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Applications of Nanotechnology in Dentistry

SECTION A: Role of Nanotechnology in Dental implants

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SECTION C: Nanomaterials and Nanotechnology in Conservative Dentistry and Endodontics

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SECTION A

Role of Nanotechnology in Dental Implants

Umesh Y Pai

Abstract:
Osseointegration of a dental implant is a primary measure of its long term success. Direct bone-to-implant contact is desired for a biomechanical anchoring of implants to bone rather than fibrous tissue encapsulation. Surface characteristics of implants such as surface treatment and thread designs play a determinant role in these biological interactions. Nanotechnologies are increasingly used for surface modifications of dental implants. Another approach to enhance osseointegration is the application of thin calcium phosphate (CaP) coatings. Bioactive CaP nanocrystals deposited on titanium implants are resorbable and stimulate bone apposition and healing. Future nanometer-controlled surfaces may ultimately direct the nature of peri-implant tissues and improve their clinical success rate. This paper reviews the different steps of the interactions between biological tissues and surfaces of implants using nanotechnology.

Key words: nanotechnology, dental implants, osseointegration

Introduction:

Implants are used in dentistry for replacing missing teeth. A challenge in implantology is the ability to achieve and maintain the osseointegration as well as the integrity of epithelial junction of the gingival area. An intimate junction of the gingival tissue with the neck of dental implants may prevent bacterial colonisation leading to peri-implantitis, while direct bone bonding may ensure a biomechanical anchoring of the artificial dental root. The first step in the osseointegration of implants is called primary stability and is related to the mechanical anchorage, design of implants, and bone structure.[1] This primary stability decreases as time progresses, giving way to secondary anchorage, which is characterized by a biological bonding at the interface between bone tissues and implant surface. As there is a gradual shift from primary mechanical to secondary biological anchorage, a decrease of implant stability could be observed during the early healing phase. Many researchers have attempted to enhance the osseointegration of implants by using different surface modifications. The aim is to provide the metal implant surface, biological properties for the adsorption of proteins, the adhesion and differentiation of cells and tissue integration. These biological properties are related to chemical composition, wettability, and roughness of metal implant surfaces. However, the control of these surface properties at the protein and cell levels, which is in the nanometer range, remains a challenge for researchers and implant manufacturers.

Nanotechnologies may produce surfaces with controlled topography and chemistry that would help understanding biological interactions and developing novel implant surfaces with predictable tissue-integrative properties.[2,3] These surfaces may then be screened by using high throughput biological assays in vitro. For instance, specific protein adsorption, cell adhesion, and differentiation of stem cells should be studied in relation to the surface properties. This approach may define the ideal surface for a specific biological response. Following in vitro screening, nanostructured surfaces may then be tested

in animal models to validate hypothesis in a complex invitro environment.
Recent nanoscale surface modifications and calcium phosphate coating technologies of dental implants are discussed. The sequence of biological events in relation to surface properties is related. Mechanisms of interaction with blood, platelets, hematopoietic, and mesenchymal stem cells on the surface of implants are described. These early events have shown to condition the adhesion, proliferation, and differentiation of cells as well as the osseointegration of implants. Future implant surfaces may improve the tissue-integrative properties and long-term clinical success for the benefits of patients.

Nanosurface coatings:

New coating technologies have also been developed for applying hydroxyapatite and related calcium phosphates (CaP), the mineral of bone onto the surface of implants. Many studies have demonstrated that these CaP coatings provided titanium implants with an osteoconductive surface.[4,5] Following implantation, the dissolution of CaP coatings in the peri-implant region increased ionic strength and saturation of blood leading to the precipitation of biological apatite nanocrystals onto the surface of implants. This biological apatite layer incorporates proteins and promotes the adhesion of osteoprogenitor cells that would produce the extracellular matrix of bone tissue. Furthermore, it has been also shown that osteoclasts, the bone resorbing cells, are able to degrade the CaP coatings through enzymatic ways and created resorption pits on the coated surface.[5] Finally, the presence of CaP coatings on metals promotes an early osseointegration of implants with a direct bone bonding as compared to non-coated surfaces. The challenge is to produce CaP coatings that would dissolve at a similar rate than bone apposition in order to get a direct bone contact on implant surfaces.

Nanoscale surface modifications:

Surfaces properties play an important role in biological interactions. The nanometer-sized roughness and the surface chemistry have a role in the interactions of surfaces with proteins and cells. These early interactions will in turn condition the late tissue integration. With these prospects in mind, different methods have been reported for enhancing bone healing around metal implants.[2,6]
Modifying surface roughness has been shown to enhance the bone-to-implant contact and improve their clinical performance.[2,7] Grit blasting, anodisation, acid etching, chemical grafting, and ionic implantation were the most commonly used methods for modifying surface roughness of metal implants. Combinations of these techniques could be used such as acid etching after grit-blasting in order to eliminate the contamination by blasting residues on implant surfaces. This grit blasting residue may interfere with the osteointegration of the titanium dental implants.[8,9,10] It has been shown that grit-blasting with biphasic calcium phosphate (BCP) ceramic particles gave a high average surface roughness and particle-free surfaces after acid etching of titanium implants. Studies conducted both in vitro and in vivo have shown that BCP grit-blasted surfaces promoted an early osteoblast differentiation and bone apposition as compared to mirror-polished or alumina grit-blasted titanium[11,12] Anodization is a method commonly used to obtain nanoscale oxides on metals including titanium[13,14] By adjusting the anodization condition such as voltage, time, and shaking, nanoscale properties could be controlled. Shankar et al[15] have reported that the diameters of the nanotubes could be modified to a range from 20 to 150 nm in modifying voltage conditions. On the other hand, Kang et al[16] found that TiO_2 nanotube arrays were more uniform on electro-polished than machined

titanium. Moreover, TiO_2 nanotubes on Ti improved the production of alkaline phosphatase (AkP) activity by osteoblastic cells. In particular, nanotubes with a diameter of 100 nm upregulated level of AkP activity as compared to 30–70 nm diameter nanotube surfaces.[17] Since AkP is a marker of osteogenic differentiation, these surfaces may demonstrate enhanced bone tissue integrative properties.

Interactions of dental implant surfaces with blood:

During surgery, blood vessels are injured and thus, dental implant surfaces interact with blood components. Various plasma proteins get adsorbed on the material surface within a minute. Platelets from blood interact also with the implant surface. Plasma proteins modified the surface while activated platelets are responsible for thrombus formation and blood clotting. Subsequently, the migrations of various cell types interact with the surface through membrane integrin receptors. These early events occur prior to peri-implant tissue healing. Plasma contains dissolved substances such as glucose, amino acids, cholesterol, hormones, urea and various ions. Most of these components are needed for the viability of cells and tissues. All of these blood substances could interact with implant surface thus modifying their chemical properties like charge or hydrophobicity.[18]

Bone replacement materials:[19]

Bone is a natural nanostructured (i.e. a material with constituent features less than 100 nm in at least one dimension) composite composed of organic compounds (mainly collagen) reinforced with inorganic ones (HA). It is this natural nanostructure that nanotechnology aims to emulate for orthopedic and dental applications. The smaller the particle is, the larger the surface area is in volume. Nano-Bone® uses this principle. The nano-crystallites show a loose microstructure, with nanopores situated between the crystallites. This material structure will be completed by pores in the micrometer area. By following this process, a rough surface area is formed on the boundary layer between the biomaterial and cell, which is very important for fast cell growth. Porosity values of around 60% can be found in both the nano and the micrometer pores. All pores are interconnecting (i.e. by being in contact with the patient's blood, bodily substances merge into the pores). Because the cells are too big for the small pores, blood plasma containing all the important proteins is retained in the interstices. The surface of the pores (and also of the nanopores) is modified in such a way that it literally "hangs on" to the proteins. This is to be carried out by silica molecules. The compound silica is most important.

Special features of bone graft materials are as follows:

- Osteoinductive
- Fully synthetic
- Not sintered
- Highly porous
- Nanostructured
- Absorbs natural body-produced proteins into the nanopores
- Degradation by osteoclasts
- Very good processability
- No ionic solution products

Tissue integration:

The biological events occurring at the tissue-implant interface are influenced by the chemistry, topography, and wettability of dental implant surfaces. The challenge in developing new implant surface consists in increasing the clinical success rate as well as decreasing the tissue healing time for immediate loading of implants, particularly in aesthetic situations[20-23]. One of the objectives is to develop implant surface having predictable, controlled, and guided tissue healing.). In order to enhance this intimate contact between tissues and implant, surface treatments at the nanometer scale have been performed on metal implants and tested in various animal models. Implant surface with various roughness have been used to increase the total area available for osteo-apposition. Kubo et al,[21] observed a substantial increase by 3.1 times in bone-titanium interfacial strength by Ti nanotube (300 nm) at 2 weeks of implantation in femur of rats. These results suggest the establishment of nanostructured surfaces for improved osteoconductivity. Moreover, Ogawa et al[24] have prepared Ti nanostructure by physical vapour deposition and tested their osseointegration in femur of rats. They found an increased surface area by up to 40% and a greater strength of osseointegration for the nanostructured compared to an acid-etched surface.

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SECTION B

Nanotechnology in Prosthodontics

Mahesh Mundathaje

Abstract:
Like other branches of dentistry, restorative dentistry including prosthodontics and implant dentistry have made remarkable progress with respect to nanotechnology. In prosthodontics, various types of nanomaterials are added to improve the properties of commonly used materials Nanoparticles are added to polymethyl methacrylate as antimicrobial agents to increase the viscoelastic property of resins.
At present, ceramic dental crown is mainly including alumina ceramic and zirconia ceramic. Traditional ceramics are made of clay and other natural occurring materials, while modern high-tech ceramics use silicon carbide, alumina, and zirconia. Compared with the conventional ceramics, nanoceramics have a unique property like superelasticity, which makes it become the hot topic in the study of materials science.
Nanomaterials have been playing a significant role in basic scientific innovation and clinical technological change of prosthodontics.

Key words: Nanotechnology, prosthodontics, polymethyl methacrylate, nanoceramics, nanoparticles

Introduction:

Like other branches of dentistry, restorative dentistry including prosthodontics and implant dentistry have made remarkable progress with respect to nanotechnology. In prosthodontics, various types of nanomaterials are added to improve the properties of commonly used materials like resin denture base material, ceramics, polyvinyl siloxane impression material, maxillofacial materials, luting cements, etc. Research on addition of nanoparticles in this regard will promote the usage of such materials with greater efficiency and durability will definitely be of great advantage to dentists and patients undergoing prosthodontic treatment.

Nanoparticles in resins (Polymethyl methacrylate {PMMA}):

Nanoparticles are added to polymethyl methacrylate as antimicrobial agents to increase the viscoelastic property of resins. Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis. *Candida albicans* adhesion and biofilm formation are regarded as essential prerequisites for denture stomatitis. Oral pathological condition like denture stomatitis is mainly caused by adherence of biofilm onto the denture base. Incorporation of nanoparticles into the denture base materials is mainly in the form of silver and platinum nanoparticles as an effective antimicrobial agent. Some researchers showed that the addition of metal nanoparticles such as TiO_2, Fe_2O_3, and silver to PMMA materials could increase the surface hydrophobicity to reduce bimolecular adherence.[1-3]
Li Z et al evaluated the effect of denture base resin containing silver nanoparticles (nano-silver) on *Candida albicans* adhesion and biofilm formation. In this study, the bioactivity and biomass of *C. albicans* biofilm, which was incubated in a series of two-fold dilutions of nano-silver suspension at 37°C for 24 h, were determined using XTT reduction and crystal violet assays respectively. The

denture base resin specimens containing nano-silver were then used in *C. albicans* adhesion (37°C; 90 min; n = 9) and biofilm formation assays (37°C; 72 h; n = 9). Confocal laser scanning microscopy was used to evaluate the architectural properties of average thickness and live/dead cell ratio in the different biofilm stages that developed on the specimens. The results showed that bioactivity and biomass of *C. albicans* biofilm successively decreased with increasing nano-silver solution concentration. Denture base resin containing nano-silver had no effect on adhesion at low concentrations, but it exhibited anti-adhesion activity at a high concentration (5%). For 72 h biofilm formed on the resin specimens, the thickness and live/dead cell ratio were successively reduced with increasing nano-silver concentrations. Nano-silver had antifungal activity and inhibited *C. albicans* biofilm formation. Antifungal activity and an inhibitory effect on adhesion and biofilm formation by denture base resin containing nano-silver were discovered, especially at a higher concentration.[4]

Monteiro et al evaluated a denture base resin containing silver colloidal nanoparticles through morphological analysis to check the distribution and dispersion of the particles in the polymer and by testing the silver release in deionized water at different time periods. In this study, a Lucitone 550 denture resin was used, and silver nanoparticles were synthesized by reduction of silver nitrate with sodium citrate. The acrylic resin was prepared in accordance with the manufacturer's instructions, and silver nanoparticle suspension was added to the acrylic resin monomer in different concentrations (0.05. 0.5 and 5 vol% silver colloidal). Controls devoid of silver nanoparticles were included. The specimen was stored in deionized water at 37˚ C for 7, 15, 30, 60 and 120 days, and each solution was analysed using atomic absorption spectroscopy.

The results showed silver particles were not detected in deionized water regardless of the silver nanoparticles added to the resin and of the storage period. Micrographs showed that with lower concentrations, the distribution of silver nanoparticles was reduced, whereas their dispersion was improved in the polymer. Moreover, after 120 days of storage, nanoparticles were mainly located on the surface of the nanocomposite specimens. This study concluded that, incorporation of silver nanoparticles in the acrylic resin was evidenced. Moreover, silver was not detected by the detection limit of the atomic absorption spectrophotometer used in this study even after 120 days of storage in deionized water. Silver nanoparticles are incorporated in the PMMA denture resin to attain an effective antimicrobial material to help control common infections involving oral mucosal tissues in complete denture wearers.[3]

Ki-Young Nam did a study to evaluate the antimicrobial property of a denture base as characterized by the synthesis of a modified PMMA denture acrylic loading platinum nanoparticles (PtN). Polymerized PMMA denture acrylic disc (20 mm × 2 mm) specimens containing 0 (control), 10, 50, 100 and 200 mg/L of PtN were fabricated respectively. The obtained platinum-PMMA nanocomposite (PtNC) was characterized by TEM (transmission electron microscopy), SEM/EDX (scanning electron microscope/energy dispersive X-ray spectroscopy), thermogravimetric and atomic absorption spectrophotometer analysis. In antimicrobial assay, specimens were placed on the cell culture plate, and 100 µL of microbial suspensions of *S. mutans* (*Streptococcus mutans*) and *S. sobrinus* (*Streptococcus sobrinus*) were inoculated, then incubated at 37℃ for 24 hours. The bacterial attachment was tested by FACS (fluorescence-activated cell sorting) analysis after staining with fluorescent probe. The results of this study showed PtN was successfully loaded and uniformly immobilized into PMMA denture acrylic with a proper thermal stability and similar surface morphology as compared to control. PtNC expressed significant bacterial anti-adherent effect rather than bactericidal effect above 50 mg/L PtN loaded when compared to pristine PMMA (*P*=.01) with no or extremely small amounts of Pt ion eluted. This is the first report on the synthesis and its antibacterial activity of Pt-PMMA nanocomposite. PMMA denture acrylic loading PtN could be a possible intrinsic antimicrobial denture material with proper mechanical characteristics, meeting those specified for denture bases. For clinical application, future studies including biocompatibility, color stability and warranting the long-term effect were still required.[5]

Improvements in the viscoelastic properties of denture base materials was noted. Hamada Zaki Mahross et al investigated the effect of silver nanoparticles (AgNPs) incorporation on viscoelastic properties of acrylic resin denture base material. In this study, a total of 20 specimens (60 × 10 × 2 mm) of heat cured acrylic resin were constructed and divided into four groups (five for each), according to the concentration of AgNPs (1%, 2%, and 5% vol) which incorporated into the liquid of acrylic resin material and one group without additives (control group). The dynamic viscoelastic test for the test specimens was performed using the computerized material testing system. The resulting deflection curves were analyzed by material testing software NEXYGEN MT. The results showed that 5% nanoparticles of silver (NAg) had significantly highest mean storage modulus E' and loss tangent Tan δ values followed by 2% NAg ($P< 0.05$). For 1% nanosilver incorporation (group B), there were no statistically significant differences in storage modulus E', lost modulus E" or loss tangent Tan δ with other groups ($P> 0.05$). The AgNPs incorporation within the acrylic denture base material can improve its viscoelastic properties[6].Other nanoparticles such as ZrO_2, TiO_2, and carbon nanotubes (CNT) have been used to improve the performance of PMMA, and the results showed that desired mechanical property enhancement can be achieved in those composites with small amounts of nanoparticles.[7-10]

Nanoceramics:

At present, ceramic dental crown is mainly including alumina ceramic and zirconia ceramic. Traditional ceramics are made of clay and other natural occurring materials, while modern high-tech ceramics use silicon carbide, alumina, and zirconia. The development of ceramic crown experienced long essence of ceramic materials: hydroxyapatite (HA) ceramic, glass ceramic, alumina ceramic, and zirconia ceramic. Alumina ceramics have good aesthetics, high gloss, chemical stability, wear resistance, high hardness, good biocompatibility, no allergies and no effect on the MRI, but the biggest drawback is crisp, and it is likely to porcelain crack.[11]

Nanoceramic refers to the ceramic material with nanoscale dimensions in the microstructures phase. Compared with the conventional ceramics, nanoceramics have unique properties, which makes it become the hot topic in the study of material science. Firstly, nanoceramics have superplasticity. Ceramic is essentially a kind of brittle material; however, nanoceramic shows good toughness and ductility. As the arrangement of atoms in nanoceramics interface is quite confusing, the atoms are very easy to migrate under the conditions of force deformation. Secondly, compared to the conventional ceramics, nanoceramic has the superior mechanical properties, such as strength and hardness increasing significantly. The hardness and strength of many nanoceramics are four to five times higher than those of the traditional materials. For example, at 100°C the microhardness of nano-TiO_2 ceramics is 13,000 kN/mm^2, while that of ordinary TiO_2 ceramics is lower than 2,000 kN/mm^2. Most importantly, toughness of nanoceramics is much higher than that of traditional ceramics. At room temperature, nano-TiO_2 ceramic exhibits very high toughness. When compressed to 1/4 of the original length, it was still intact without being broken.[12]

Glass ceramics based on lithium disilicate with lack of mechanical properties are commonly used in dental veneers and crowns. Due to insufficient mechanical properties of glass ceramics, failure in clinical cases have been often reported. To improve mechanical properties of glass ceramics based on lithium disilicate, Persson et al used a sol-gel method to produce glass ceramics in the zirconia-silica system with nanosized grains, which was found to be translucent, with a transmittance of over 70%, and possessed excellent corrosion resistance. It also presented a somewhat lower elastic modulus but higher hardness than the conventional lithium disilicate.[13]

Nanoparticles in Impression materials:

Improved physical properties of polyvinylsiloxane impression materials was done by addition of nano-sized fumed silica. Choi JH et al have done a study in which polyvinylsiloxanes (PVS) were used as dental impression materials, formulated with the variation of loading combination of six types of fillers including nano-sized fumed silica. The fillers were blended with three types of silicone polymers together with cross-linker and inhibitor in base paste and with plasticizer and platinum catalyst in catalyst paste. By replacing parts of crystalline quartz with other fillers, the setting time became much faster. The test group in which quarter of quartz was replaced with fumed silica showed the most ideal working and setting time for clinical use. There was a negative correlation between pH and setting time ($p < 0.05$). Combining the fumed silica was effective in increasing the viscosity, tensile strength and maximum% strain. Combining the diatomaceous earth reduced the setting time and maximum% strain, and dramatically increased the viscosity and tensile strength. The best modulation of physical properties of PVS material was possible by combining fillers during the formulation.[14]

Nanotechnology in maxillofacial prosthodontics:

Pesqueira et al evaluated the effect of disinfection and accelerated ageing on the dimensional stability and detail reproduction of a facial silicone with different types of nanoparticle. A total of 60 specimens were fabricated with Silastic MDX 4-4210 silicone and they were divided into three groups: colourless and pigmented with nanoparticles (make-up powder and ceramic powder). Half of the specimens of each group were disinfected with Efferdent tablets and half with neutral soap for 60 days. Afterwards, all specimens were subjected to accelerated ageing. Both dimensional stability and detail reproduction tests were performed after specimen fabrication (initial period), after chemical disinfection and after accelerated ageing periods (252, 504 and 1008 hours). The dimensional stability test was conducted using AutoCAD software, while detail reproduction was analyzed using a stereoscope magnifying glass. Dimensional stability values were statistically evaluated by analysis of variance (ANOVA) followed by Tukey's test ($p < 0.01$). Detail reproduction results were compared using a score. Chemical disinfection and also accelerated ageing affected the dimensional stability of the facial silicone with statistically significant results. The silicone's detail reproduction was not affected by these two factors regardless of nanoparticle type, disinfection and accelerated ageing.[15]

Nanoparticles in hybrid resin luting cements:

Habekost et al investigated the influence of nanoparticle loading level on properties of experimental hybrid resin luting agents. In this study, silanated 2-μm barium borosilicate glass microparticles and 7-nm silica nanoparticles were used. Five materials were obtained by loading a photocurable Bis-GMA/TEGDMA co-monomer with a total mass fraction of 60% inorganic fillers. The mass fraction of nanoparticles was set at 0% (control), 1% (G1), 2.5% (G2.5), 5% (G5), or 10% (G10). The properties evaluated were flexural strength (σ) and modulus (E_f), Knoop hardness number (KHN), and film thickness (FT). Dispersion/interaction of the particles with the resin phase was assessed by scanning electron microscopy (SEM). Data were submitted to statistical analysis (5%). The results showed, for σ, G1 > G2.5 = G5 = G10, and control > G10. For E_f, G2.5 > control = G1 > G5 > G10. For KHN, G5 = G10 > control = G1 = G2.5. For FT, G10 = G5 > control = G1, and G10 > G2.5. Incorporation of nanoparticles was associated with observation of clusters in the SEM analysis. The clusters were more frequent for higher nanoparticle loadings. It was concluded that modest incorporation of nanoparticles may improve the properties of resin luting materials. Nanofiller mass fractions above 2.5% should however be avoided because they may be detrimental to the properties of the resin luting agents.[16]

Conclusion:

In this paper, the latest research progress on the applications of nanometals, nanoceramic, nanoresin and other nanomaterials in prosthodontics was reviewed, which clearly shows that materials used in prosthodontics can be significantly improved after their scales were reduced from micron-size into nanosize by nanotechnology and that the performances of composites can also be enhanced by adding appropriate nanomaterials. This review article could provide some valuable information for the future scientific and technological innovations in the related field. Future development of prosthodontics technology has been recognized to be dependent on the progress of materials science. Nanomaterials have been playing a significant role in basic scientific innovation and clinical technological change of prosthodontics.

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SECTION C

Nanomaterials and Nanotechnology in Conservative Dentistry and Endodontics

Laxmish Mallya[1], Kanchana[2]

Abstract:
Nanotechnology was first described in 1959 by physicist Richard P Feynman. The term "NANO" is derived from the Greek word "DWARF". Application in the field started in the 1980 with the invention of scanning tunnelling microscopes and the discovery of carbon monotubes. The aim of this article is to review potential application, hazards of nanoscience in Conservative dentistry and Endodontics. While bacteria reach a size of 10 $^{-6}$ m, nanotechnology deals with structures as small as 10 $^{-9}$ m.
Key words: Nanotechnology, Nanofillers, Nano hybrid, Nanomaterials

Introduction:

Professor Keric E Dexler coined the term 'nanotechnology'. It is the manipulation of matter on molecular and atomic levels.[1, 2] Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, dealing with the development of new materials to investigating whether we can directly control matter on atomic scale. [3] The various nanoparticles are Nano pores, nanotubes, quantum dots, Nano shells, dendrimers, liposomes, Nano rods, fullerenes, Nano spheres, nanowires, Nano belts, Nano rings, Nano capsules. [4] Quantum dot-assisted detection of pathogens and OFNASET (oral fluid Nano sensor test) helps in diagnosis. Dentrifices containing Nano sized hydroxyapatite, calcium carbonate crystals helps in caries prevention. Certain chemicals can directly interfere with the proliferation of microorganisms at concentrations that can be tolerated by the host. Orthodontic adhesives with Nano silver particles had their antibacterial capacity raised without compromised silver particles. Dentin extra cellular matrix proteins contain growth factors which can promote tooth healing and pulp regeneration. Nano materials include silver, zinc oxide, copper oxide, titanium oxide, gold, chitosan, quaternary ammonium, carbon nanotube. Silver release of Ag ions causes disruption of bacterial cell membranes impairing the electron transfer system and DNA damage. Zinc oxide, copper oxide, titanium oxide, releases ions, causes generation of H_2O_2 and disruption of cell membranes. Gold reacts with bacterial cell membrane and has strong electrostatic effect. Quaternary ammonia and carbon nanotube inhibits bacterial cell membrane. (QPEI) Nano particles quaternary ammonium polyethylene has been incorporated into sealers like AH plus, Epiphany and Gutta flow.

Applications in Conservative Dentistry and Endodontics

Nano composites: These restorative materials have excellent aesthetic, polishability and very low degree of polymerization shrinkage. The incorporation of nanoparticles in composite resins has given rise to a new class of materials with improved properties over micro and macro filled composites and provides clinicians a reliable option for anterior and posterior restoration. The size of these particles range from 0.05-0.01 μm.[5,6] Evolution of direct RBC (Resin Based Cement) has been recently reviewed by Puckett et al. Advantages of these composites are primarily in terms of smoothness, polishability and precision of shade characterization plus flexural strength and microhardness similar to or more than conventional RBC. [7, 8,9,10] Beun et al compared the physical properties of Nano filled, universal hybrid and micro filled composites and observed a higher elastic modulus with Nano filled RBC than most of hybrids tested. [11] One Nano composite system has three different types of fillers, non-agglomerated "discrete" silica particles, barium glass and pre-polymered filler. [12] Non-agglomerated discrete Nano particles that are homogenously distributed in resins or coatings to produce Nano composites have been successfully manufactured by Nano Products Corporation. The Nano filler used: aluminosilicate powder with 1:4 ratio of alumina to silica and it has refractive index more than 1. [13] A recent study by Xu et al has evaluated the incorporation of Nano sized calcium phosphate into RBC which could inhibit dental caries. Nano composites have the potential to enhance the adhesion and provide a stable and natural interface between the mineralized hard tissue of the tooth and these advanced restorative materials.[14,15,16] ORMOCER (organically modified ceramics) use particles comprising silicones organic polymers and ceramic glass.[17] Ormocers also claim decreased surface roughness.[18 19] Moszner et al found that modifying ormocers with organic content such as methacrylate substituted zinc oxide and silica dioxide nanoparticles was to improve the mechanical properties and biocompatibility of resin based cements. Nano fissure sealants result in high wear resistance and reduced shrinkage, good sealing ability and easy to use. Silver Nano particles are being used which has unique advantages of antibacterial and antifungal properties.[20,21] Resin incorporated with silver Nano particles has long term inhibitory effect against *Streptococcus mutans*.

Nano light–curing glass ionomer cement:

Glass ionomer cement was introduced by Wilson and Kent in the year 1970 as dental filling material. An improvement has also been made in Resin-modified glass ionomer cement (RMGIC) with addition of Nano sized filler. This enhances aesthetic properties and polishability of resin modified ionomers. By using bonded Nano fillers and Nano cluster fillers, manufacturers have begun to produce Nano ionomer in an effort to make their surface finish more closely approximate that of a hybrid composite. FILTEK is supreme universal restorative material with fluoro alumina silicate technology. [22, 23, 24] The new ionomer (Ketac Nano: 3M ESPE) has been for clinical use since 2007.

Use of Nanomaterials in Endodontics as disinfectant and antimicrobial agent:

Metal nano particles have been intensively studied and been an important subject in basic and applied sciences. The use of root canal filling materials with anti-bacterial activity is considered beneficial in the effort to further reduce the number of remaining microorganisms and to eradicate infection. Nanotechnology focuses on strategies for inhibiting cellular adhesion and attachment, interfering in bacterial physiology and avoiding biofilm development. Bio-aggregate is a biocompatible white powder composed of ceramic particles which are used in root canal repair and it promotes cementogenesis. Some ceramics such as bio-glass, sintered hydroxyl apatite, calcium hydroxide, mesa porous silica based ceramics and tri-oxide aggregate spontaneously respond to living bone. Zinc oxide nanoparticles have received considerable attention due to their unique anti-bacterial, anti-fungal and UV filtering properties, high catalytic and photochemical activity. Synthesis of zinc oxide nanoparticles was achieved by using zinc acetate, polyethylene glycol and ammonium carbonate by precipitation method. The anti-microbial activity of zinc oxide nanoparticles is used to inhibit growth of *Bacillus subtilis* and *Escherichia coli* using disc diffusion method. Chitosan is a safe, non-toxic natural polysaccharide prepared by N-deacetylation of chitin. Chitosan Nano particles and Nano fibres are used for enzyme immobilization; they are also promising candidates for drug delivery carriers and cell proliferation enhancers. The synergistic effect of the chitosan conjugated nanoparticles was able to eliminate mono-species and multi-species bacterial films with complete disruption of the biofilm structure. Endodontic cement (Sealapex), Resin luting cement (Rely X arc), Glass ionomer cement (Vitre bond) has 0.05 ml quantity of silver in volume. Silver nanoparticles were prepared by reduction of silver nitrate. Silver has been used for its antibacterial properties for many years in different forms: ionised and elementary forms as silver zeolites or as nanoparticles. Silver particles, zinc oxide, chitosan, bioactive glass are being evaluated for use as disinfectant and anti-microbial agent. [25, 26,27,28,29]

Health hazards and Health issues

Nano toxicology is defined as a science that deals with adverse effects of engineered nanodevices and nanostructures in living organisms. Studies have shown significant association of increased cardiovascular mortality, other extra pulmonary effects, tissue damage, systemic effects due to increased rate of absorption of non-degradable nanoparticles by skin, lungs, etc. Silver nanoparticles are showing unacceptable toxic effect on human health and environment. The chronic exposure to silver causes adverse effects such as permanent bluish grey discoloration of skin (argyria) and eyes (argyrosis), liver and kidney damage.[30, 31, 32,33,34,35]

Conclusion:

Nano science is a new approach and will bring changes in fields of medicine, dentistry, research, healthcare, engineering enhanced research opportunities; it will help dentists with more equipment, drugs and precision-made materials by which patient compliance is enhanced.

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