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Review Article

New Face and Vision of Dentistry Through Revolutionized Technique-An Era of Nanotechnology

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Abstract

With the growing demand for advances in diagnostic and treatment modalities, nanotechnology is viewed as an innovative and sustainable research topic. This technology, which deals with matter in nano-dimensions, has broadened our views of poorly understood health problems and opened up a new diagnostic and treatment possibilities. Dental Researchers and scientists have studied the potential of nanoparticles in existing therapeutic modalities with moderate success. Nanotechnology is very diverse, ranging from extensions of conventional device physics to entirely a unique approach based upon molecular self-organization that deal with developing new materials to investigate whether we can directly control matter at atomic level. The technology can be conveniently applied to the medical and dental field to categorized the terminology nanomedicine and nano-dentistry respectively.

The most important implementations in the field of dentistry include local drug delivery agents, dentinal hypersensitivity, oral hygiene and mouthwashes (dentrifrobots), restorative materials and nanocomposite resins, bone replacement materials, and implant surface modifications. With the help of science and technology, there have been manufacturing of various nanoparticles which we often find and use in everyday life without knowing that it is part of the future revolution. The various nanoparticles are nano pores, nanotubes, quantum dots, nano-shells, dendrimers, liposomes, nanorods, fullerenes, nanospheres, nanowires, nanobelts, nano-rings, nano-capsules.

Nanotechnology has multiple applications in dentistry, from diagnosing of pathological conditions to local anaesthesia, orthodontic tooth movement, periodontics, Prosthodontics, oral and maxillofacial surgery and endodontics. Nanotechnology is a relatively a new field, that involves manipulation of matter at the molecular level, including individual molecules and the interactions between them. It focuses on achieving positional control with a high degree of specificity, thereby achieving the desired physical and chemical properties. There has been an upsurge in interest in deciphering the property of matter at this dimension, thus making nanotechnology one of the most promising and influential areas of scientific research.

Keywords: Nanotechnology; Nano robots; Drug delivery devices; Nano-fillers; Tissue regeneration; Bone graft scaffolds; Nanocomposites

Abbreviations: $CaCO_3$: Calcium Carbonate; CA-HAP: Calcium Hydroxyapatite; CAP: Carbonate Apatite; $CaSO_4$: Calcium Sulphate; GTR: Guided Tissue Regeneration; HAP: Hydroxyapatite; nCHAC/PLGA: Nanocarbonated Hydroxyapatite/Collagen/Polylactic-co-glycolic acid; NHAP: Nanocrystalline Hydroxyapatite; OFNASET: Oral Fluid Nano Sensor Test; PDGF: Platelet-Derived Growth Factor; ZnO: Zinc oxide.

Introduction

The only thing in life is a consistent change. The human traits of interest, wonder and ingenuity are as vintage as mankind. People round global had been harnessing their interest into inquiry and the manner of scientific and clinical methodology. Science is the fuel for engine of newer technology and subsequently the fuel for advancement [1]. Last decade witnessed an unparalleled extension

in all the aspects of research in medicine. Nanotechnology is growing rapid in current years and prefer different scientific fields it is also set to convert dentistry in a massive way. It is now taken into consideration as a multidisciplinary discipline of clinical studies. Nanotechnology is a natural end result of clinical research achievement and our potential to apprehend and manipulate matter at smaller levels [2].

Nanoscience or nanotechnology refers to the achievement and research of an applied clinical science at the atomic or molecular level. Nanotechnology can be described as science and engineering involved in the design, synthesis, characterization and application of substances and technological devices whose smallest functional organization in at least one dimensions is on the nano-meter scale. The word „‟Nano" means „‟dwarf" and in greek prefix indicates a „‟bilionth" [2, 3]. According to the National Nanotechnology Initiative, a United States government research and development program, nanotechnology entails the:…research and technological development at atomic, molecular, or macromolecular levels, in the length scale of approximately 1-100 nanometer (nm) range, with creation and use of structures, devices, and systems that have novel properties and functions as a result of their small and/or intermediate size; and ability to control or manipulate matter on the atomic scale [4].

Nanodentistry is the science and technology of maintaining near perfect oral health through the use of nanomaterials such as tissue engineering and nanorobotics. Nanotechnology entails the achievement of materials and substances, devices, and systems showing properties which can be one of a kind from those found on a bigger scale. In the nano-size variety of 1-100nm, the decreased restriction is marked through the scale of a hydrogen atom (0.25nm) and the top restriction commences from a length wherein phenomena different from larger system begins appearing. In layman's terms, if a child's marble is as compared to a nano-meter, a meter might seem because of the earth's diameter. This novel scale of era has appealed to researchers of diverse branches of dentistry. The key implementation of nanotechnology, novel material and the techniques within the discipline of dentistry had been advanced the usage of its concepts for disease diagnosis, prevention, rehabilitation, and treatment modalities. Nanotechnology has numerous applications in dentistry, from diagnosis of pathological conditions to local anaesthesia, orthodontic tooth movement and periodontics. Biomaterial's science has also greatly benefited through this technology. This review provides a comprehensive discussion of the present and future of nanotechnology in dentistry.

Historical Background

In 1959 Noble Physicist Richard. P. Feynman (Father of Nanotechnology), professor of Californian Institute of Technology, proposed usage of gadget tools, which, in turn, might be used to make nonetheless smaller tools, and so forth all the manner right all the way down to the molecular level [5]. In this historical lecture, he concluded that "this is a development which I think cannot be avoided". He cautioned with such types of nanomachines, nanorobots and nanodevices ought to in the long run be used to broaden a huge variety of atomically specific microscopic instrumentation and manufacturing tools. The term "nanotechnology" was coined by Nario Taniguchi in 1975. In 1979, Eric Drexler encountered Freynman"s 1959 talk "There's Plenty of room at the bottom". In 1986 Drexler [6] recoined the term„ "Nanotechnology"" and wrote "Engines of Creation" "The Coming Era of Nanotechnology, a book to popularize the potentials of molecular nanotechnology. In 2000s begin the commercial applications of nanotechnology [7, 8]. To enhance the scientific studies in this discipline "National Nanotechnology Initiative" was evolved in 2000 by Michael Roco. During 2005 and 2010, numerous improvements in the discipline of 3D robotics, networking and energetic nanoproducts manufacturing had been carried out and from 2011, the era of subatomic nanotechnology has been in use.

Nanorobots

Nanorobots are macroscale or microscale machines which permits precision interactions with nanoscale items or can manage with nanoscale resolution. According to nanorobotic concept nanorobots are microscopic in size, it might likely be essential for extremely massive wide variety of them to work together to carry out microscopic and macroscopic task.

Fabrication and Mechanism of Action

Nanorobots in medicine are used for the reason of preserving and defends the human body towards pathogen. They are 0.5-3u in diameter and are built of elements within side the variety of 1-100nm. The essential material used is carbon in the form of diamond and fullerene nanocomposite because of its higher strength and chemical inertness. Other non-essential elements which include oxygen, nitrogen may be used for unique purposed. The external passive diamond coating presents a smooth, lawless coating and conjures up much less response from the body immune system.

The powering of the nanorobots may be carried out with the aid of using metabolizing neighbourhood glucose and oxygen for power & externally provided acoustic energy. Other sources of energy within the body can also be used to provide the essential energy for the devices. They could have easy onboard computer system able to acting round 1000 or fewer computations according to seconds. This is due to the fact their computing necessities are simple and précised. Communication with the tool may be performed with the aid of using broadcast-type acoustic signalling. A navigational network can be installed and hooked up with in the body, providing, High positional accuracy to all passing nanorobots that interrogate them, looking to understand their location. This enables physician to keep track of the various devices in the body. These nanorobots can be able to differentiate among distinct cell types with the aid of using their surface antigens. They are accomplished through the use

of chemo tactic sensors keyed to the unique antigens on the specific target cells. When the task of the nanorobots is completed, they may be retrieved through permitting them to exfuse themselves through the usual human excretory channels. These can also be eliminated with the aid of using an active scavenger system.

Nanoparticles

Nanomaterials are the ones substance with components less than 100nmin as a minimum one measurement which includes clusters of atoms, grains much less than 100 nm in size, fibres which are much less than 100 nm diameter, films much less than 100nm in thickness, nanoholes, and composites which are an aggregates of these [9]. The numerous nanoparticles are Nanopores, Nanotubes, Quantum dots, Nano-shells, Dendrimers, Liposomes, Nanorods, Fullerenes, Nanospheres, Nanowires, Nanobelts, Nano-rings, Nano-capsules [10].

The classification of nanomaterials is primarily based on the wide variety of dimensions as shown in (Figure 1). According to Siegel, nanostructured materials are classified as: zero-dimensional (0D), one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) nanomaterials.

(i) Zero-dimensional nanomaterials: Here, all dimensions (x, y, z) are at nanoscale, i.e., no dimensions are more than 100 nm. It consists of nanospheres and nanoclusters.

(ii) One-dimensional nanomaterials: Here, two dimensions (x, y) are at nanoscale and the other is outside the nanoscale. The end in needle formed nanomaterials. It consists of nano-fibres, nanotubes, nanorods, and nanowires.

(iii) Two-dimensional nanomaterials: Here, one dimension (x) is at nanoscale and the other two are outside the nanoscale. The 2D nanomaterials exhibit plate-like shapes. It includes nanofilms, nanolayers and nano-coatings with nanometre thickness.

(iv) Three-dimensional nanomaterials: These are the nanomaterials that are not restricted to the nanoscale in any dimension. These materials have three arbitrary dimensions above 100 nm. The bulk (3D) nanomaterials consist of a multiple arrangement of nano size crystals in different orientations. It consists of dispersions of nanoparticles, bundles of nanowires and nanotubes in addition to multi-nanolayers (polycrystals) in which the 0D, 1D and 2D structural elements are in close contact with each other and form interfaces (Figure 1).

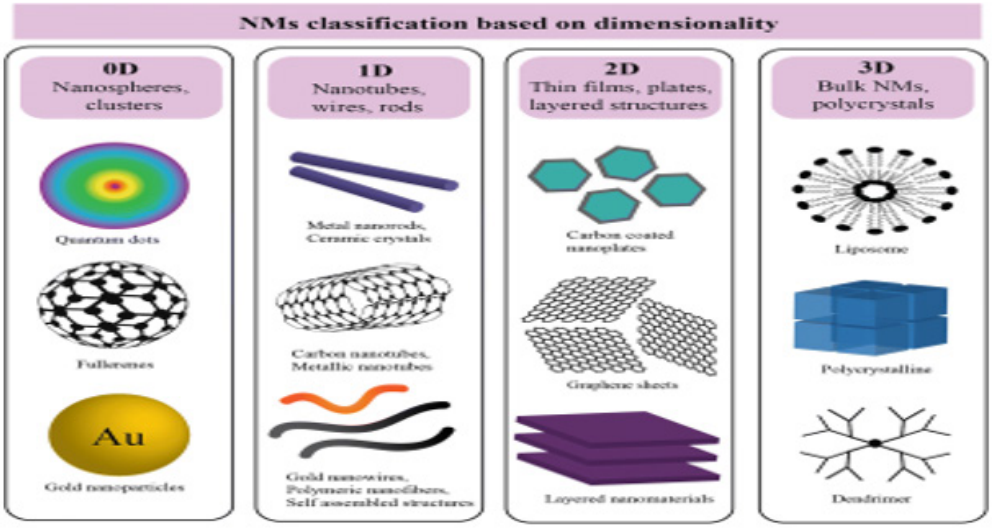

Figure 1: Classifiation of Nanomaterials Based on Number of Dimensions.

Two strategies are utilized in Nanodentistry:

1. Top-down/ mechanical- physical production processes: In the "Top-down" method, nano-objects are manufactured from larger entities without control at molecular level. It is primarily based on the concept of microsystem technology [11]. The conventional mechanical-physical crushing techniques for generating nanoparticles includes diverse milling strategy.

Nanodentistry As Top-Down Approach: This includes:

1. Nanocomposites
2. Nano light curing glass ionomer restorative
3. Nano impression materials
4. Nano composite denture teeth
5. Nano solutions
6. Nanoencapsulation
7. Plasma Laser application
8. Prosthetic Implants
9. Nanoneedles
10. Bone replacement materials

2. Bottom -up/ Chemo-physical production processes: In the "Bottom- up" method, materials and devices are constructed from molecular additives which bring together themselves through the concept of molecular recognition. The main principle of this method is physicochemical principles of molecular or atomic self-organization [12]. This method produces selected extra complicated structures from atoms or molecules better controlling sizes shapes and size ranges. It consists of aerosol processes, precipitation reactions and sol gel processes.

Nanodentistry As Bottom-Up Approach: This comprises of

1. Inducing anaesthesia
2. Major tooth repair
3. Dentin Hypersensitivity
4. Dental Durability and Cosmetics
5. Nanorobotic Dentifrice (dentirobots)
6. Tooth repositioning
7. Local drug delivery
8. Nano-diagnostics
9. Therapeutic aid in oral diseases

Clinical Approach of Nanotechnology in Dentistry

Nanodentistry will make feasible the up keep of complete oral health through using nanomaterials, biotechnology, along with the tissue engineering, and ultimately, dental nanorobotics [13]. New potential treatment modalities in dentistry can also additionally include, local anaesthesia, dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondized enamel, and continuous oral health maintenance using mechanical dentifrobots.

When the primary micro-size dental nanorobots may be constructed, dental nanorobots would possibly use unique motility mechanisms to move slowly or swim via human tissue with navigational precision, collect energy, sense, and control their surroundings, obtain safe cyto-penetration and use any of the multitude strategy to monitor, interrupt, or adjust nerve impulse traffic in individual nerve cells in actual time. These nanorobot capabilities can be managed through an onboard nano-computer that executes pre-programmed instructions in reaction to local sensor stimuli. Alternatively, the dentist can also additionally problem strategic commands through transmitting orders directly to in vivo nanorobots through acoustic signals or different means (Figure 2).

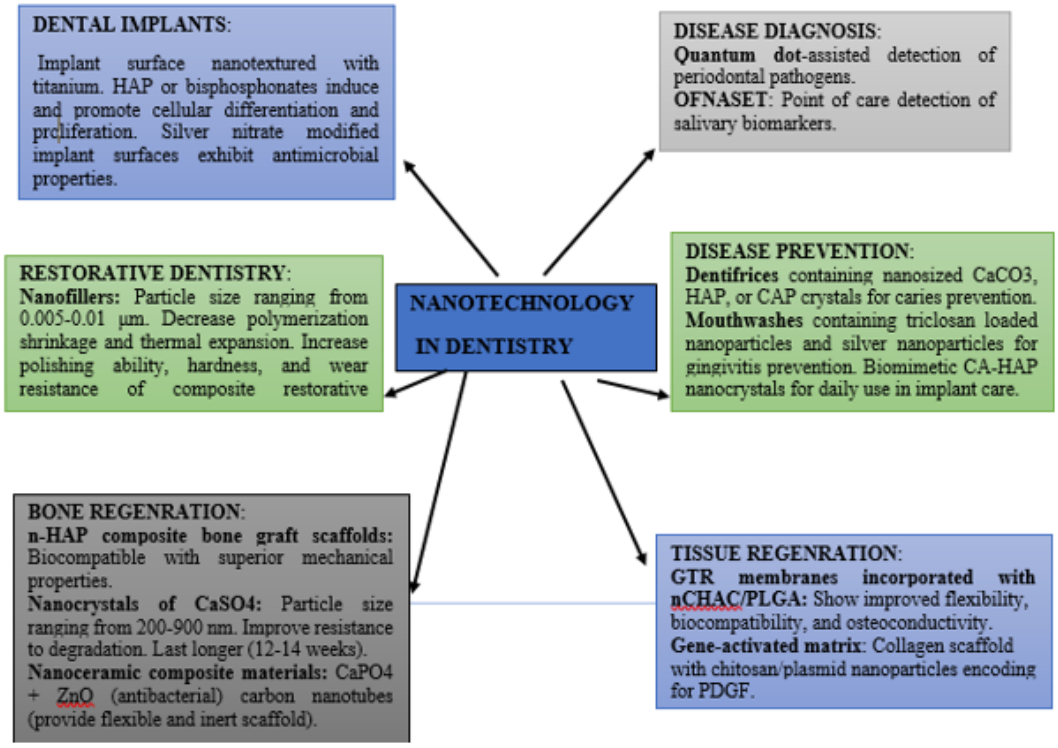

Figure 2: Clinical Approach of Nanotechnology in Dentistry [14].

1. Nanodiagnostics: used nanodevices for initial disease identification or predisposition at cellular and molecular level. In in-vitro diagnostics, nanomedicine ought to boom the proficiency and reliability of the diagnostics the use of human fluids or tissues sample through selective nanodevices, which therein makes multiple analyses at sub cellular scale or level,

etc. In vivo diagnostics, nanomedicine ought to broaden the new technological devices which have the capability to work inside the human body system in order to identify the disease at initial stages, to identify and quantify toxic molecules, tumour cells [13, 15].

Nano electromechanical systems-Nanotechnology primarily based on totally NEMS biosensors that reveals remarkable sensitivity and specificity for analyte detection right all the way down to single molecule level are being evolved. They transform the chemical to electrical signal.

Oral fluid nano-sensor test (OFNASET)-The oral fluid nano-sensor test technology is used for multiplex detection of salivary biomarker for oral cancer. It has been verified that the blend of two salivary proteomic biomarkers (thioredoxin and IL-8) and four salivary mRNA biomarker (SAT, ODZ, IL-8, IL-b) can come across oral cancer with high specificity and sensitivity.

Optical Nano-biosensor-The nano-biosensor is a completely unique fiber optics primarily based device which permit the minimally invasive evaluation of intracellular additives including cytochrome C, that is a complete crucial protein to the process which produces cellular energy and is well known as the protein concerned in apoptosis or programmed cell death [16].

2. Treatment of Oral Cancer- Nanomaterial for brach therapy- BrachySil TM (Sivida, Australia) delivers 32P, clinical trial Photodynamic therapy-Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of stable cancers or ocular vascularization diseases [16].

3. Local Nano-anaesthesia- In the era of Nanodentistry, to induce local anaesthesia, dental experts set up a colloidal suspension containing millions of active and energetic analgesic micrometres sized dental nanorobotic particles on the patient's gingivae. After contacting the surface of the crown or mucosa, the ambulating nanorobots attain the dentin through migrating into the gingival sulcus and passing painlessly via the lamina propria or the 1-3 μm thick layer of loose tissue at the cementodentinal junction. On attaining the dentin, the nanorobots enter dentinal tubule holes which can be 1-4 μm in diameter and continue toward the pulp, guided through a blend of chemical gradients, temperature differentials or even positional navigation, all under the control of the onboard nano-computer, as directed by the dentist [13].

There are many approachable pathways for the nanorobots to travel from dentin to pulp. Because of various tubular branching patterns, tubular density may present a significant challenge to navigation. this analgesic approach is patient friendly, because it reduces anxiety, needle phobia and maximum importantly, is a brief and absolutely reversible action [17].

4. Nano-solution-Nano-solutions produce particular specific type dispersible nanoparticles, which may be utilized in bonding agents. This ensures homogeneity that the adhesive is flawlessly blend with each other every time. Advantage consists of better dentin bond strength and better performance; no shaking of bottle is required.

5. Impression materials-Nanofillers are included in vinylpolysiloxanes, generating a complete unique additive of siloxane impression materials. The material has better flow, improvement in hydrophilic properties and greater detail precision.

6. Nano-encapsulation- SWRI [South West Research Institute] has evolved targeted release systems that encompass nano-capsules which includes novel vaccines, antibiotics and drug delivery with decreased side effects. At present, targeted delivery of genes and drugs to human liver has been evolved via means of Osaka University in Japan 2003. Engineered Hepatitis B virus envelope L particles were permitted to form hollow nanoparticles displaying a peptide which is indispensable for liver-specific entry through virus in humans. Future specialized nanoparticles might be engineered to target oral tissues, which further include cells derived from the periodontium [18].

7. Oral Hygiene and Halitosis-Properly configured dentifrobots ought to discover and break the pathogenic microflora residing in the dental plaque and elsewhere, which permits the 500 or more species of harmless or innocent oral micro flora to flourish in a healthy oral ecosystem. Dentifrobots additionally might offer a nonstop barrier to halitosis, considering with the fact that the bacterial putrefaction is the central metabolic process involved in oral malodor.

These invisibly small dentifrobots [1-10 micron], crawling at 1-10 microns/sec, might be inexpensive, purely and complete form of mechanical devices which might safely deactivate themselves if swallowed and may be programmed with strict occlusal avoidance protocol [19].

8. Dentinal Hypersensitivity-Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is primarily based on the concept that hypersensitive teeth have eight times greater surface density of dentinal tubules and tubules have diameters twice as larger than non-sensitive teeth. Dental nanorobots ought to selectively and precisely occlude selected dentinal tubules within minutes, through native logical materials, offering patients a quick and permanent treatment modality [13].

9. Tooth renaturalization-Dentition renaturalization technique can also additionally turn out to be a famous addition to the standard dental practice, presenting best treatment modality for aesthetic dentistry. This trend may start with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials so that the affected teeth are remanufactured to become

indistinguishable from the natural teeth.

10. Specific tissue regenration-Recent scientific research were carried out at the promise and applications of nanotechnology within side the regeneration of specifically précised tissue, including bone, cartilage, vascular and neural tissues. Nanoscale primarily based grafts are visible to have superior and advanced outcome, due to their small dimensions that mimic the natural bone particles. They may be efficiently used for the treatment modality in intrabony defects, socket preservation and sinus augmentation technique.

Bone Replacement Materials- Hydroxyapatite nanoparticles used to treat bone defects are:

•Ostim HA,

•VITOSSO (Orthovita, Inc., Great Valley Parkway Malvern, PA 19355 USA) HA+TCP,

•HA+ TCP Nan OSS.

The nano-crystallites display a loose microstructure, with nanopores located among the crystallites. This material structure may be completed through pores in the micrometer area. By following this technique, a rough surface area is formed on the boundary layer among the biomaterial and cell, which is crucial and necessary for fast cell growth. Porosity values of around 60% may be present in both the nano- and the micrometer pores. All pores are interconnecting and blended with each other (i.e., through direct contact with the patient's blood, bodily substances blend into the pores). Because the cells are too large in size for the small pores, blood plasma containing all the necessary proteins is retained in the interstices. The surface of the pores (and additionally of the nanopores) is modified and changed in such a manner that it literally "hangs on" to the proteins. This is to be achieved through the silica molecules and compound silica is one of the most important elements.

Periodontal tissue reactions to customized nano-hydroxyapatite block scaffold in one wall intrabody defect: a histologic study in dogs [20]. This study evaluated histologically the tissue responses to and the effects of a customized nano-hydroxyapatite block bone graft on periodontal regeneration in one wall periodontal defect model. All defect sites healed uneventfully with minimal signs of inflammation except for one control site exhibiting gingival recession. Radiographically there is a formation of radiopaque mineralized tissue at the defect site with aggregation of small particle in contact with the native bone and the denuded root surface and a few particles observed beyond the graft area.

Another Clinical comparison of nano crystallin hydroxyapatite (Ostim) and autogenous bone grafts in the treatment of periodontal intrabony defects. They concluded that there is a significant improvement in soft and hard tissue parameters without any complication or infection at the treated site.

Nanotechnology and Dental Implants

Implant are typically utilized in dental surgery for restoring teeth in the arch to maintain the functional integrity of the jaw. One of the demanding situations in implantology is to gain and keep the osseointegration in addition to the epithelial junction of the gingival with implants. An intimate junction of the gingival tissue with the neck of dental implants can additionally inhibit the growth of bacterial colonisations which may results in periimplantitis while direct bonding may satisfy a biomechanical anchoring of the artificial dental root. The first step of the osseointegration of implant is referred to as primary stability which may be related to the mechanical anchorage, design of implant, and bone structure. This primary interlock decreases with time for the benefit of the secondary anchorage, that is characterized by a biological bonding at the interface among bone tissue and implant surface. Among the primary mechanical and secondary biological anchorage, there may be decrease in implant stability.

Many scientific research has tried to increase the osseointegration of implants via means of diverse surface modifications. The intention is to offer metallic implants along with surface biological properties for the adsorption of proteins, the adhesion and differentiation of cells, and tissue integration. These biological properties are associated with chemical composition, wettability and roughness of metallic implants surfaces. However, the control of the surface's properties at the protein and cell levels, results in the nanometre range remains a challenge for research and dental implants manufacturers. Nanotechnologies can also additionally produce surfaces as a controlled topography and chemistry that could assist understanding towards the biological interactions and growing novel implant surface with predictable tissue integrative properties.

•Nanoscale surface modifications

•Interactions of surface dental implants with blood

•Interaction between surfaces and mesenchymal stem cells

•Migration, adhesion and proliferation

•Differentiation

•Tissue Integration

Conclusion

This is the era of nanotechnology since there is a gradual increase in research and applications of nanotechnology in numerous fields. Nanotechnology is a relatively novel field, which involves manipulation of matter at the molecular level, including individual molecules and the interactions among them. It focuses on achieving positional control with a high degree of specificity, thereby achieving the desired physical and chemical properties. There has been an upsurge in interest in deciphering the property of matter at this dimension, thus making nanotechnology one of the most promising and influential areas of scientific research.

The current applications of nanotechnology will pave the way for further research opportunities in device and drug development, thus commencing an era of unprecedented advances in dental diagnostics and therapeutics.

Acknowledgment

None.

Conflict of Interest

No conflict of interest.

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