# Nanotechnology : Its Implications in Conservative Dentistry and Endodontics

Sumit Mohan[†], Anuraag Gurtu[††], Anurag Singhal[†††], Ankita Mehrotra[††††]

† Senior Lecturer, Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences, Bareilly (U.P).
†† Reader, Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences, Bareilly (U.P).
††† Professor & Head, Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences, Bareilly (U.P).
†††† P. G. Student, Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences, Bareilly (U.P).
Date of Receiving : 27/Feb/2013
Date of Acceptance : 02/Apr/2013

**Abstract:** *Feynman postulated concept of nanotechnology as an unavoidable development in the progress of science. Since then, nanotechnology has been part of mainstream scientific theory with potential medical and dental applications. Numerous theoretical predictions have been made based on the potential applications of nanotechnology in dentistry. The most substantial contribution of nanotechnology to dentistry is the more enhanced restoration of tooth structure with nanocomposites. The field of nanotechnology has tremendous potential, which if harnessed efficiently, can bring out significant benefits to the human society such as improved health, better use of natural resources. The future holds in store an era of dentistry in which every procedure will be performed using equipments and devices based on nanotechnology. This article reviews the potential clinical applications of nanotechnology in conservative dentistry and endodontics.*

**Key words :** Nanotechnology, Nanodentistry, Nanocomposites; Dentifrobots, Nanosolution.

## INTRODUCTION

Nanotechnology also known as molecular nanotechnology or molecular engineering is production of functional materials and structures in range of 0.1 to 100 nanometeres. Today the revolutionary development of nanotechnology has become the most highly energized disciplined in science and technology.[1]The term Nanotechnology was coined by Prof. Kerie E Drexler.[2] Nano is derived from vaos, the Greek word for dwarf and usually is combined with noun to form words such as nanometer, nanotechnology or nanorobot.[3]

First described in 1959 by physicist Richard P Feyman, who said it as an avoidable development in progress of science, nanotechnology has been a part of mainstream scientific theory with potential medical and dental application since early 1990's. Nanoparticle, nanosphere, nanorodes, nanotubes, nanofibres, dendrimers and other nanostructures has been studied for various applications to biologic tissue and systems. Growing interest in future medical application of nanotechnology is leading to the emergence of new field called Nanomedicine. Emerging technologies and new nanoscale information have the potential to transform dental practice by advancing all aspects of dental diagnostics, therapeutics and cosmetic dentistry into a new paradigm of state-of-the-art patient care beyond traditional oral care methods and procedures.[4]

New potential treatment opportunities in dentistry may include bottom up approach and bottom down approach.

### The bottom up approaches are:

1. Local anaesthesia:- a colloidal suspension containing millions of active analgesic micron size dental robot will be instilled on patients gingivae. After contacting the surface of crown or mucosa, ambulating nanorobots reach the pulp. Once installed there, analgesic dental robots may be commanded by dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedure is completed , dentist orders the nanorobots to restore all sensations to relinquish control of nerve traffic and to egress from tooth by similar pathways used to ingress.[5]
2. Hypersensivity cure:- Dentine hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to pulp. Dental nanorobots could selectively and precisely occlude selected tubule in minutes, using native biological materials, thus offering patients a quick and permanent cure.[2]
3. Nanorobotic dentifrices (dentirobots):- Subocclusal dwelling nanorobotic dentifrices delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolising trapped organic matter into harmless and odourless vapours and performing continuous calculus debridement. Toothpaste containing synthesized hydroxyapatite, calcium peroxide, patented nano-technology aka Nanoxyd has proven useful to freshen breathe as well as whiten teeth[6].
4. Dental durability and cosmetics:- Tooth durability and appearance may be improved by replacing upper enamel layers with pure sapphire and diamond which can be made more fracture resistance as nanostructure composites, possibly including embedded carbon nanotubes.[5]
5. Orthodontic treatment:- Orthodontic nanorobots could directly manipulate the periodontal tissues allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours.[7] Sliding a tooth along a archwire involves a frictional type of force that resist this movement. Use of excessive orthodontic force might cause loss of anchorage and root resorption, but coating orthodontic wire with inorganic fullerene like tungsten disulfide nanoparticles, reduction in friction has been reported.
6. Photosensitizers and carriers:- Quantum dots can be used as

photosensitizers and carriers. They can bind to the antibody present on surface of target cell and when stimulated by UV light. They can give rise to reactive oxygen species and thus will be lethal to target cell.[5]

7. Diagnosis and treatment of oral cancer:- Nano electromechanical system (NEMS) which can convert biochemical to electrical signal and cantilever array sensor which is an ultrasensitive mass detection technology, can be used for detection of 10-12 bacteria, viruses and DNA. These are extremely useful for diagnosis of oral cancer and diabetes mellitus. Nanomaterials for brachytherapy like 'BrachySilTM' delivers $P^{32}$, are in clinical trial. Drug delivery system that can cross the blood brain barrier is vision of the future with this technology. Parkinson disease, Alzheimer disease, brain tumour will be managed more efficiently by the use of this technology. Nanovectors for gene therapy are in a developing stage to correct disease at molecular aspect.[5]

**Top-Down Approaches include:**

1. Nanocomposites:- Nanocomposites has been successfully manufactured by non-agglomerated discrete nanoparticles that are homogenously distributed in resins or coatings to produce them.[4] The nanofiller used includes an alumino silicate powder having a mean particle size of 80 nm[2]. Commercially they are available as Filtek O Supreme Universal Restorative Pure Nano O.
2. Nanosolutions:- It produces unique and dispersible nanoparticles which can be used in bonding agents. This insures homogeneity and adhesive is mixed every time.[2]
3. Impression materials:- Nanofillers are integrated in vinylpolysiloxanes, producing a unique additions of siloxane impression materials, having better flow, improved hydrophilic properties and enhanced details.[5] Commercially available as Nanotech Elite H-D.
4. Nanoencapsulation:- Nanomaterials, including hollow spheres, core-shell structure, nanotubes and nanocomposite, have been widely explored for controlled drug release. South-west research institute has developed targeted systems that encompass nanocapsules include novel vaccines, antibiotics and drug delivery with reduced side effects.[5] Pinon-Segundo et al studied Triclosan loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontal disease. These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is arestin in which minocycline is incorporated into microsphere for drug delivery by local means to a periodontal pocket.[8]
5. Nanoneedles:- Suture needles incorporating nano sized stainless steel crystals have been developed. Nanoneedles like Sandvik Bioline, RK 91 needles are available.[5]
6. Nanotweezers:- In 1999, Philip Kim and Charles Lieber at Harward University created the first general purpose nanotweezer. Its working end is a pair of electrically controlled carbon nanotubes made from a bundle of multiwalled carbon nanotubes. To operate the tweezers, a voltage is applied across the electrode, causing one nanotube arm to develop a positive electrostatic charge and the other to develop a negative charge.[9]
7. Bone replacement materials:- Hydroxyapatite nanoparticles are used to treat bone defects are Ostium, Vitosso and NanOSS .These can be used in maxillofacial injuries requiring bone graft, cleft patients and osseous defects in periodontal surgeries.[7]
8. Other products are:- Protective clothing and filtration masks, using antipathogenic nanoemulsions and nanoparticles. Medical appendages for instantaneous healing. Bone targeting nanocarriers like calcium phosphate based biomaterials are developed.[6,3]

## ROLE OF NANOTECHNOLOGY IN CONSERVATIVE DENTISTRY & ENDODONTICS

### NANOCOMPOSITE

One of the most significant contributions to dentistry has been the development of resin based composite technology. Adhesively bonded composites have the advantage of conserving sound tooth structure with the potential for tooth reinforcement, while at same time providing cosmetically acceptable restorations. However, no composite material has been able to meet both functional needs of posterior class I or II restorations and superior esthetics required for anterior restorations. There was a need to develop a composite dental filling material that could be used in all areas of mouth with high initial polish and superior polish retention as well as excellent mechanical properties suitable for high stress – bearing restoration [1].

Composition: Nanocomposite has the basic composition of conventional composite resin. Dental composites are composed of synthetic polymers, inorganic fillers, initiators, and activators that promote light-activated polymerization of the organic matrix to form cross-linked polymer networks, and silane coupling agents which bond the reinforcing fillers to the polymer matrix. They have fillers that are 0.005 to 0.01µm.[6] Nanoproducts Corporation has successfully manufactured nonagglomerated discrete nanoparticles that are homogeneously distributed in resins or coatings to produce nanocomposites. The nanofiller used include an alumino silicate powder having a mean particle size of 80 nm[2].

Additionally, nanofillers are capable of increasing the overall filler level due to their small particle sizes. More filler can be accommodated if smaller particles are used for particle packing. Theoretically, with the use of nanofillers, filler levels could be as high as 90-95% by weight. However, the increase in nanofillers also increases the surface area of the filler particles, which limits the total amount of filler particles because of the wettability of the fillers. Since polymerization shrinkage is mainly due to the resin matrix, the increase in filler level results in a lower amount of resin in nanocomposites and will also significantly reduce polymerization shrinkage and dramatically improve the physical properties of nanocomposites. The nanocomposite is composed of three different types of filler components: nonagglomerated discrete silica nanoparticles, barium glass, and prepolymerized fillers.

Caries prevention fillers: To increase mineral content to control dental caries, calcium and phosphate ion-releasing fillers have been developed, such as nanoparticles of dicalcium phosphate anhydrous (DCPA) [11,12] and tetracalcium phosphate [TTCP: $Ca_4(PO_4)_4O$]-whiskers.[13]

## LOCAL ANAESTHESIA

One of the most common procedures in dentistry is the injection of local anesthetic, which can involve long waits and varying degrees of efficacy, patient discomfort and complications. Well-known alternatives, such as transcutaneous electronic nerve stimulation, cell demodulated electronic targeted anesthesia and other transmucosal, intraosseous or topical techniques are of limited clinical effectiveness.[5,7] To induce oral anesthesia in the era of nanodentistry, dental professionals will instill a colloidal suspension containing millions of active analgesic micrometer-sized dental nanorobot particles on the patient's gingival (fig.6). After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria[14] or the 1 to 3µm thick layer of loose tissue at the cemento-dentinal junction.[15] On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 µm in diameter[16,17] and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation,[7] all under the control of the onboard nanocomputer, as directed by the dentist.

There are many pathways to choose from. Dentinal tubule number density is typically 22,000 $mm^{-2}$ near the dentino-enamel junction, 37,000 $mm^{-2}$ midway between the junction and the pulpal wall, and 48,000 $mm^{-2}$ close to the pulp in coronal dentin, with the number density slightly lower in the root (for example,13,000 $mm^2$ near the cementum). Tubule diameter increases nearer the pulp, which may facilitate nanorobot movement, although circumpulpal tubule openings vary in number and size.[18]

## MAINTAINANCE OF ORAL HYGIENE

Nanorobotic dentifrice delivered by a mouthwash or toothpaste could patrol all supragingival and subgingival surfaces, at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement.[19]

These almost invisible (1 to 10 micrometre) dentifrobots, perhaps numbering 1000 to 100000 per mouth and crawling at 1 to 10 micrometre per second might have the mobility of tooth amoebas but would be inexpensive purely mechanical devices that safely deactivate themselves, if swallowed. Moreover, they would be programmed with strict protocol to avoid occlusal surfaces. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or so species of harmless oral micro flora to flourish in a healthy ecosystem. Dentifrobots also would provide a continuous barrier to halitosis since bacterial putrefaction is the central metabolic process involved in oral malodor. With this kind of daily dental care available from an early age, conventional tooth decay and gingival disease will disappear.

## NANO TOOTHPASTE

Nano-Whitening Toothpaste is toothpaste that contains synthesized hydroxyapatite, a key component of tooth enamel, as nanosized crystals. It has been proven to freshen breathe as well as whiten teeth. This toothpaste contains ingredents such as: Patented nano technology aka Nanoxyd, Calcium peroxide, Contains Enzymes such as (papain and bromelain), Fluoride combination, Co-enzyme Q10 and Vitamin E.[7]

The risks of nanotechnology toothpaste: Nanotechnology toothpaste has been shown to be harmful because some of the nanotechnology toothpastes are made with silver hydroxyapatite:

1. If this accumulates in the tissues of people who use this toothpaste, it could cause potential health effects. If the silver particles build up in our water systems, they may start accumulating in other people and animals as well.
2. Risk of nanoparticles flowing through the body if the toothpaste is actually swallowed.
3. Some people feel that this is not friendly for the environment.
4. "They can even slip through the olfactory nerve into the brain, evading the protective blood brain barrier. It's not clear whether they penetrate the skin. Once they're inside the body, it's not clear how long they remain or what they do" says Caroline Bass of Environmental 360.[6]

## NANOFILLED RESIN MODIFIED GLASS IONOMER

A new nano-filled RMGI restorative material has been introduced for restoration of primary teeth and small cavities in permanent teeth. It is based on a prior RMGI with a simplified dispensing and mixing system (paste/paste) that requires the use of a priming step, but no separate conditioning step. Its primary curing mechanism is by light activation, and no redox or self curing occurs during setting. Apart from the user-friendliness, the major innovation of this material involves the incorporation of nano-technology, which allows a highly packed filler composition (69%), of which approximately two-thirds are nano-fillers.[20]

Composition: Chemistry of nanoionomer is based on the methacrylate modified polyalkenoic acid, which is capable of both crosslinking via pendate methacrylate groups as well as the acid-base reaction between the fluoroaluminosilicate glass (FAS) and the acrylic and itaconic acid copolymer groups. It contains surface treated nanofillers (approx 5-25nm) and nanoclusters (approx 1 to 1.6 microns). Filler loading is approx. 69% by weight of which the relative proportion of two filler types (FAS and combination of nanofillers ) are approx 2/5 and 3/5 respectively. All nanofillers are further surface modified with methacrylate silane coupling agents to provide covalent bond formation into free radically polymerized matrix.[21]

## DENTAL HYPERSENSITIVITY

Dentin hypersensitivity is defined as a sharp pain arising from exposed dentin as a result of various stimuli such as heat, cold, chemical or osmotic, and that cannot be ascribed to any other pathology. It a may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have 8 times higher surface density of dentinal tubules and tubules with diameters twice as large as nonsensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.[5] On reaching the dentin, the nanorobots enter dentinal tubular holes that are 1 to 4 µm in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even position of navigation, all under the control of the onboard nanocomputer as directed by the dentist.

Novamin containing dentrifice has the ability to significantly reduce dentin sensitivity within one week compared to placebo dentrifices.[22] Novamin (calcium sodium phosphosilicate) is a bioactive glass in the class of highly biocompatible material that were originally developed as bone regenerated material. The Chinese researchers have demonstrated that dentinal tubules can be blocked with the aid of gold nanoparticles. One of the method of closing sub micron sized dentinal tubules involved sintering of highly concentrated gold nanoparticles that were brushed into exposed open ends of tubules. Laser irradiation induced the photofusion of these particles via photothermal conversion. This method seems to be very promising for the purpose of occlusion of dentinal tubules.[23]

## BONE REPLACEMENT MATERIAL

Although tooth enamel, cementum, and bone are composed of organized assemblies of carbonated apatite crystals, enamel is unusual in that it does not contain collagen and does not remodel. Self-assembly of amelogenin protein into nanospheres has been recognized as a key factor in controlling the oriented and elongated growth of carbonated apatite crystals during dental enamel biomineralization.

## BIOCERAMICS

Nanosized hydroxyapatite (HA) is the main component of mineral bone in the form of nanometer sized needle-like crystals of approximately 5-20 nm width by 60 nm length. Synthetic HA possesses exceptional biocompatibility and bioactivity properties with respect to bone cells and tissues, hence have been widely used clinically in the form of powders, granules, dense and porous blocks and various composites. Nanophase HA properties such as surface grain size, pore size, wettability, etc, could control protein interactions modulating subsequent enhanced osteoblast adhesion and long-term functionality. However, since nanophase materials can mimic the dimensions of constituent components of natural tissues, implants developed from nanophase material can be a successful alternative. Several encouraging reports on nanophase materials encourage its use for tissue engineering applications. This has been achieved by the combined effect of its ability to mimic the natural nano dimensions and also the cell responses encouraging high reactivity and in turn helps in regenerating tissues.[5,7,24]

NanOss[R] bone void filler from Angstrom Medica is considered to be the first nanotechnology medical device to receive clearance by the US Food and Drug Administration in 2005. Utilizing nanotechnology, calcium and phosphate are manipulated at the molecular level and assembled to produce materials with unique structural and functional properties. It is prepared by precipitating nanoparticles of calcium phosphate in aqueous phase and the resulting white powder is compressed and heated to form a dense, transparent, and nano crystalline material. It is strong and also osteoconductive.[24]

Ostim[R] is an injectable bone matrix in paste form which received CE marking in 2002. It is composed of synthetic nanoparticulate hydroxyapatite which is indicated for metaphyseal fractures and cysts, acetabulum reconstruction and periprosthetic fractures during hip prosthesis exchange operations, osteotomies, filling cages in spinal column surgery, combination with autogenous and allogenous spongiosa, filling in defects in children etc.[24]

## NANOTECHNOLOGY AND BIOFILM[23]

Nanotechnology is a promising field of science which offers better insight into the spatial relationship between different species and how their diversity increases over time. Nanotechnology can guide our understanding of the role of interspecies interaction in the development of bio-film. The contribution of modern technology in the field of oral microbiology started with the detection of cultivable as well as uncultivable bacteria by examining bacterial 16 sRNA and DNA.

The spatial distribution of different oral bacteria within the plaque has been revealed by fluorescent in situ hybridization. The metagenomic project for oral microbial flora will reveal the metabolic genes and virulence factors of oral microbes.

Nanotechnology has been used to study the dynamics of demineralization/remineralization process in dental caries by using tools such as atomic force microscopy (AFM) which detect bacteria induced demineralization at an ultrasensitive level. Using AFM the correlation between genetically modified Streptococcus mutans sp. scale morphology has been assessed. The nanoscale cellular ultrastructure is a direct representation of genetic modifications as most initiate changes in surface protein and enzyme expression, where host- cell nutrient pathways and immune response protection likely occur. The surface proteins and enzymes, common to S. mutans strains are a key contributor to the cariogenicity of these microbes.

Another nanotechnology application used so far is $O^{16}/O^{18}$ reverse proteolytic labelling to determine the effect of biofilm culture on the cell envelope proteome of oral pathogen, Porphyromonas gingivalis sp. which is linked to chronic periodontitis. A group of cell-surface located C-terminal domain family proteins including R gp A, Hag A, CPG 70 and PG99 increased in abundance in the bio-film cells. The other proteins which increased were transport related proteins (Hmu Y and Iht B), metabolic enzymes (Frd AB) and immunogenic proteins. Nanotechnology can further enable us to detect both cultivable bacteria and non cultivable with the help of nanochip. Similarly plaque acidity which is a good index for monitoring tooth demineralization can be monitored using a microscale planer pH sensor. Application of nanotechnology to this prototype will further reduce the size of the sensors and make the device more user friendly to both the patients and clinicians.

New silver nanotechnology chemistry has proven to be effective against biofilms. Silver works in a number of ways to disrupt critical functions in a micro-organism. For example it has a high affinity for negatively charged side groups on biological molecules such as sulphydryl, carboxyl, phosphate and other charged groups distributed throughout microbial cells. Silver attacks multiple sites within the cell to inactivate critical physiological functions such as cell wall synthesis, membrane transport, nucleic acid (RNA and DNA) synthesis and translation, protein folding and function and electron transport. For certain bacteria as little as one part per billion of silver may be effective in preventing cell growth. Recent studies show that ionic plasma disposition silver antimicrobial nanotechnology is effective against pathogens associated with bio- films including E.coli sp., S.pneumoniae sp., S.pneumoniae, S.aureus and A.niger.

## CONCLUSION

Nanodentistry will give a new vision to comprehensive oral health care, as now trends of oral health have been changing to more preventive intervention than a curative and restorative procedure. This science might sound like a fiction now, but Nanodentistry has a strong potential to revolutionize dentistry as to diagnosing and treating dental diseases in future. It opens up new avenues for vast, abundant research. Nanotechnology will change dentistry, health care and human life more profoundly than other developments.

**REFERENCES**


1. Mitra S, Holmes B. An application of nanotechnology in advanced dental material. J Am Dent Assoc 2003; 134(10): 1382-1390.
2. Schleyer TL. Nanodentistry Fact or Fiction. J Am Dent Assoc 2000; 131:1567-1568.
3. Saunders SA. Current practicality of nanotechnology in dentistry. Part 1: Focus on nanocomposite restoratives and biometics. Clin, Cos Investi Dent 2009:47-56.
4. Freitas RA. Personal choice in the coming era of nanomedicine. Nanoethics: The Ethical and Social Implications of Nanotechnology, John Wiley, NY, 2007, pp. 161-172.
5. Kumar S R, Vijayalakshmi R. Nanotechnology in dentistry. Ind J Dent 2006;17 (2): 62-65.
6. Future of Nanotechnology Toothpaste: Nanodentistry Archive for category Nanotechnology Toothpaste.
7. Freitas RA. Nanodentistry. J Am Dent Assoc 2000; 131(11): 1559-1565.
8. Verma SK et al. A critical review of the implication of nanotechnology in modern dental practice. National J of oral maxillofacial surgery. 2010 (1) : 1: 41-44.
9. Freitas RA. The future of nanofabrication and molecular scale devices in nanomedicine. Studies in health technology and molecular scale devices in nanomedicine. 2002;80:45-59.
10. Chen MH. Update on Dental Nanocomposites. J Dent Res 2010;89(6): 549-560.
11. Xu HH. Nano DCPA-whisker composites with high strength and Ca and $PO_4$ release. J Dent Res 2006;85:722-727.
12. Xu HH. Effects of calcium phosphate nanoparticles on Ca-PO4 composite. J Dent Res 2007;86:378-383.
13. Xu HH, Weir MD, Sun L. Calcium and phosphate ion releasing composite: effect of pH on release and mechanical properties. Dent Mater 2009;25:535-542.
14. Paulsen F, Thale A. Epithelial-Connective tissue boundary in the oral part of human soft palate. J Anat 1998;93:457-67.
15. YamamotoT. The structure and function of the cemento-dentinal junction in human teeth. J Perio Res 1999;34(5): 261-8.
16. Dourda AO. A morphometric analysis of the cross-sectional area of dentine occupied by dentinal tubules in human third molar teeth. Int End J 1994;27(4):184-89.
17. Arends J .The diameter of dentinal tubules in human coronal dentine after demineralization and air drying: a combined light microscopy and SEM study. Caries Res 1995; 29(2):118-21.
18. Marion D, Jean A, Hamel H. Scanning electron microscopic study of odontoblasts and circumpulpal dentin in a human tooth. J Endod 1991; 72(4) 473-8.
19. Ling Xue Kong. Nanotechnology and its role in the management of periodontal diseases. Periodontol 2000; 40:184–196.
20. Ketac Nano Light Curing Glass Ionomer Restorative. 3M ESPE technical product profile.
21. Requicha AAG Nanorobots NEMS and Nanoassembly. Proc. IEEE J Endod 2003;91(11):1922-1933.
22. Marini I, Checchi L, Greenspan D. Pilot clinical study evaluating efficacy of NovaMin – containing dentifrice for relief for relief of dentin hypersensivity. NovaMin Research Report 2002.
23. Bhardwaj SB, Mehta M, Gauba K. Nanotechnology: Role in dental biofilms. Indian J Dent Res 2009;20(4 ):511-513.
24. Paul W, Sharma CP. Nanoceramic Matrices: Biomedical Applications. Am J Biochem Biotech 2006;2(2):41-48.


Corresponding Address:
Dr. Sumit Mohan
Email: samsharma770@gmail.com

# LIST OF PHOTOGRAPHS

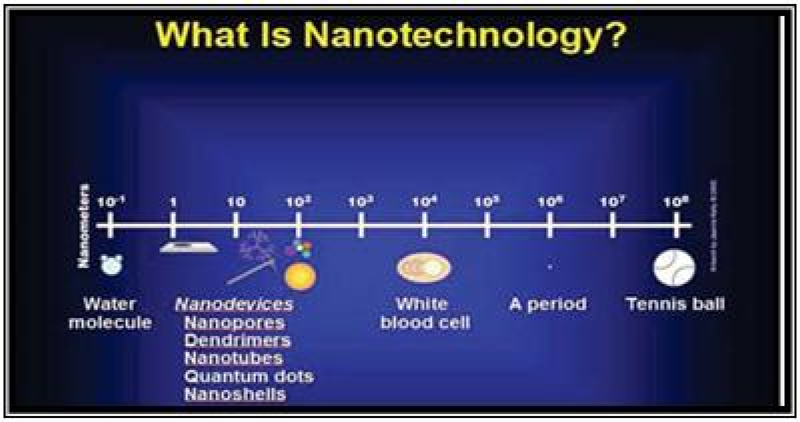


Fig 1: Comparison of nanoparicle with water molecule and tennis ball

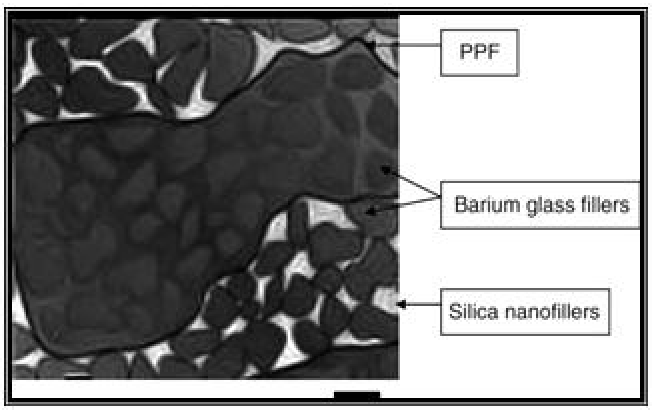


Fig. 2 Three different types of fillers components, non-agglomerated discrete silica nanoparticles, prepolymerized fillers (PPF) and barium glass filler in nanocomposite.

Fig.3 Nanorobots in local anaesthetic solution