Review Article

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Application of Robotics in Dentistry

Farheen Tafti[1] Suyog Savant[2*] Nikita Lilaramani[3] Smita Bodalkar[4] Vasudha Sodani[5]

[1]BDS, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, India.
[1]Associate Professor and Head, Department of Public Health Dentistry, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, India.
[3]BDS, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, India.
[4]Assistant Professor, Department of Public Health Dentistry, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, India.
[5]Associate Professor and Head, Department of Preventive and Paediatric Dentistry, Ahmedabad Dental College, Ahmedabad, Gujarat, India.

ABSTRACT

Background: Nano robotics is a new invention or development in technology which uses specific peculiar motility or migration mechanisms to travel through human tissues with navigational precision. This article specifies its usage and implementation in dentistry as a diagnostic material and filler material in the restorative cements used in dentistry. Its role in delivery of anaesthesia, impression materials, dental biofilms and interdental floss has been well specified. Reconstructive dental nanorobots, microscopes and anti-microbial agents using native indigenous biological organic materials have been precisely described. Further usage in tooth repair, orthodontic tooth sensitivity, implant fabrication, dentifrice and its role of detection and diagnosis of oral cancer has been specified.

Keywords: Robotics, dentistry, technology.

INTRODUCTION

Nanorobots might use specific peculiar motility or migration mechanisms to travel through human tissues with navigational precision. They will acquire and achieve energy and sense and manipulate to influence their surroundings. These nanorobotic functions may be controlled or supervised by an onboard nano computer that executes to complete pre- programmed instructions in response to feedback to local nanorobots via acoustic signals or other means (**Fig 1).** [1]

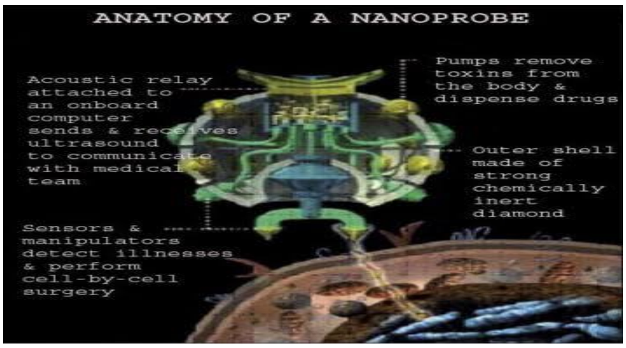

Fig 1: Anatomy of nanopore

Various possible uses in dentistry are as follows:-

1. **Nano diagnostic: -** It is the utilization of nanodevices for the early disease identification or predisposition susceptibility at primary and atomic level. [2] Utilization of atomic force microscopy (AFM) as nano diagnostic tool, for detection or exposure of dental caries, has been stated to recognise bacteria induced demineralization at an ultrasensitive level (**Fig. 2**). Using AFM the interaction between genetically modified Streptococcus mutans and nanoscale morphology has been determined by evaluating nanoscale cellular ultrastructure [3,4]

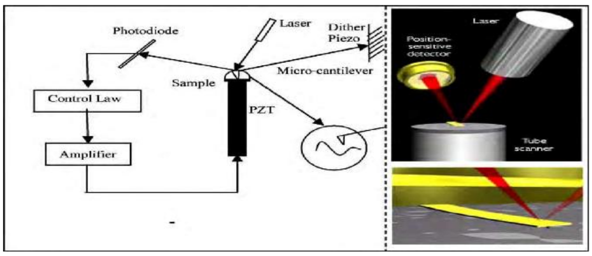

Fig 2: Schematic of basic Atomic force microscope operations.

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*Correspondence Dr. Suyog Savant.
Department of Public Health Dentistry, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, India.
Email: suyogsavant@gmail.com

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2. **Nano Glass Ionomer Cement: -** They are designed and constructed to meet the various discrete requirements, same as other materials used in the mouth. Nanotechnology was used in the development and advancement to provide and contribute some value added supplemental features not typically or commonly associated and correlated with glass ionomer restorative materials. By using bonded nanofillers and nanocluster fillers, along with FAS glass newer type of GIC was formulated and developed using nanotechnology along with its fluoride releasing property **(Fig 3)**. This product meets a wide range of clinical indications ranging from Class I, II, V and core build-up. Nano GIC is an ideal quintessential restorative material for everyday prosaic dentistry. Advantages of this material are superior polish, excellent exquisite aesthetics, higher wear resistance, It is faster, easier to mix and dispense. [5,6]

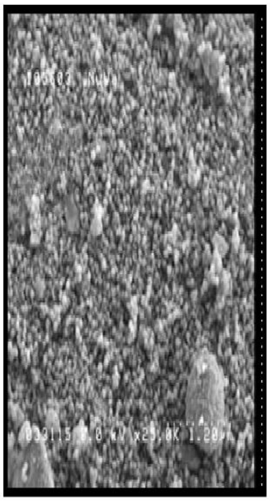

Fig 3: SEM image of nanofillers in nano GIC matrix

3. **Nanocomposites: -** They are no agglomerated discrete and distinct nanoparticles that are homogeneously dispersed in resins or coatings. The nanofiller used include an aluminosilicate powder having a mean particle size of 80 ran and a 1:4 M ratio of alumina to silica and a refractive index of 1.508. It shows Superior hardness, Superior flexural strength, modulus of elasticity and translucency, 50% reduction in filling shrinkage and Excellent handling properties. [7,8] **(Fig 4)**

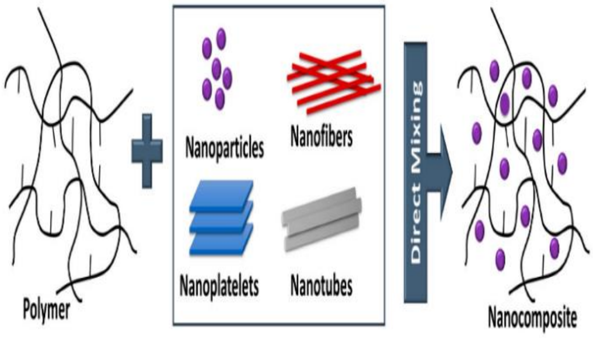

Fig 4: Composition of nanocomposite

4. **Nano solution: -** They display a unique, unparalleled and dispersible nanoparticles, which can be used in bonding agents. This facilitates homogeneity and assures that the adhesive is perfectly mixed every time. [7]

5. **Impression materials**: - Nanofillers are integrated, unified in vinylpolysiloxanes, generating a unique exclusive addition or inclusion of siloxane impression materials. The material has improved flow, refined hydrophilic properties and enhanced upgraded detail precision [7,8]

6. **Local anaesthesia**: - In the era of nano dentistry a colloidal suspension encompassing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of crown or mucosa, the ambulating nanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules. Once incorporated in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. After oral procedures are completed, the dentist instructs the nanorobots to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress. [5,9,10,11] **(Fig 5)**

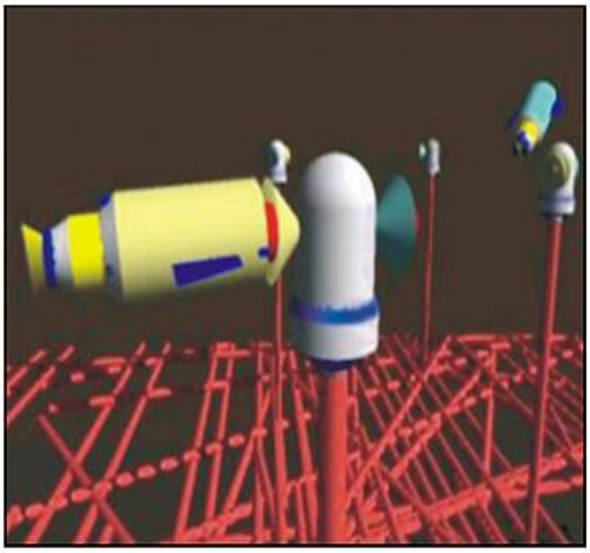

Fig 5: Nanorobots in drug delivery

7. **Role in dental biofilms: -** New silver nanotechnology has been documented to be effective against biofilms. Silver has high affinity for negatively charged side groups sulfhydryl, carboxyl, and phosphate on the cell membrane of the microbes. It targets multiple sites within the cell and interferes and hinders with various cellular pathways, cell wall and protein synthesis and function activity of the cell. It is mainly active against the microbes found in biofilms including Escherichia coli, Staphylococcus pneumoniae, Staphylococcus aureus and Aspergillus Niger. [5,12]

8. **Nanotech floss**: - Ultra-thin, ultra-glide, completely non-shredding with excellent exceptional tensile strength. The unique extra-ordinary nano-structure of dental tape allows for the addition of flavors, and delivery and distribution of medications. [5,13]

9. **Nano needle**: - These are used to execute accomplish the surgery on a single living cell and are nano-meter wide in dimension. Nano tweezers are also under development that will aid and promote in cellular level surgeries in coming years. Trade name: Sandvik Bio line, RK 91™ needles. [5,13] **(Fig 6)**

10. **Dental hypersensitivity: -** Reconstructive dental nanorobots, using native indigenous biological organic materials, could selectively, precisely and accurately occlude specific tubules within minutes, offering patients a quick/rapid and permanent perpetual cure. 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 on board nano computer as directed by the dentist.

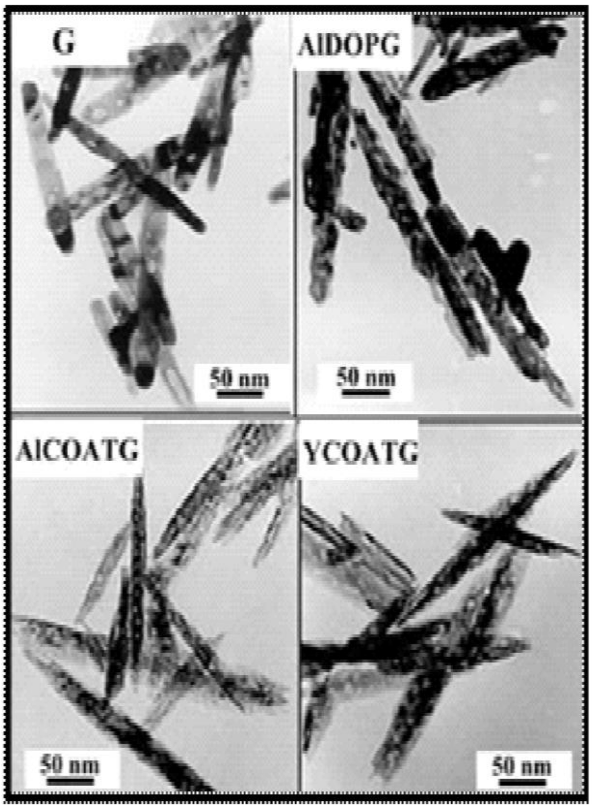

Fig 6: TEM images of nanoneedles.

There are many pathways to travel nanorobots from dentin to pulp. Because of different tubular branching patterns, tubular density may present significant substantial challenge to navigation. Assuming a total path of length of about 10 mm from the tooth surface to the pulp and a modest travel speed of about 100 μm\second. Nanorobots can completely perform the journey into the pulp chamber in approximately 100 seconds. The presence of natural cells that are steadily in motion around and inside the teeth including human gingival, pulpal fibroblasts, cement oblasts, odontoblasts, and bacteria inside dentinal tubules, lymphocytes within the pulp or lamina propria suggests that such journey be feasible by cell-sized nanorobots of similar mobility. [7,14,15]

Dentin hypersensitivity is a pathological phenomenon caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have eight times higher surface density of dentinal tubules and tubules with diameters twice as large as non-sensitive teeth.[16] **(Fig 7)**

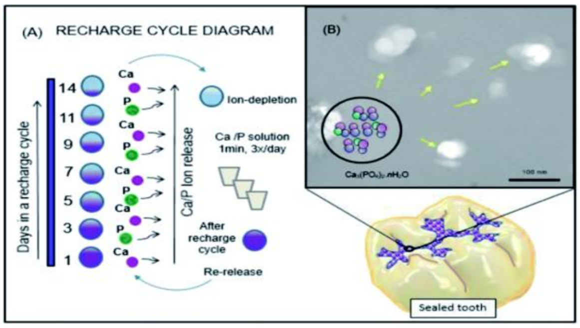

Fig 7: Recharge cell diagram

11. **Aesthetics by ultrafine polishing: -** Polishing the teeth results in roughness, this provides the medium for biofilm formation. Ultra-fine polishing of teeth leads to nanoscale roughness which is few in nanometres. It protects the teeth from cariogenic bacteria, which can be easily and quickly removed from these ultrafine polished surfaces, therefore prevent and thwart staining and lead to superior aesthetics of the restorations.[5,17]

12. **Nano technology microscope: -** The new developed deep probe detectors consisting of the electromagnetic spectrum will be available to screen the human body to reveal hidden matter such as, deep tumours and occult caries in teeth. This is known as Terahertz radiation, **(Fig 8)** which lies in between light and radio waves in the spectrum.[5,18]

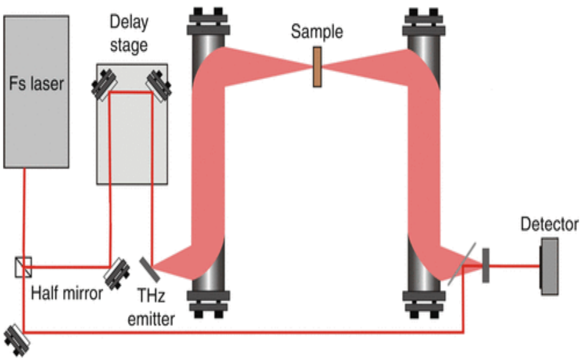

Fig 8: Mechanism of action of Terahertz radiation

13. **Nanoparticles as antimicrobial agents: -** Nano particulates display demonstrates higher antibacterial activity because of their polycationic or polyanionic nature, which extends broadens their applications in numerous fields. Treatment of bacterial biofilms and wound healing gets the benefit from nanoparticles primarily because of their antimicrobial properties and biocompatibility. These disinfect the canal by eliminating the residual microbes in the canal and enhance and intensify the antibacterial action of the intra canal medicaments.[5,19] **(Fig 9)**

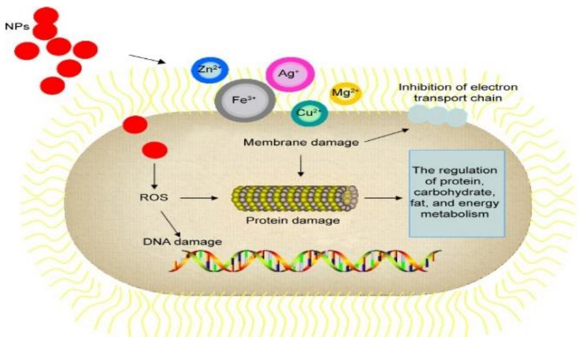

Fig 9: Mechanism of action of nanoparticles as antimicrobial agents.

14. **Nano bond (Bonding agents):-** The new bonding agents are prepared and adapted from nano solutions which contain and incorporates homogenous nanoparticles dispersed in the solution. Silica nanofillers are stable and do not cluster in the solution, so provide the superior bond strength values. Nano interaction zone (NIZ - <300 nm) with minimal decalcification and almost with no exposure to collagen fibers; producing and generating an insoluble calcium compound for a better bond less presumably to deteriorate from enzymes contained in the mouth.[5,20]

15. **Nano ceramics: -** The Organically Modified Ceramic nano-particles constitute a polyciliate backbone. These Nano-Ceramic particles can be described as inorganic-organic hybrid particles where the inorganic part consisting of siloxane and the methacrylic organic part blends or integrates all the particles with resin matrix. The good resistance to microcrack propagation might be related to the strengthening effect of the nano-ceramic particles. Propagating cracks

are either more often reflected or absorbed by the nano- ceramic particles. [5,21]

16. **Orthodontic treatment: -** Orthodontic nanorobots could directly manipulate and influence the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. [7,14]

17. **Tooth repair: -** It involves manufacturing and installation of a biologically autologous whole replacement teeth that includes mineral and cellular components i.e Complete Dentition Therapy. Nano dental techniques involve genetic engineering, tissue engineering, tissue regeneration procedures for major tooth repair. [2]

18. **Tooth durability and appearance: -** Nano dentistry has given material that is nano-structured composite material, sapphire which strengthens tooth durability and appearance. Upper enamel layers are replaced by covalently bonded artificial material such as sapphire. Like enamel, sapphire is a somewhat considerably susceptible responsive to acid corrosion. Sapphire has the best standard whitening sealant, cosmetic alternative[2]

19. **Nanorobotic dentifrice (Dentifrobots): -** Sub occlusal dwelling nanorobotic delivered by mouthwash or toothpaste could patrol and inspect all supragingival and subgingival surfaces at least once a day, metabolising trapped captured organic biological matter into harmless and odourless vapours and operating continuous calculus debridement. These invisibly small miniature Dentifrobots [1-10 micRon], crawling at 1- 10 microns/sec, would be inexpensive and economical which are purely mechanical devices, that would safely and cautiously disactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol. [3] Properly configured Dentifrobots could identify and pinpoint and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing to recognize the 500 or so species of harmless oral micro flora to flourish and develop in a healthy ecosystem. Dentifrobots also would provide and contribute a continuous extended barrier to halitosis, since bacterial putrefaction is the central metabolic process involved in oral malodour. [2] **(Fig 10)**

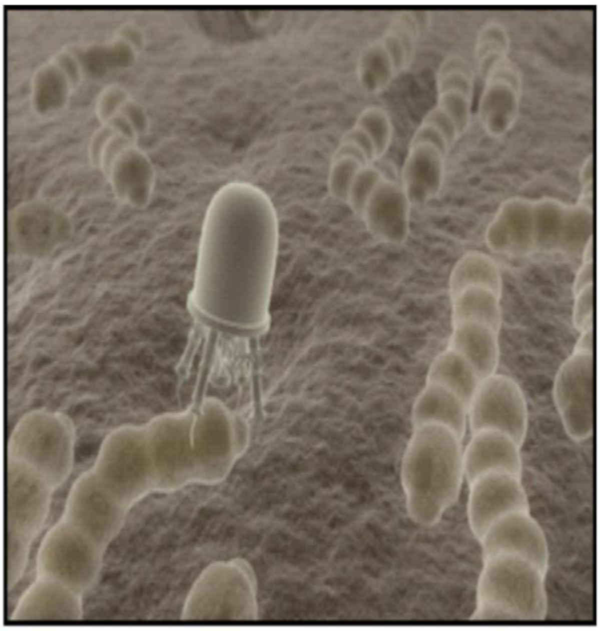

Fig 10: Nanorobotic dentifrice (Dentifrobots) acting on oral microflora

20. **Use of nanotechnology in implant material fabrication: -** In recent years, the development of nanostructured ceramic materials in order to achieve increased strength and toughness has attracted the interest of the manufacturers of ceramic implant material. It has been claimed that composites made with such nanoscale reinforcing fortifying materials as nanotubes, platelets, and nanofibers would have exceptional, remarkable properties. It has been shown that a possible probable path to combining high strength and toughness in a ceramic material is to take advantage of the transformation revolutionary toughening mechanisms in nano zirconia-alumina materials. Alumina-zirconia nanocomposites with relatively low zirconia content (below the percolation limit, ~16 vol%) exhibit similar hardness values to alumina and are not susceptible to the hydrothermal instability. It offer an example of how nanotechnology offers an attractive path to the development of new implant materials but ceramics, even nanocomposite ceramics, will not replicate the unique combinations of mechanical properties

of tooth tissues as they are, for example, much stiffer and wear- resistant future [3,22,23] **(Fig 11)**

Fig 11: NanoTite implants.

21. **Nanoencapsulation: -** They are targeted release systems that encompass nano capsules including novel vaccines, antibiotics and drug delivery with reduced diminished side effects. Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the periodontium. [7,24] South West Research Institute (SWRI) has developed targeted release systems which includes nano capsules including novel vaccines, antibiotics, and drug delivery with reduced side effects. Other products manufactured by SWRI include protective clothing and filtration masks, medical appendages for instantaneous healing. Biodegradable nanofiber delivery platforms for haemostatic wound dressings are in development along with nanocrystalline silver particles with antimicrobial properties on wound dressings, bone targeting nanocarriers: calcium phosphate-based biomaterial is developed, which is an easily flowable and mouldable paste that conforms to and interdigitates with host bone [7,25,26]

22. **Diagnosis of oral cancer and disease:-**

a) **Nano Electromechanical Systems (NEMS)/Cantilever array sensors:-** Nanotechnology based NEMS biosensors that exhibit and reveal precise sensitivity and specificity for analyte detection, down to single molecule level are being developed. They convert (bio) chemical to electrical signal. [2,27]

(i) **Dendrimers:-** These are highly branched macromolecules with a controlled three-dimensional architecture. The branched structure makes it possible to attach other molecules like drugs and contrast agents to the surface. [28] **(Fig 12)**

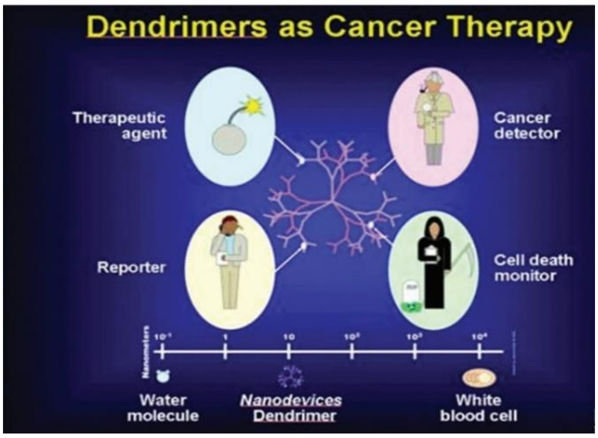

Fig 12: Dendrimers used for detection of cancer

(ii) **Nano shells**: - These are miniscule beads coated with gold. By manipulating the thickness of the layers making up the nano shells, scientists can design these beads to absorb near-infrared light, creating an intense heat that is lethal to cancer cells. Nano shells have a core of silica and a metallic outer layer. [28] **Fig 13**

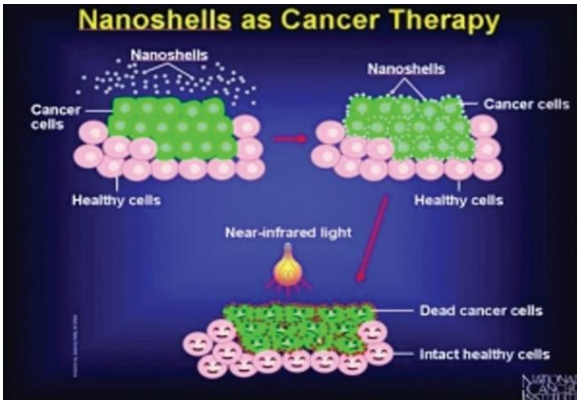

Fig 13: Nanoshells used for detection of cancer

b) **Oral Fluid Nano Sensor Test (OFNASET):-** The Oral Fluid Nano Sensor Test (OFNASET) technology is used for multiplex detection of salivary biomarkers for oral cancer. It is a portable, automated, user-friendly, integrated system that will detect the salivary proteins and nucleic acid targets in the saliva. [5,29] It has been demonstrated that the combination of two salivary proteomic biomarkers (thioredoxin and IL- 8) and four salivary mRNA biomarkers (SAT, ODZ, IL-8, and IL-1b) can detect oral cancer with high specificity and sensitivity [2,30] (**Fig 14)**

Fig 14: Oral fluid nano sensor test machine (OFNASET)

c) **Optical Nano biosensor:-** The nano biosensor is a unique fibreoptic-based tool which allows the minimally invasive analysis of intracellular components such as cytochrome c, which is a very important crucial protein to the process which produces and generates cellular energy and is well-known as the protein involved in apoptosis or programmed cell death. [2,30]

d) **Nanoscale cantilevers:-**These are flexible beams resembling a row of diving boards that can be engineered to bind constrain to molecules associated with cancer. [28]

e) **Nanopores: -** These are tiny holes that allow DNA to pass through one strand at a time. They will make DNA sequencing more efficient. [28] (**Fig 15)**

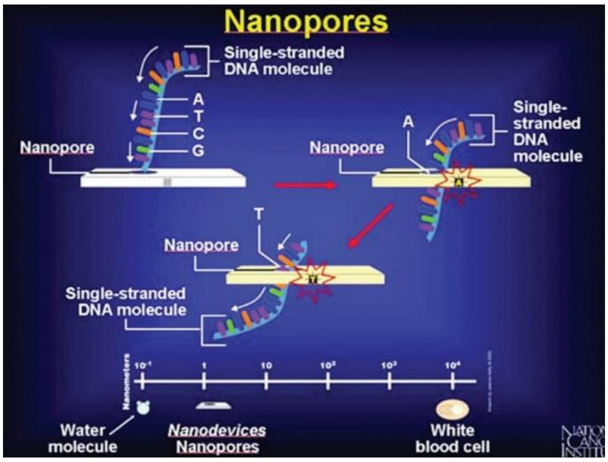

Fig 15: Nanopores used in detection of cancer

f) **Nanotubes:-** These are carbon rods about half the diameter of a molecule of DNA that not only can detect and identify the present existence of altered genes but also may help researchers pinpoint the exact and precise location of those changes. [28]

g) **Quantum dots: -** Quantum dots are nanomaterials that glow very brightly when illuminated by ultraviolet light. They can be laminated with a material that makes the dots attach specifically and precisely to the molecule to be tracked. Quantum dots bind themselves to proteins unique uncommon to cancer cells, literally bringing tumours to light. [28] (**Fig 16)**

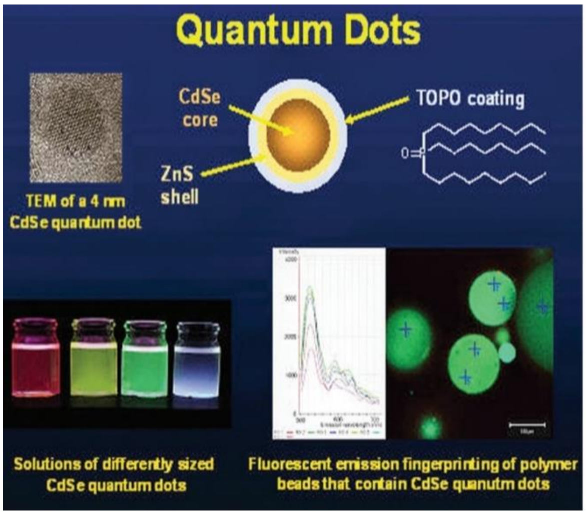

Fig 16: Quantum dots used for cancer detection

23. **Treatment of oral cancer:-**

a) **Nanomaterials For Brach therapy:-** BrachySilTM (Sivida, Australia) delivers 32P, clinical trial.[2]

b) **Photodynamic Therapy: -** Hydrophobic porphyrins are potentially interesting molecules for the photodynamic therapy (PDT) of solid cancers or ocular vascularization diseases. [2,32]

Nanotechnology will have future medical applications in the field of nano dentistry. Nano dentistry will make it possible available to maintain near-perfect oral health through the use of nanomaterials biotechnology and nanorobotics. Through this it will be possible to provide high-quality dental care to the millions of the world's population who current and importantly receive no significant dental are [22] Reconstructive dental nanorobots could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure. Nano dentistry could also play a vital inheritable role in natural tooth maintenance. The appearance and durability of teeth may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which have 20 to 100 times the hardness and strength of natural enamel. A sub occlusal-dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odourless vapours and performing continuous calculus debridement. [7,22,33]

Emerging developing technologies and new nanoscale information have the potential capability to transform revolutionize dental practice by advancing or introducing 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. One of the key changes is the application and utilization of new research tools that have changed and recreated the size-scale of dental research. Nanotechnology permits a new understanding, consideration and manipulation of these biological processes and materials at the nanoscale (1-100 nm) level. Based on their unique, extraordinary capabilities efficiency/proficiency and resolution, nanoscale science probes surfaces using forces, displacement resolutions and concentrations on the piconewton, nanometre and picomolar scales, respectively. There is a hope that nanotechnology will change dentistry, healthcare, and human life more profoundly than many developments of the past, as they have a potential ability to bring about significant important benefits, such as improved health, better use of natural resources, and reduced environmental pollution. Molecular technology is destined and intended to become the core nucleus and technology underlying all of 21st century medicine and dentistry. [22]

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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