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Nanotechnology in Restorative Dentistry

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Abstract

In order to achieve reliable dental treatment outcomes, nanotechnology has been implicated in various parts of restorative dentistry. The current study aimed to comprehensively review research papers focused on the application of nano-based materials, methods and technologies used in restorative dentistry. Related articles were retrieved by searching in many databases such as Google scholar, PubMed and Scopus. The appropriate references regarding the subject of research were also assessed. According to the obtained findings, nanotechnology could yield beneficial outcomes in restorative dentistry. The mechanical characteristics of restorative materials such as fracture toughness and flexural strength could be enhanced via the dispersion of nano-sized structures in restorative materials. However, these improvements rely on various variables like type of nano-sized materials and additional materials utilised along with nano-based restorative materials.

Keywords: Nanotecgnology, Nanocomposite, Nano materials

Introduction

Nanotechnology is the science of developing new beneficial materials and structures with dimensions ranging from 0.1-100 nm. These materials have unique chemical, physical, and biological properties different from those characteristics available on larger scale materials [1].

The application of nano-materials and nanotechnology in dentistry has given a rise to new concept named as "nano-dentistry", which might be described as maintenance and improvement of oral health utilizing biotechnology and nano-materials, encompassing nanorobotics and tissue engineering. Research of nanodentistry includes many different topics, encompassing dental disease identification (nanodiagnosis), caries prevention (nanoprevention), and dental treatments (nanotreatment) [2,3].

Nanotechnology is considered to be the best innovation and upcoming technology. It is one which will alter the utilization of materials in various fields. By the development of nanotechnology, the properties of existing dental materials have been worked on and improved by working on the properties of existing materials. The utilization of nanoparticles in dental restorative materials has raised their life and quality resulting in better oral care and hygiene [4].

Nanostructures employed in dental applications encompass anorods, nanotubes, nanofibers ,nanospheres, dendrimer and dendritic copolymers [5]. Nanotechnology can also minimize the postoperative pain following the usage of endoactivator and endodontic sealer as a result of enhanced mechanism of drug delivery of nanoparticles [6].

Based on the properties and cytotoxic actions of nano particles, the utilization of nano particles have been advocated on specific fields. Conventional restorative materials like GIC (Glass Ionomer Cement) and composites have been improved in various ways by adding different nanoparticles. Currently, the used restorative materials with nanoparticles are nanocomposites, nano glass ionomers, nano adhesives and endodontic sealers.

Nanotechnology is paving the way for recent advances in nanomaterials innovations. The development and advancement of nanoparticles are promising by yielding new materials with high quality and subsequently helping the future of dentistry [7]. The main shortcoming faced the using of nanoparticles is the toxicity resulted from the nanoparticles but the need for preparation of nano based dental material has increased, therefore, there is a demand for new nanomaterials [8]. The purpose of this review article is to give an overview of the development and advancement of nanotechnology in restorative dentistry.

Why need nanomaterials in dentistry?

Despite the recent improvements in chemical and physical properties of dental materials, no material has been found to be an ideal for dental applications [9]. For instance, there has been major concerns regarding amalgam restoration representing in mercury toxicity [10-14] and aesthetic requirements [15-17]. However, composite restoration sort out the issue of color, but this material is very technique sensitive and its mechanical characteristics are not as good as of amalgam [18].

Until now, no one could combine physical and biological properties of materials to produce ideal structures to respond to external stimuli as the natural tissues [19].

There are many options to get smart materials similar to the nature in dental applications (Table 1).

Table 1: Options for smart materials productions in dental applications.

Option	Description
Material Synthesis	A synthetic material is produced with its morphology and properties similar to that of natural dental tissues.
Biomimetic Approaches	Lost dental tissues are replaced with biomaterials having properties very close to the original natural tissues.
Tissue Engineering	Replacing lost dental tissues using tissue engineering and regenerative medicine via regenerations.

Without the intervention of nanotechnology, all these approaches are not possible. For example, dental hard tissues are consisting of nanoscale structural units, with varied mechanical properties from one point to the other. Thus, new synthetic biomaterials with similar nature and properties are needed to closely match the characteristics of natural tissues [20-24].

Approaches in Nanodentistry

In dentistry, many nanotechnology approaches (Figure 1) has been applied for a variety of practical applications [25,26]. There are two key approaches **(top down and bottom up)** for designing new smaller materials or use smaller components into more complex assembling. Top-down approach is based on solid-state processing of materials. Coating medical implants is example of this approach. The Bottom-down approach is based on organization of material synthesis and growth. The best example of this approach is repairing cells and protein synthesis [27].

Applications of nanotechnology in dentistry

Top-down Approach

Bottom-up Approaches

Top-down Approach	Bottom-up Approaches
Nanocomposite and nanoclusters	Local anaesthesia
Nano-light curable glass ionomer cements	Hypersensitivity cure
Nano impression materials	Tooth regeneration
Nanoparticles coating in dental implants	Orthodontics treatment nanorobotics
Nano-based bone replacement cements	Nanodiagnosis
Nanoencapsulation	Oral tissue biomimetic
Nanoneedles	Endodontic regeneration
	Impression materials

Figure 1: **Approaches of nanotechnology and their applications in dentistry.**

Application in Dentistry

In recent years, there have been remarkable researches on nanotechnology in dentistry, which has transferred it from theoretical foundation to clinical practice. Nowadays, there is a wide range of nanomaterial's applications (Table 2) in different branches of dentistry [9,19,21,22,26,28,29]. In near future, the remarkable increase for various nano-products in different dental application is expected due to the active research for developing new dental nano-products [8].

Table 2: Application of Nanotechnology in dentistry with available products.

Discipline	Available Materials
Restorative Den tistry	Ketac N100; Nano-ionomers (3M ESPE), Ketac™ (3M ESPE, St. Paul, MN, USA), Filtek Supreme XT (3M ESPE), Nano-primer, Fuji IX GP (GC, Leuven, Belgium), Ceram X™ (DENTSPLY International, Milford, CT, USA), Adper™ Single bond plus Adhesive (3M ESPE), Premise™ (Kerr/Sybron, Orange, CA, USA).
Regenerative Dentistry and Tissue Engineering	Nano-Bone® (ARTOSS, Rostock, Germany), VITOSSO™ (Orthovita-Inc, Malvern, PA, USA), Ostim® (Osartis GmbH, Elsenfeld, Germany).
Periodontics	Nanogen® (Orthogen, Springfield, IL, USA), Arestin® (Valeant, Bridgewater, MA, USA).
Endodontic	Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA), AH plus™ (DENTSPLY International), Guttaflow® (Coltène, Altstätten, Switzerland).
Preventive Dentistry	NanoCare® Gold (Nano-Care, Saarwellingen, Germany).
Orthodontics	Filtek Supreme Plus Universal (3M ESPE), Ketac™ N100 Light Curing Nano-Ionomers (3M ESPE).
Prosthodontics	GC OPTIGLAZE color® (GC), Nanotech elite H-D plus (Zhermack, Badia Polesine, Italy).
Oral Implantology	Nanotite™ Nano-coated implant (BIOMET 3i, Palm Beach Gardens, FL, USA).

Nanotechnology for Restorative Dentistry

Currently, there has been a drastic evolution for restorative materials, especially tooth color materials [29].

Nanocomposite

Nanotechnology has revolutionized restorative dentistry by providing nano materials [30]. Nanocomposite is a composite material with at least one of its phases shows dimension in nanometer range (1 nm = 10^{-9} m). This results in indistinctive mechanical, physical, and optical properties. Nanocomposites exhibit better hardness, flexural strength, shade matching and finishing and polishing ability than conventional composites [31]. Beun et al. compared the physical properties of nanofilled, microfilled and universal hybrid composites. They reported a higher elastic modulus of nanofilled composite more than most of the hybrids composite tested. Camargo et al. 2009 also reported high performance and properties of nanocomposite compared with its micro counterpart, as well as, novel and unique features were developed as a result of nano-sized components [32].

According to matrix materials, nanocomposites can be classified into three categories:

- Ceramic Matrix Nanocomposites (CMNC);
- Metal Matrix Nanocomposites (MMNC) and

- Polymer Matrix Nanocomposites (PMNC).

Nanocomposites are composed of two kinds of nanofiller particles: nanocluster (NCs) and nanomeric (NM). The particle size of NC filler varies from 2-20 nm, with an average particle size of 5-75nm. NM particles are silica nanoparticles that are non-aggregated, mono-dispersed and un-agglomerated [31].

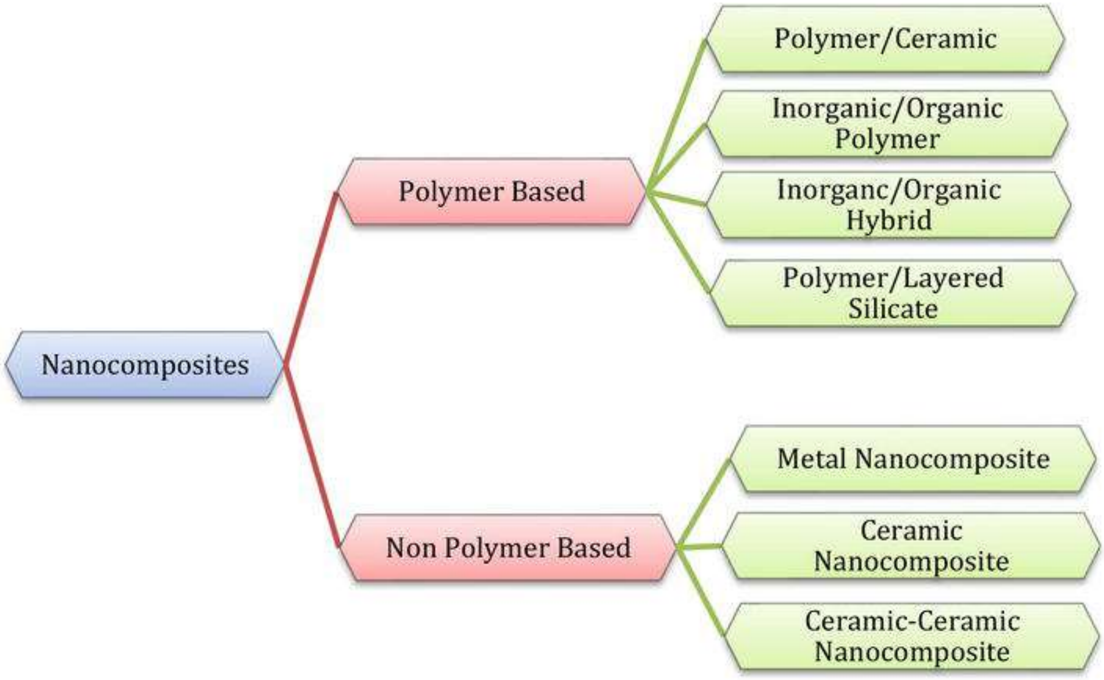

Figure 2: Types of nanocomposites

Nanotechnology in endodontic dentistry

The utilization of nanotechnology in endodontics encompasses various applications such as root canal disinfection, intracanal medicaments, root canal obturation and its use in endodontic sealer [3]. Nanoparticle applications possess the ability to kill variety range of pathogens including Enterococcus faecalis bacteria that are implicated greatly in most endodontic infections. Also, they enhance effect of irrigants with bioactive and biodegradability properties. Silver nanoparticles solution, chitosan solution, and zinc oxide nanoparticles solutions have effective disinfection activity in root canal (Table 3) [33]. Silver nanoparticles (size 20nm) incorporated with calcium hydroxide as intracanal medication had expressed a greater antibacterial activity than the conventional one either with chlorhexidine irrigation or without it [34]. In the other side, a study was carried out by Versiani et al. to evaluate zinc oxide based Grossman sealer after incorporation zinc oxide nanoparticles. The results showed improvements in setting time, solubility, setting time, radio-opacity, and dimensional stability of Grossman sealer by replacing 25% of conventional ZnO powder with ZnO-Np, which met ANSI/ADA criteria [35].

Table 3: Some nanoparticle solutions and their antimicrobial effects

Nanoparticle solution	**Antimicrobial Effect**	**Mechanism of action**	**Antibiofilm efficacy**
Chitosan	Broad range of gram-positive & gram-negative bacteria as well as fungi	Alteration of cell wall by organized release of singlet oxygen species exhibited increased bacterial breakdown.	Yes
Silver oxide	gram-positive & gram-negative bacteria as well as fungi	Reactive oxygen species (ROS) generation is inhibited by respiratory enzymes and ATP synthesis and leads to damaging the cell membrane	Yes
Zinc oxide	More effective on gram positive bacteria than on gram negative	Increased permeability of the cell wall membrane and release of cytoplasmic content causes cell death.	Yes

Challenges faced by Nanotechnology

• Precise manufacture and positioning of nanoscale parts.

• Cost of manufacturing methods of nanorobot mass.

• Synchronization of various independent nanorobots.

• Biocompatibility concern.

• Tactical and financing concerns.

• Inadequate capacity of clinical research.

• Social issues of ethics, regulation and human safety and public acceptance. [36].

Future

Nanotechnology is expected to alter health care in a substantial way. The Foresight Institute has offered the $250,000 Feynman Grand Prize to the first researcher or researchers who develop two devices: a basic nanocomputer and a nanorobot. Christine Peterson, president of the Foresight Institute, estimates that the prize will be claimed between 10 and 30 years from now. Because the initial nano-devices will be basic, prototypical units, commercial applications will follow years later [36].

Conclusion

Nanotechnology will bring huge changes into the fields of dentistry and medicine. However, with all advancements, it might also pose a risk for abuse and misuse. Many factors including economical and technical resources, newer developments, time, and human needs will define which the application are realized first.

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نانوتكنولوجي في طب الأسنان الترميمي

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المستخلص

تقنية النانوتكنولوجي استخدمت في مجالات عديدة في طب الأسنان الترميمي لغرض الحصول على نتائج جيدة في علاج الأسنان. الهدف من هذه الدراسة مراجعة شاملة للأوراق البحثية التي تركز على تطبيق المواد والأساليب والتقنيات المعتمدة على النانو المستخدمة في طب الأسنان الترميمي. تم الحصول على المقالات ذات الصلة من خلال البحث في العديد من قواعد البيانات مثل:,Google scholar, PubMed and Scopus

كما تم تقييم المراجع المناسبة فيما يتعلق بموضوع البحث. ووفقا للنتائج التي تم الحصول عليها، يمكن الاستنتاج بأن تكنولوجيا النانو مفيدة في طب الأسنان الترميمي، فيمكن تعزيز الخصائص الميكانيكية للمواد المستخدمة في حشو الأسنان مثل صلابة الكسر وقوة الانحناء من خلال تشتت الهياكل النانوية الحجم في مواد الحشو. على أية حال فإن هذه التحسينات تعتمد على متغيرات مختلفة مثل نوع المواد النانوية والمواد الإضافية المستخدمة إلى جانب المواد الترميمية المعتمدة على النانو.

الكلمات المفتاحية: نانوتكنولوجي, حشوة العاج, الحشوات المعالجة بالنانوتكنولوجي