REVIEW ARTICLE

Nanotechnology—Applications in Prosthodontics: A Literature Review

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ABSTRACT

Nanoscale particles are not new to nature or science. However, the recent leaps in areas, such as microscopy have given scientists new tools to understand and take advantage of phenomena that occur naturally when matter is organized at the nanoscale. Nanotechnology is not simply working at ever smaller dimensions; rather, working at the nanoscale enables scientists to utilize the unique physical, chemical, mechanical, and optical properties of materials that naturally occur at that scale. In this article, we have made an attempt to have an early glimpse on impact of nanotechnology in the field of dentistry.

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INTRODUCTION

Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, their unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. All disciplines of human life will be impacted by advances in nanotechnology in the near future.

Matter, such as gases, liquids, and solids can exhibit unusual physical, chemical, and biological properties at the nanoscale, differing in important ways from the properties of bulk materials and single atoms or molecules. Some nanostructured materials are stronger or have different magnetic properties compared to other forms or sizes of the same material. Others are better at conducting heat or electricity. They may become more chemically reactive or reflect light better or change color as their size or structure is altered. Nano is derived from Greek word for dwarf. In simple terms, it is engineering at atomic or molecular scale. The prefix 'nano' means ten to the power of minus nine (10^{-9}), and is usually combined with a noun to form words, such as nanometer, nanotechnology, nanorobot, etc.[1]

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Nanotechnology has been defined as 'the creation of functional materials, devices and systems through control of matter on the nanometer scale (1-100 nm), and exploitation of novel phenomena and properties (physical, chemical and biological) at that length scale'.[2]

The growing interest in the field of nanotechnology is giving emergence to new fields, such as nanomedicine and nanodentistry. Nanodentistry is defined as 'the science and technology that will make possible the maintenance of comprehensive oral health by employing use of nanomaterials, biotechnology including tissue engineering and ultimately dental nanorobotics.[1]

HISTORY[2]

Pre Modern Era

Early examples of nanostructured materials were based on craftsmen's empirical understanding and manipulation of materials. Use of high heat was one common step in their processes to produce these materials with novel properties.

Fourth century: The Lycurgus Cup (Rome) is an example of dichroic glass; colloidal gold and silver in the glass allow it to look opaque green when lit from outside but translucent red when light shines through the inside.

Metals in powder form were used as medicine in ayurveda since from the Samhita period (600-1000 BC) in the fine form called 'Ayaskrithi'. The development of 'Rasa Shastra' (7th century AD) has revolutionized ayurvedic system of medicine. Metals and minerals were converted into very fine and absorbable powders called 'Bhasma', which were therapeutically most effective and least toxic.[4]

Nineth to 17th Centuries: Glowing, glittering 'luster' ceramic glazes used in the Islamic world, and later in Europe, contained silver or copper or other metallic nanoparticles.

Sixth to 15th Centuries: Vibrant stained glass windows in European cathedrals owed their rich colors to nanoparticles of gold chloride and other metal oxides and chlorides; gold nanoparticles also acted as photocatalytic air purifiers.

Thirteenth to 18th centuries: 'Damascus' saber blades contained carbon nanotubes and cementite nanowires—an ultrahigh-carbon steel formulation that gave them strength, resilience and the ability to hold a sharp edge.

Modern Era

These are based on increasingly sophisticated scientific understanding and instrumentation, as well as experimentation.

1857: Michael Faraday discovered colloidal 'ruby' gold, demonstrating that nanostructured gold under certain lighting conditions produced different-colored solutions.

1936: Erwin Muller, working at Siemens Research Laboratory, invented the field emission microscope, allowing near-atomic-resolution images of materials.

1947: John Bardeen et al at Bell Labs discovered the semiconductor transistor and greatly expanded scientific knowledge of semiconductor interfaces, laying the foundation for electronic devices and the information age.

1950: Victor La Mer and Robert Dinegar developed the theory and processes for growing mono disperse colloidal materials. Controlled ability to fabricate colloids enables myriad industrial uses, such as specialized papers, paints, and thin films, even dialysis treatments.

1951: Erwin Müller pioneered the field ion microscope, a means to image the arrangement of atoms at the surface of a sharp metal tip; he first imaged tungsten atoms.

1956: Arthur von Hippel at MIT introduced many concepts and coined the term—'molecular engineering' as applied to dielectrics, ferroelectrics, and piezoelectrics.

1958: Jack Kilby of Texas instruments originated the concept, designed, and built the first integrated circuit, for which he received the Nobel prize in 2000.

1959: The vision of nanotechnology was born, when the renowned physicist Richard P Feynman speculated the potential of nanosize devices in his historic lecture 'there is plenty of room at the bottom.'[3]

1974: The term nanotechnology was defined by Norio Taniguchi as consisting of the processing of separation, consolidation and deformation of material by one atom or one molecule.

The field started to develop in 1980's with the birth of cluster science and the development of scanning tunneling microscope (STM) by Binnig and Roher in 1981, by which the individual atoms were easily identified for the first time.[3]

Some of the limitations of this microscopy were eliminated through the invention of the atomic force microscope (AFM). Binnig et al invented the first atomic force microscope in 1986. The first commercially available atomic force microscope was introduced in 1989, which could image non-conducting materials, such as organic molecules. This invention was integral for the study of carbon buckyballs, discovered at RICE University in 1985-1986 and carbon nanotubes few years later.[3]

In 1986, the term 'nanotechnology' was coined by Professor Kerie E Drexeler, in his book named ' Engines of Creation', who promoted the technological significance of nano scale phenomena.[3]

1990s: Early nanotechnology companies began to operate, e.g. nanophase technologies in 1989, Helix Energy Solutions Group in 1990, Zyvex in 1997, NanoTex in 1998.

1999 to early 2000's: Consumer products making use of nanotechnology began appearing in the marketplace, including lightweight nanotechnology-enabled automobile bumpers that resist denting and scratching, golf balls that fly straighter, tennis rackets that are stiffer (therefore, the ball rebounds faster), baseball bats with better flex and 'kick,' nanosilver antibacterial socks, clear sunscreens, wrinkle- and stain-resistant clothing, deep-penetrating therapeutic cosmetics, scratch-resistant glass coatings, faster-recharging batteries for cordless electric tools, and improved displays for televisions, cell phones and digital cameras.

NANODENTISTRY

There are varieties of new dental products available, ranging from implants to oral hygiene products that rely on nanoscale properties. The application of atomic force microscopy (AFM) and optical interferometry to a range of issues in dentistry, including characterization of dental enamel, oral bacteria, biofilms and the role of surface proteins in biochemical properties and nanomechanics of bacterial adhesions, is being reviewed.

Nanodentistry developments, such as saliva exosomes based diagnostics, designing of biocompatible and antimicrobial dental implants are revolutionalizing.

APPROACHES TO NANODENTISTRY

Manufacturing at the nanoscale is known as nanomanufacturing. Nanomanufacturing involves scaled-up, reliable, and cost-effective manufacturing of nanoscale materials, structures, devices and systems. It also includes research, development, and integration of top-down processes and increasingly complex bottom-up or self-assembly processes. In more simple terms, nanomanufacturing leads to the production of improved materials and new products. As mentioned above, there are two basic approaches to nanomanufacturing, either top-down or bottom-up. Top-down fabrication reduces large pieces of materials all the way down to the nanoscale, like someone carving a model airplane out of a block of wood. This approach requires larger amounts of materials and can lead to waste, if excess material is discarded. The bottom-up approach to nanomanufacturing creates products by building them up from atomic- and molecular-scale components, which can be time-consuming. Scientists are exploring the concept of placing certain molecular-scale components together that will spontaneously 'self-assemble,' from the bottom-up into ordered structures.[4]

The commonly used approach in dental material manufacturing is top-down approach.

Nanodentistry products manufactured using top-down approach are:[5]

- Nanocomposites
- Nano light-curing glass ionomer restorative materials
- Nano impression materials
- Nano composite denture teeth
- Nano engineered acrylic resin
- Nanosolutions
- Prosthetic implants
- Bone graft materials.

COMPOSITE RESINS

Dental composite resins are types of synthetic resins which are used in dentistry as restorative materials or adhesives. Currently, nanotechnology has had its greatest impact on restorative dentistry by offering refinements to already clinically proven resin-based composite systems. Nanohybrid and nanofilled resin-based composites are generally the two types of composite restorative materials referred to under the term 'nanocomposite', usually in a context of particle size (Fig. 1). They are characterized by filler-particle sizes of ≤100 nm. A study comparing the physical properties of three nanofilled (Supreme, Grandio and Grandio Flow), four universal hybrid (Point-4, Tetric Ceram, Venus, Z 100) and two microfilled (A 110, Durafill VS) composites observed a higher elastic modulus with the nanofilled than most of the hybrids tested.[6]

Composition

The fillers are a non-agglomerated/non-aggregated surface-modified 20 nm silica filler, a non-agglomerated/non-aggregated surface modified 75 nm silica filler, and a surface-modified aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4-11 nm zirconia particles). The aggregate has an average cluster particle size of 0.6 to 10 microns. The inorganic filler loading is approximately 65% by weight (46% by volume).

Advantages of nanofillers in dental composites:[7]

1. They do not thicken the resin.
2. Size below absorption of visible light (0.4-0.8 mm) – makes fillers invisible.
3. Enhances the polish ability of resin.
4. Extreme surface to volume ratio and the ability to fit between several polymer chains-high filler loading in workable consistencies.
5. Increased hardness and wear resistance.
6. Fifty percent reduction in polymerization shrinkage and less staining.
7. Superior translucency and esthetic appeal.
8. Superior flexural strength and modulus of elasticity.

GLASS IONOMER CEMENT

A glass ionomer cement (GIC) is a dental restorative material used in dentistry for filling teeth and as a luting agent. These materials are based on the reaction of silicate glass powder and polyalkenoic acid.

Luting agents based on nanotechnology are being produced for permanent cementing of conventional prosthesis, including all ceramic constructions on aluminum oxide or zirconium dioxide (Alumina or zirconia) frames. In this product, conventional glass ionomer technology has been interlaced with nanotechnology to give its unique handling characteristics.

The 'new material' comprises two stable hydrates: the minerals katoite and gibbsite. Katoite is a calcium-alumina-

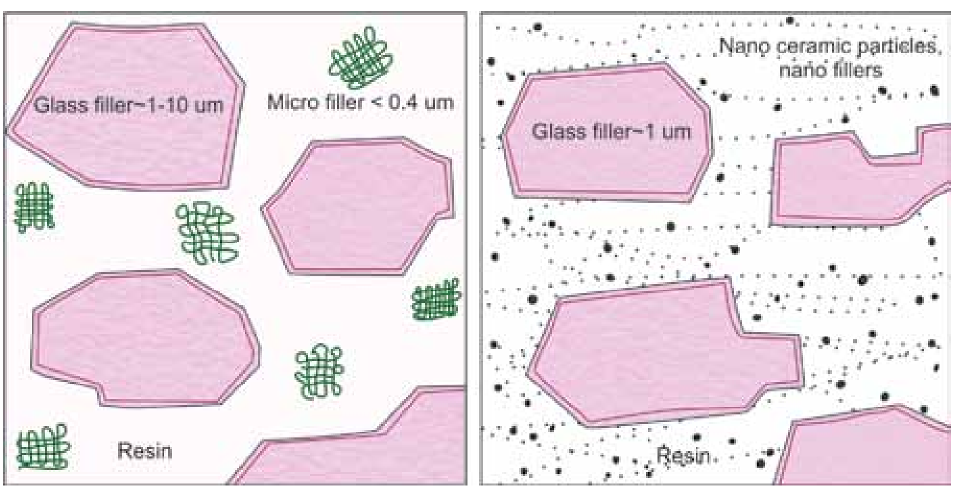

Fig. 1: The difference between microfilled and nanofilled resin

hydrate and is built as crystals, each being between 10 and 40 nanometers in size. Gibbsite is an aluminum-hydroxide and is formed first as an amorphous gel which transforms over time into crystalline gibbsite. The material attaches itself to the tooth surface by so-called nanostructural integration and therefore, by definition, product, belongs to the material group, nanostructurally integrating bioceramics (NIB).[8]

This material displays extremely high pulp-friendliness. Utilization of nanotechnology and nanostructural integration makes it possible to minimize leakage between tooth and material over time. Leakage is normally measured by varying tests of micro- and nanoleakage. It has a low film thickness of around 15 μm, which is a prerequisite for restorations to fit well. Mechanical strength has been measured in terms of compression strength and gives 170 MPa after 24 hours, comfortably on par with the best resin-based materials. It has a radiopacity corresponding to 1.5 mm Al (aluminum radiopacity equivalent). The material is highly retentive as well as dimensionally stable. The material's hardening mechanism is built on nanotechnology, which implies that it does not shrink during the consolidation process, as opposed to what happens with resin-composites.[8]

IMPRESSION MATERIALS

A dental impression is an imprint of hard (teeth) and/or soft tissues, formed with specific types of impression materials that are used in different areas of dentistry including prosthodontics, such as making dentures, inlays, maxillofacial prosthetics (prosthetic rehabilitation of intraoral and extraoral defects due to trauma, congenital defects, and surgical resection of tumors) and in oral and maxillofacial surgery for both intraoral and/or extraoral needs.

Nanofillers are integrated in vinylpolysiloxanes, an addition-reaction silicone elastomer impression material producing a material that has better flow, improved hydrophilic properties and has fewer voids at margin and better model pouring with enhanced detail precision.[9]

Advantages[5]

- Increased fluidity
- High tear resistance
- Hydrophilic properties
- Resistance to distortion and heat resistance
- Snap set that consequently reduces errors caused by micro movements.

ACRYLIC RESIN[10]

A denture is a removable replacement for missing teeth and the tissues connected to those teeth. It is made of acrylic resins and sometimes porcelain and metal/alloys. A denture closely resembles natural gum tissue and teeth.

Polymethyl methacrylate resin with TiO_2 and Fe_2O_3 nanoparticles as pigments that provide the same color, as the gingiva are being manufactured. This material presented a higher molecular weight, lower porosity, and a capacity to prevent *Candida albicans* adherence. Furthermore, tests showed that the new resin was non cytotoxic for mammalian cell cultures.

Silver nanoparticles and silver ions interact with the disulfide bonds of the glycoprotein/protein contents of microorganisms and are able to change the three-dimensional structure of proteins, blocking the functionality of the microorganism.

DENTURE TEETH

Wear resistance is the most desired physical property of denture teeth. Porcelain denture teeth are most wear resistant, but they are brittle, lack bonding to the denture base, and difficult to polish. Acrylic resin denture teeth are easier to recontour, but undergo excessive wear.[11] A nanocomposite denture tooth comprises of polymethylmethacrylate (PMMA), and uniformly dispersed nano-sized filler particles.

Advantages[5]

- Highly polishable, stain and impact resistant material
- Lively surface structure
- Superior surface hardness and wear resistance.

NANOSOLUTION

Nanosolutions produce unique and dispersible nanoparticles that can be added to various solvents, paints, and polymers in which they are dispersed homogeneously. Nanotechnology in bonding agents ensures homogeneity and so the operator can now be totally confident that the adhesive is perfectly mixed every time.[9]

Types of nanofillers[7,9,12]

1. *Nanomeric*: These are monodisperse non-aggregated and non-agglomerated silica nanoparticles. They reduce the interstitial spacing and increase the filler loading.
2. *Nanoclusters*: These are zirconia-silica particles (2-20 nm) and zirconyl salt (from 75 nm) which are spheroidal agglomerated particles. They have dentin, enamel and body shades because of radiopacity and there is high gloss retention with silica nanomer.

Nanodentin adhesives incorporate 10% by weight of 5 nm diameter spherical silica particles through a process that prevents agglomeration. As discrete particles, their extremely small size keeps them as a colloidal suspension.

BONE GRAFT MATERIAL

Research was carried out to take advantage of the latest developments in the area of nanotechnology to mimic the natural biomineralization process to create the hardest tissue in the human body, dental enamel. This is the outermost layer of the teeth and consists of enamel prisms, highly organized micro-architectural units of nanorod-like calcium hydroxyapatite (HA) crystals arranged roughly parallel to each other. In particular, the researchers synthesized and modified the hydroxyapatite nanorods surface with monolayers of surfactants to create specific surface characteristics which will allow the nanorods to self-assemble into an enamel prism-like structure at a water/air interface. The size of the synthetic hydroxyapatite nanorods can be controlled and they have synthesized nanorods similar in size to both human and rat enamel.[13]

Biologically, inspired rosette nanotubes and nanocrystalline hydroapatite hydrogel nanocomposites can be used as improved bone substitutes. Helical rosette nanotubes (HRN) are formed by chemically immobilizing 2 DNA base pairs, creating a novel type of soft nanomaterial that biomimics natural nanostructural component of bone. They are 3.5 nm in diameter and are self assembled.[3]

Nanocrystalline hydroxyl apaptite of 2 and 10% wt was well dispersed into HRNs.[14] It demonstrated improved mechanical properties, increased osteoblast adhesion upto 236% compared to hydroxyl apatite. Stimulated hydroxyl apaptite showed nucleation and mineralization along their main axis in a way similar to hydroxy apatite/collagen assembly pattern in natural bone.[3]

NANOTECHNOLOGY IN DENTAL IMPLANTS

A dental implant (also known as an endosteal implant or fixture) is a surgical device, used to replace one or more missing teeth by fusing to bone and supporting a crown, bridge, denture, facial prosthesis or acts as an orthodontic anchor.

The application of nanotechnology in dental implants can be made by coating of nanoparticles over the dental implants. It has been demonstrated that different cell types respond positively to nanotopography. The surface of the implant plays a critical role in determining biocompatibility and biointegration, because it is in direct contact with the tissues.

Implant surface composition, surface energy, surface roughness and surface topography are the four material related factors which can influence events at bone-implant interfaces. Various surface textures have been created and used to successfully influence cell and tissue responses. Surface textures are of three types: macro, micro and nano.

The 'nanostructured' materials can exhibit enhanced mechanical, electrical, magnetic and/or optical properties compared with their conventional micron-scale or macro-scale (larger) counterparts. Nanostructured (NS) materials contain a large volume fraction (>50%) of defects, such as grain boundaries, inter phase boundaries, and dislocations, and this strongly influences their chemical and physical properties.

Biomimetic dental implants may be the next development in the field. A variety of biomimetic coatings may be helpful for application in individual patients. For example, coating implants with nanotextured titanium, hydroxy apatite, and pharmacological agents, such as bisphosponates may induce cell differentiation and proliferation and may promote greater vascularity in highly cortical bone, thereby improving conditions for early and long-term (in response to functional loading) bone remodeling.

Surface Modifications[15]

Nanoscale topography is a powerful way of altering protein interactions with the surface. Surface profiles in the nanometer range play an important role in the adsorption of proteins, adhesion of osteoblastic cells and thus the rate of osseointegration. There is an increased vitronectin adsorption on nanostructured surfaces when compared to conventional surfaces. This leads to increased osteoblast adhesion when compared to other cell types, such as fibroblasts, on the nanosurfaces.

The application of nanotechnology to dental implant surfaces deals with many different arrangements. In particular, surfaces could potentially assume an organized (isotropic) or unorganized (anisotropic) pattern. Due to the difficulties of application of standardized sequences to complex designs, the pattern for dental implants is generally anisotropic.[16]

A great variety of techniques is used to create nanofeatures on dental implant surfaces. These can be divided into chemical and physical processes.

Chemical Modifications

Anodic Oxidation

Anodization is one of the most commonly used techniques to create nanostructures with diameters of less than 100 nm on titanium implants.[17] Voltage and direct current (galvanic current) are used to thicken the oxide layer among the implant surfaces. Through the regulation of voltage and density, it is possible to control the diameters of nanotubes and the gap between them.

As an example, the outcome of the anodization of titanium in diluted hydrofluoric acid at 20 V for 20 minutes is the creation of surface nanotubes, while the anodization at

10 V for the same time produces nanoparticles. In addition, the distance between nanotubes/nanoparticles can be very different among different surfaces. Nanoscale features can be separated alternatively by microscale or nanoscale spaces.

Oxidative nanopatterning confers Ti-based metals the exciting capacity to selectively influence cellular behavior by enhancing the growth of osteoblastic cells while limiting the proliferation of fibroblasts. The physic-chemical signaling impacts on gene and protein expression, in a way that is strongly determined by slight modifications of the dimensions of the nanofeatures.

Studies provided the confirmation that implant surface with interface features of 30 nm TiO_2 nanotubes positively influence bone-to-implant contact (BIC) and peri-implant bone formation.[18]

Combinations of Acids (Bases) and Oxidants

The combination of strong acids is effective in creating a thin grid of nanopits on a titanium surface (diameter 20-100 nm). The titanium sample etched with a solution of strong acids, e.g. H_2SO_4 and H_2O_2, at a constant temperature and for a specific duration. Etching is then stopped by adding distilled water. The recovered disks are washed further with ethanol in an ultrasonic bath for 20 minutes and dried.[19]

As for anodic oxidation, some reaction parameters, such as temperature, duration, and solutes, can be adjusted in order to modify the number and depth of nanopits, therefore modulating cell function. Specifically, the treatment with H_2SO_4-H_2O_2 on titanium screw-shaped implants creates a nanopattern that has been demonstrated *in vivo* to be associated with an enhanced osteogenesis. Studies confirmed this observation, stating the promotion of stem cells growth provided by oxidative nanopattering.[20] Further studies characterized the most suitable nanoarrangement of TiO_2 nanotubes, noting that a diameter of 15 nm with a vertical alignment was associated with a high spreading and differentiation of rat mesenchymal stem cells into the osteogenic lineage. Notably, 15 nm roughly correspond to the predicted lateral spacing of integrin receptors in the focal adhesion complexes.[21]

Physical Modifications

Plasma Spray

The plasma deposition process is able to create an engineered-surface nanostructure, with features usually standing below 100 nm. The process enables a wide range of materials (e.g. Ag, Au, Ti, etc.) to be coated onto a wide range of underlying materials (e.g. metals, polymers and ceramics).[22] In dental implants, titanium particles deposit on the implant surface with a uniform pattern.

This method consists of injecting titanium powders into a plasma torch at high temperature. The titanium particles are projected on to the surface of the implants where they condense and fuse together, forming a film about 30 μm thick. The thickness must reach 40 to 50 μm to be uniform. The resulting titanium plasma-spray coating has an average roughness of around 7 μm, which increases the surface area of the implant. It has been shown that this three-dimensional topography increased the tensile strength at the bone/implant interface.

The nanoparticulate coating with titanium particles achieved through the plasma spray technique has been demonstrated to increase the osteoblast density on the implant surface both in *in vitro* and in *in vivo* studies. Particularly, Reising et al detected a greater deposition of calcium on the nano Ti-coated surfaces when compared to uncoated surfaces.

Blasting

Another approach for roughening the titanium surface consists in blasting the implants with hard ceramic particles. The ceramic particles are projected through a nozzle at high velocity by means of compressed air. Depending on the size of the ceramic particles, different surface roughnesses can be produced on titanium implants. The blasting material should be chemically stable, biocompatible and should not hamper the osseointegration of the titanium implants. Various ceramic particles have been used, such as alumina, titanium oxide and calcium phosphate particles.

The thickness of the porous layer can be modulated by the granulometry of the particles. For example, the surface of commercial endosseous titanium implants is a rough porous layer ranging between 50 and 200 nm created through the combination of particles blasting and hydrogen fluoride treatment. The rough surface has been demonstrated to stimulate osteoblastic gene expression, as well as to enhance bone formation and bone-implant fixation.[23,24] While an associated inflammatory response was reported, the overall success rate was satisfactory, with the majority of implants yielding good osseointegration and stability at 1 year after surgery. Among the range of available materials, aluminia is one of the most used for blasting. Nevertheless, Aparicio et al highlighted some features related to alumina blasting for dental implants that could compromise osseointegration, like particles detachment during the healing process and absorption by the surrounding tissues.[25]

TiO_2 is also used as a blasting material showing interesting results in experimental studies. Particularly,

TiO_2 blasted implants were associated in humans to a significant enhancement of BIC when compared with machined surfaces.[26] A further enhancement in the blasting technology was achieved through the integration of bioceramic grit-blasting and acid etching (BGB/AE), to produce submicrometric topographies on titanium implants. The evaluations made 2 months after implantation showed a significantly higher BIC and osteocyte density around modified implants when compared to simple dual-acid etching implants. Clinically, the combination of blasting and etching on the surfaces has been associated to a 10-year cumulative survival rate of 96.2%.[27] Studies further demonstrated that around this surface human mesenchymal stem cells increased the expression of type I collagen and of alkaline phosphatase, which is a key enzyme in the biomineralization along the bone-implant interface.

Nanoscale modification of an implant surface could contribute to the mimicry of cellular environments to favor the process of rapid bone accrual. Cell adhesion to basement membranes is an often cited example of nanoscale biomimetics. Successful osseointegration is influenced by both the chemical composition and the surface geometry or topography of the implant. Literature indicates that degradation of an implant surface coating may help to promote *de novo* bone formation, as a result of either enhanced osteoconductivity due to the resulting changes in surface topography or enhanced osteogenesis due to local release of calcium or other elements that may promote bone formation. Surface nanotopography affects cell interactions at surfaces and alters cell behavior when compared to conventional sized topography. Different physical relationships exist between cells at micron scale level and nanoscale level. Nanotopography-specific effects on cellular behavior have been demonstrated using a wide range of different cell types including epithelial cells, fibroblasts, myocytes and osteoblasts. Nanostructured surfaces possess unique properties that alter cell adhesion by direct (cell-surface interactions) and indirect (affecting protein-surface interactions) mechanisms.

Future Trends

Biomimetic Calcium Phosphate Coatings on Titanium Dental Implants[28]

To avoid the drawbacks of plasma-sprayed HA coatings scientists have developed a new coating method inspired by the natural process of biomineralization. In this biomimetic method, the precipitation of calcium phosphate apatite crystals onto the titanium surface from simulated body fluids (SBFs) formed a coating at room temperature.

Incorporation of Biologically Active Drugs into Titanium Dental Implants

The surface of titanium dental implants may be coated with bone-stimulating agents, such as growth factors in order to enhance the bone healing process locally. Members of the transforming growth factor (TGF-β) superfamily, and in particular bone morphogenetic proteins (BMPs), TGF-β1, platelet-derived growth factor (PDGF) and insulin-like growth factors (IGF-1 and 2) are some of the most promising candidates for this purpose.

SAFETY ISSUES[29]

Nanoparticles have a large surface area—volume ratio. The greater the specific surface area, the more chance it could lead to increase rate of absorption through the skin, lungs, or digestive tract. This could cause unwanted effects in the body as non-degradable nanoparticles could accumulate.

Decrease of particle size in the nanoscale has been identified as a main parameter for the increased toxicity of different materials. Polystyrene, e.g. is a very biocompatible polymer used in cell culture. Nanoparticles, however, made from this material are cytotoxic. Accumulation of metal and metal oxide nanosized materials is seen also in lower animals, such as fruit flies, mussels, planktonic crustaceans, rainbow trouts and in plants which shows the environmental risk of nanotechnology. In laboratory animals, accumulation of these particles especially in liver, spleen and kidney is seen. Nanoparticles are so small that they could easily cross the blood-brain barrier.

Proper care should be taken about nanoparticles and nanotechnology safety issues for the personal health and safety of the workers who are involved in the nanomanufacturing processes and also the consumer to eliminate its effect on the environment.

'Research is needed to determine the key physical and chemical characteristics of nanoparticles that determine their hazard potential.'

CONCLUSION

The emerging fields of nanoscale science, engineering and technology, the ability to work at molecular level, atom by atom, to create large structures with fundamentally new properties and functions are leading to unprecedented understanding and control over the basic building blocks and properties of natural and man-made materials. As with all emerging technologies, a successful future for nanotechnology will only be achieved through open sharing of ideas and research findings.

Instead of waiting for things to happen, let us start believing and contribute our part for a healthier future.

REFERENCES

1. Gorav S, Kamlesh V, Nidhi P. BFUDJ 2010 July;1(1):43-45.
2. Available at: http://www.nano.gov/timeline (Accessed on 25-01-14).
3. Satyanarayana TS, Rai R. Nanotechnology: the future. J Interdisc Dent 2011 Jul-Dec;1(2):93-100.
4. Available at: http://www.nano.gov/nanotech-101/what/manufacturing. (Accessed on 25-01-14).
5. Chandki R, Kala M, Kumar NK, Brigit B, Banthia P, Banthia R. Nanodentistry: exploring the beauty of miniature. J Clin Exp Dent 2012;4(2):119-124.
6. Beun S. Characterization of nanofilled compared to universal and microfilled composites. Dent Mater 2007 Jan;23(1):51-59.
7. Kaira LS. Nanotechnology: the new era of technology. NUJHS 2012 Dec;2(4):88-92.
8. Kraft L. Calcium aluminate based cements as dental restorative materials. PhD Thesis, Faculty of Science and Technology, Uppsala, University, Sweden; 2002.
9. Patil M, Mehta DS, Guvva S. Future impact of nanotechnology on medicine and dentistry. J Indian Soc Periodont 2008 May;12(2):34-40.
10. Miao X, Zhu M, Li Y, Zhang Q, Wang H. Synthesis of dental resins using diatomite and nanosized SiO_2 and TiO_2. Progress in Natural Science: Materials Int 2012;22(2):94-99.
11. Freitas RA Jr. Nanotechnology, nanomedicine and nanosurgery. Int J Surg 2005;3(4):243-246.
12. Mitra SB, Dong Wu, Holmes BN. An application of nanotechnology in advanced dental materials. JADA 2013 Oct;134(10):1382-1390.
13. Chen H, Clarkson BH, Sun K, Mansfield JF. Self-assembly of synthetic hydroxyapatite nanorods into an enamel prism-like structure. J Colloid Interface Sci 2005 Aug 1;288(1):97-103.
14. Zhang L, Ramsaywack S, Fenniri H, Webster TJ. Enhanced osteoblast adhesion on a self-assembled nanostructured hydrogel scaffolds. Tissue Eng Part A 2008 Aug;14(8):1353-1364.
15. Variola F, Brunski JB, Orsini G, de Oliveira TP, Wazen R, Nanci A. Nanoscale surface modifications of medically relevant metals: state-of-the art and perspectives. Nanoscale 2011 Feb;3(2):335-353.
16. Yao C, Slamovich EB, Webster TJ. Enhanced osteoblast functions on anodized titanium with nanotube-like structures. J Biomed Mater Res A 2008 Apr;85(1):157-166.
17. von Wilmowsky C, Bauer S, Lutz R, Meisel M, Neukam FW, Toyoshima T, Schmuki P, Nkenke E, Schlegel KA. In vivo evaluation of anodic TiO_2 nanotubes: an experimental study in the pig. J Biomed Mater Res B Appl Biomater 2009 Apr;89(1):165-171.
18. Nanci A, Wuest JD, Peru L, Brunet P, Sharma V, Zalzal S, McKee MD. Chemical modification of titanium surfaces for covalent attachment of biological molecules. J Biomed Mat Res 1998 May;40(2):324-335.
19. Vetrone F, Variola F, de Oliveira TP, Zalzal SF, Yi JH, Sam J, Bombonato-Prado KF, Sarkissian A, Perepichka DF, Wuest JD, et al. Nanoscale oxidative patterning of metallic surfaces to modulate cell activity and fate. Nano Lett 2009;9(2):659-665.
20. Grössner-Schreiber B, Herzog M, Hedderich J, Dück A, Hannig M, Griepentrog M. Focal adhesion contact formation by fibroblasts cultured on surface-modified dental implants: An in vitro study. Clin Oral Implants Res 2006 Dec;17(6):736-745.
21. Reising A, Yao C, Storey D, Webster TJ. Greater osteoblast long-term functions on ionic plasma deposited nanostructured orthopedic implant coatings. J Biomed Mater Res A 2008 Oct;87(1):78-83.
22. Ellingsen JE, Johansson CB, Wennerberg A, Holmén A. Improved retention and bone-to lmplant contact with fluoride-modified titanium implants. Int J Oral Maxillofac Implants 2004 Sept-Oct;19(5):659-666.
23. Abrahamsson I, Albouy JP, Berglundh T. Healing at fluoride-modified implants placed in wide marginal defects: an experimental study in dogs. Clin Oral Implants Res 2008 Feb;19(2):153-159.
24. Aparicio C, Gil FJ, Fonseca C, Barbosa M, Planell JA. Corrosion behavior of commercially pure titanium shot blasted with different materials and size of shot particles for dental implant applications. Biomaterials 2003 Jan;24(2):263-273.
25. Ivanoff CJ, Hallgren C, Widmark G, Sennerby L, Wennerberg A. Histologic evaluation of the bone integration of TiO_2 blasted and turned titanium microimplants in humans. Clin Oral Implants Res 2001 Apr;12(2):128-134.
26. Buser D, Mericske-Stern R, Dula K, Lang NP. Clinical experience with one-stage, non-submerged dental implants. Adv Dent Res 1999;13:153-161.
27. Santander S, Alcaine C, Lyahyai J, Angeles M, et al. In vitro osteoinduction of human mesenchymal stem cells in biomimetic surface modified titanium alloy implants. Dent Mater J 2012;29(5):843-850.
28. Mantri SS, Mantri SP. The nano era in dentistry. J Natural Sci Bio Med 2013;4(1):39-44.
29. Nayar S, Buminathan S, Muthuvignesh J. Upsurge of nanotechnology in dentistry and dental implants. Indian J Multidisciplinary Dent 2011 July-Aug;1(5):264-268.
30. Savrikar SS, Ravishankar B. Introduction to 'Rasa Shastra' the Iatrochemistry of Ayurveda. Afr J Tradit Complement Altern Med 2011;8(Suppl 5):66-82.