human dentin and the smart behaviour of GIC. The thermal expansion coefficient of GlCs is comparable to that of dental hard tissues. Although the mechanical properties of GIC have improved as a result of numerous modifications to its constituent parts, secondary caries are still a concern due to bacterial adhesion on the surface of GIC. Effective remineralization of developing caries is made possible by the fluoride-releasing capacity of GIC. The addition of CPP-ACP to GIC has modified it, and it has been demonstrated that doing so increases the flexural strength of the original GIC [1].

8.6. Smart Dental Bonding System

ACP, DMADDM- dimethylaminododecyl methacrylate, and silver nanoparticles, which make dental adhesives antibacterial and self-repairable, are now being added to studies to give them intelligence. According to studies, ACP releases phosphate and calcium ions that can help tooth lesions remineralize. The biofilm and its metabolic activities are significantly reduced by DMADDM and silver nanoparticles, preventing secondary caries [6].

8.7. Smart composites

It is a light-activated, alkaline, nano-filled glass restorative material that releases fluoride, calcium, and hydroxyl ions when intraoral pH levels fall below the crucial pH of 5.5. This helps to prevent demineralization of the tooth surface and promote remineralization. The material can successfully cure in bulk up to a thickness of 4mm. Class I and Class II lesions in both permanent and primary teeth should be restored using this method. For instance, Ivoclar-Vivadent Company introduced the Ariston pH control [2, 7].

Amorphous calcium phosphate (ACP), one of the most soluble of the biologically significant calcium phosphates, exhibits the fastest conversion to crystalline hydroxyapatite (HAP) in smart composites [2].

8.8. Self-healing composites

Materials typically degrade over time as a result of various chemical, physical, and/or biological stimuli. Some of these include internal stress states, external static or dynamic forces, dissolution, corrosion, biodegradation or erosion. This gradually causes the structure of the material to deteriorate and eventually fail. If the epoxy composite material cracks, some of the microcapsules disintegrate nearby and release resin, which then fills the crack and promotes healing [2].

Smart Composite is a alkaline, light-activated, nano-filled glass restorative substance. When intraoral pH values fall below the crucial pH of 5.5, it promotes the remineralization of the tooth surface by releasing hydroxyl, calcium, and fluoride ions. Additionally modified to cure in bulk thicknesses of up to 4 mm are smart composites. Smart composites use amorphous calcium phosphate (ACP), one of the most soluble calcium phosphates. These ions combine intraorally to form a gel in just a few seconds when the pH drops below 5.8, which is considered a critical pH. In less than two minutes, calcium and phosphate ions are produced, and the gel transforms into an amorphous crystal. Dental composites have a characteristic that makes them behave intelligently [1,8,9].

8.9.Nickel-titanium (Ni-Ti) rotary instruments

The use of Ni-Ti in rotary endodontic has made instrumentation during biomechanical preparation for root canal treatment simpler and faster than with traditional hand instrumentation. Rotating Ni-Ti files have the benefit of reducing the possibility of file breakage during instrumentation, operator fatigue, transportation costs, the occurrence of canal aberration, and patient post-operative pain. For example, Ni-Ti rotary fittings [3,8,9].

8.10. Interappointment Intracanal medicaments

Anti-inflammatory and antibacterial medications that can be used between appointments are known as intracanal medications. They come in the form of points that are inserted into the canal, pastes, and gels.Calcium hydroxide paste is the material that is most frequently used. It results in the generation of hydroxyl ions, which raises the pH in the root canal and damages enzymes, cytoplasmic membranes, and DNA in microorganisms [4].

Silver nanoparticles (size 20 nm) combined with calcium hydroxide (alone or in combination with chlorhexidine) demonstrated improved antibacterial effect. An intracanal medication called Nanocare Plus Silver and Gold has demonstrated promising antimicrobial properties [4].

8.11. Smart paste Bio

Smartpaste Bio, a resin-based sealant that includes bioceramics, is another illustration. Calcium hydroxide and hydroxyapatite are produced as byproducts of the setting process in Smartpaste Bio, making the substance highly biocompatible and antibacterial. It sets slowly, taking between 4 and 10 hours, and because it is hydrophilic, the propoints are encouraged to hydrate and swell, filling in all the gaps. The lateral forces produced are less than the dentin's tensile strength and less than those produced by conventional methods. The Smartpaste Bio contains bioceramics, which give the sealer dimensional stability and prevent it from resorbing in the root canal [1].

8.12. Smartseal obturation system

The root canals should be sealed off to prevent periapical disease and the root canal space from becoming infected again. This could be done by filling the instrumented canal and accessory canals in three dimensions. The C Point system, a smart seal obturation system made by EndoTechnologies, LLC in Shrewsbury, Massachusetts, is a point-and-paste method for filling root canals that uses hydrophilic endodontic points that are already made and a sealant to go with them. The deformable endodontic point (C Point), which comes in a variety of tip sizes and tapers, works by absorbing residual water from the instrumented canal space to expand laterally without expanding axially. Trogamid T and Trogamid CX, two exclusive nylon polymers, make up the inner core of C Point [2].

The two main components of a smart seal are hydrophilic obturation points and a sealer. Obturation points come in a variety of tip sizes and taper shapes and are composed of polymorphs. As a result, a sealer should be used in conjunction with this endodontic material for proper sealing. The smart obturating material's hydrophilic property helps it absorb moisture and expand laterally to fill voids. There are various tip sizes and tapers for SmartSealTM [1].

8.13. Smart impression material

To obtain an impression without voids, they are hydrophilic. They have shape memory, which prevents distortion during elastic recovery for a more accurate impression, and their toughness prevents tearing. They have a snap-set behaviour that produces precise, distortion-free fitting restorations. Working and setting hours were reduced by at least 33%. They flow well because they have low viscosity. For instance, Aquasil ultra (Dentsply), ImpregimTM, and Imprint TM 3 VPS [2].

The dental industry has been transformed by the use of smart materials. Its use in conservative dentistry aids in cavity prevention and conservative cavity treatment. For clinical application, more research is required. Because smart materials have the ability to select and carry out specific functions smartly in reaction to different local alterations in the environment, they have the potential to improve reliability and long-term efficiency while also significantly raising the standard of dental care.

9. Conclusions

Many aspects of dentistry, including conservative cavity preparation, have been transformed by the development of smart materials; however, in order to give patients the results they want, ongoing research into active materials with a variety of properties is still necessary. These materials are helpful for the dentist, in a way making it simple and convenient for the clinician, and they may increase the effectiveness of the dental practiseand also may result into a more conservative dentistry by acting actively in the curing process.

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