IP International Journal of Periodontology and Implantology 2021;6(1):6–10

Content available at: https://www.ipinnovative.com/open-access-journals

IP International Journal of Periodontology and Implantology

Journal homepage: https://www.ipinnovative.com/journals/IJPI

Review Article

Nano-robotics: The future of health and dental care

Shivani Sachdeva[1], Amit Mani[1], Shubhangi A Mani[2,*], Hiral R Vora[1], Sonali S. Gholap[1], Jaseleen Kaur Sodhi[1]

[1]*Dept. of Peridontology, Rural Dental College, Loni, Maharashtra, India*
[2]*Dept. of Orthodontics, Rural Dental College, Loni, Maharashtra, India*

ARTICLE INFO

Article history:
Received 10-03-2021
Accepted 23-03-2021
Available online 16-04-2021

Keywords:
Nanorobotics
Periodontics
Nanodentistry

ABSTRACT

Background: The future of medical health care is evolving day in and out. Researchers are focusing on facing the biggest challenges in the field by using smallest of the solutions. Nanotechnology uptil now have been seen only in science fiction stories and movies. An upcoming future is now promising us turn this fiction turn into reality.
Content: Nanorobotics is a field where microsocopic robots will be created to perform medical and dental procedures. Gaining access to robotics at nano level in the dental world, the aim will be to treat dental conditions rapidly and more efficiently, by causing minimum pain. Nanorobots to be made up of "smart" structure which will have the ability of inciting, sensing, signalling, processing information and perform the required treatment at nano scale.
Conclusion: The emergence of nanorobtics in healthcare sector will change the face of medical sciences. The article aims to elucidate the current scenario of nano world in dentistry and how nanorobotics will fabricate a better future in treatment modalities in dentistry.

1. Introduction

Nano is measured as billionth of meter, or 10^{-9} of a meter. It is taken from a Greek word which means dwarf. It is defined as the research and development of materials, systems and devices exhibiting biological, physical and chemical that are different from those found on a bigger scale (matter smaller than scale of things like molecules and viruses).[1] Nano the word when combined with nouns; forms terms such as nanotechnology, nanometer, nanomedicine and nanoscience. Nanoscience and nanotechnology introduces us to a world where we are able to see and can achieve control at atomic and molecular level. In the nanoworld, a tiny difference in size adds 1huge differences in function.

Nanorobotics is the technology of creating machines or robots at or close to the microscopic scale of nanometers ($10-^{9}$).[2] According to the theory of nanorobotics "nanorobots being microscopic in size, will probably be necessary for numerous of them to work together, and perform microscopic & macroscopic tasks".[3] With emergence of Scanning Tunnelling Microscope (STM) and Atomic Force Microscope (AFM), emergence of nanotechnology took place. With increasing interest in the future of dental applications in nanotechnology has given birth to nanodentistry involving maintenance of oral health by using nanomaterials, biotechnology and nano-robotics.[2]Nanorobots are microscopic devices which are measured in nanometers (one nanometer equals to one millionth of one millimeter).[2] Nanorobots are so minute that they will easily traverse the physical human body. Nanorobotics is that technology which creates robotic or machines on the brink of microscopic scale of nanometers.[4,5] Nanorobots will be aimed to be contructed in such a way that they will take care of the method which initiates from diagnosing the condition, treating it, and

* *Corresponding author*.
E-mail address: dr.shivani19@gmail.com (S. A. Mani).

https://doi.org/10.18231/j.ijpi.2021.002

further preventing the disease, thus intercepting diseases and improvising human health by the use of molecular tools and knowledge of molecular nature of human body. The unique phenomenon that happens at the nanoscale, has been drawing attention of the researchers from many different fields, including medicine, dentistry chemistry, physics, engineering and others. Nanorobotics in surgery has provided wonderful tools for surgeons with excellent control over precision instruments, which are being useful for minimally invasive surgery. Instead of instruments, surgeons will use joystick handles to control robotic arms containing miniature instruments performing micro-movements in cell surgery.[5] Nanorobots will amalgamate surgeon's motor performance, diagnostic proficiency and sensations with haptics and augmented reality.

The scientists from the fields of regenerative medicine and tissue engineering are constantly looking for new ways to apply the principles of cell material science, transplantation & bioengineering for the construction of biological substitutes which will further restore and maintain the normal functions in injured and diseased and tissues.

1.1. Theory and evolution of tissue engineering

Long before, nanotechnology was introduced by, Sir Richard Feynman on December 29 in 1959 talked about "There's Plenty of Room at the Bottom" at an American Physical Society meeting at the California Institute of Technology (CalTech), where he spoke on concepts and ideologies behind nanoscience and nanotechnology.[6]

Albert Hibbs (circa 1959), who was Richard Feynman's former graduate student and collaborater had originally suggested the idea of medical use of "biological machines." Thus further probably the idea of microstructured biological machines could be used in medical treatment came into picture. As Feynman put it "swallow the surgeon"ideology was seen in his 1959 essay, "There's Plenty of Room at the Bottom."[6]

Prof. Kerie E. Drexler (1996), a great writer & researcher in nanotechnology, coined the term 'Nanotechnology'.[2]He got inspired by Feynman and published his book, "Engines of Creation", where he penned about genetically programmed molecular machines as upcoming technologies in cellular biology.[7]

Robert Frietas (1998), was the first person to study nanorobots which was related to medical nanorobots called as respirocytes which were made in resemblance to red blood cells.[8]

2. Discussion

2.1. Types of hypothetical nanorobotic systems

2.1.1. Microbivores

1. Used for making of artificial mechanical cell walls.[9]
2. • Its primary function is to destroy microbiological pathogens found in the human bloodstream using a digest and discharge protocol.[10]
3. Microbivores would fully eliminate septic infections in minutes to hours, in compared to the natural phagocytic defenses. Even when aided by antibiotics, natural defenses can often require weeks or months to achieve complete clearance of target bacteria from the bloodstream.
4. Hence microbivores appear to be up to ∼1000 times faster-acting than either unaided natural or antibiotic-assisted biological phagocytic defenses, and able to extend the therapeutic competence of the physician to the entire range of potential bacterial threats, including locally dense infections.[9]

2.1.2. Respirocytes

1. These are artificial red blood cells which are able to deliver 236 times more oxygen to the tissues per unit volume than natural red cells.
2. Primary medical applications of respirocytes will include transfusable blood substitution; partial treatment for anaemia, perinatal/ neonatal and lung disorders; enhancement of cardiovascular/neurovascular procedures, tumour therapies and diagnostics; prevention of asphyxia; artificial breathing; and a variety of sports, veterinary, battlefield and other uses.[9]

2.1.3. Clottocytes

1. These are artificial mechanical platelet.
2. The artificial mechanical platelet or clottocyte may allow complete hemostasis in as little as ~1 second, even in moderately large wounds.
3. This response time is on the order of 100-1000 times faster than the natural system.[11]

2.1.4. Pharmacytes

1. These are nanorobotic system aimed for pharmaceutical drug delivery.
2. Pharmacytes will be self-powered, computer-controlled nanorobotic systems capable of digitally precise transport, timing, and targeted delivery of pharmaceutical agents to specific cellular and intracellular destinations within the human body.[12]

2.1.5. Chromallocytes

1. It is aimed to use chromallocytes in gene delivery, chromosome replacement therapy.
2. The chromallocyte is a hypothetical mobile cell-repair nanorobot capable of limited vascular surface travel into the capillary bed of the targeted tissue or organ, followed by extravasation, histonatation, cytopenetration, and complete chromatin replacement

in the nucleus of one target cell, and ending with a return to the bloodstream and subsequent extraction of the device from the body, completing the chromosome recplacement therpay mission.[13]

2.2. Applications of nanorobotics in medicine and dentistry

Nanodentistry will take us into a unique world of minute dentistry for the enhancement of the complete oral health and hygiene by employing nanomaterials, biotechnology, including tissue engineering & ultimately dental nanorobotics, advancing for the better future.

2.2.1. Nanoanaesthesia

1. The dentist will instil a colloidal suspension containing millions of active analgesic micron-sized dental nanorobot ‘particles’ on the patient’s gingivae.
2. Once it comes in contact with the surface of the crown or mucosa , the ambling nanorobots reach dentin by migrating into the gingival sulcus and pass painlessly through the lamina propria or through 1-3μ thick layer of loose tissue at the CEJ.
3. Upon reaching the dentin, they enter the dentinal tubules up to 1-4μ depth and move towards the pulp guided by a combination of chemical gradient, temperature differentials and positional navigation under nanocomputer control.
4. Thus the migration of nanorobots from tooth surface to the pulp occurs within 100 seconds.
5. Once installed in the pulp, they establish control over nerve impulse, analgesic nanorobots commanded by the dentist shut down all sensitivity in any particular tooth requiring treatment.
6. The selected tooth is immediately anaesthetized as soon as the dental professional presses the hand held control.
7. After the procedure is completed, the dentist orders the nanorobots to revive all the sensations and will emanate from the tooth.[14]

2.2.2. Dentine tubule blocking to alleviate hypersensitivity

1. Dental hypersensitivity is one of the most common clinical problem encountered.
2. Hypersensitivity is caused by changes in the pressure transmitted hydrodynamically to the pulp.
3. The dentinal tubules of a hypertensive tooth have twice the diameter and eight times the surface density of those in non sensitive teeth.
4. These characteristics have led to the utilization of nanorobots that selectively and precisely occlude tubules in minutes, by using local, native materials, thus offering patients a quick and permanent cure.[15]

2.2.3. Bone replacement materials

1. Nanotechnology aims to mimic the natural structure of bone for orthopaedic and dental applications and, more particularly, for the development of nanobone.
2. Nanocrystals have a loose microstructure, with nanopores situated between the crystals.
3. The surfaces of the pores are modified such that they adsorb protein, because of the addition of silica molecules.[16]
4. Hydroxyapatite nanoparticles used to treat bone defects are:
5. Ostim (Osartis GmbH & Co. KG, Ohernburg, Germany) HA.
6. VITOSSO (Orthovita, Inc., Great Valley Parkway Malvern, PA 19355, USA) HA þ TCP.
7. NanOSS (Angstrom Medica, USA) HAThese can be utilized in maxillofacial injuries which require bone graft, cleft patient and osseous defect in periodontal surgeries.[17]

2.2.4. Nanoencapsulations

1. Targeted release systems which include the nanocapsules are yet under trial for inclusion in vaccines and antibiotics.[16]

2.2.5. Nanorobotic dentifrices (dentifrobots)

1. Dentifrobots are planned to be devised intrinsically such that there will be subocclusal – dwelling nanorobotic dentifrice delivery by mouthwash or toothpaste.
2. This will enable the invigilation of all supragingival and subgingival surfaces at least one time per day.
3. These dentifrobots will metabolize trapped organic matter into harmless and odourless vapours and will perform continuous calculus debridement.
4. Dentifrobots will provide a continuous barrier to halitosis, since bacterial putrefaction is the central metabolic process involved in oral malodour.
5. If such precise dental care will be available on a daily basis from an early age, conventional caries and gum disease will start reducing eventually.[18]

2.2.6. Orthodontics

1. Nanorobots in orthodontics will allow painless tooth up righting, rotating, and vertical repositioning, and also rapid tissue repair.
2. A new stainless-steel wire that uses nanotechnology is under the study which will combine ultra-high strength with good deformability, corrosion resistance, and surface finish.
3. In the near future, orthodontic nanorobots could directly manipulate the periodontal tissues, further allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to

hours.[17]

2.2.7. Nanocomposites

1. Microfillers in composites and microcore materials have long been in use. Although the filler particle size cannot be reduced below 100 nm, nanocomposite particles are minute enough to be synthesized at the molecular level.
2. These nanoparticles improve the compressive strength of the material. Filler particles of submicron size, such as zirconium dioxide, are also necessary to improve polishability and aesthetics.
3. However, when particles of this size are used, the material may be more prone to brittleness and cracking or fracturing after curing.
4. To address this issue, hybrid composites and composites containing a wider distribution of filler particles have come into use.
5. Although these composites display a better balance of strength and aesthetics, they are weak due to nanoparticle clumping or agglomeration.
6. This problem can be overcome by incorporating a proprietary coating process during the particle manufacturing procedure, thereby eliminating weak spots and providing consistent strength throughout the entire “fill” of the core build-up.
7. Additionally, the even distribution of nanoparticles results in a smoother, creamier consistency and improves flow characteristics.
8. Once the material is cured to its hardened state, these properties contribute to the dentin-like cutability and polishability of the material.

2.2.8. Major tooth repair/nanotissue engineering

1. Replacement of the whole tooth, including the cellular and mineral components, is referred to as complete dentition replacement.
2. This therapy is possible through a combination of nanotechnology, genetic engineering, and tissue engineering.
3. Complete dentition replacement was the basis for research by Chan et al., who recreated dental enamel, the hardest tissue in the human body, by using highly organized microarchitectural units of nanorods.[18]

2.2.9. Drawbacks

1. Initial costing will be expensive.
2. These will be difficult to interface, customize and complex mechanisms will get involved.
3. It will be technique sensitive
4. Electrical system may be hazardous which may create stray fields which could activate bioelectric based molecular systems in the body
5. Nanorobots can pose as a brutal risk in the field of terrorism. The terrorism and anti-groups could make use of nanorobots which would aim at harassing the communities because nanotechnology also has the capability of destructing the human body at the molecular level.

3. Conclusion

Nanoworld is evolving on daily basis. Researchers and scientists are working to device the most minute changes that can bring revolutionary changes in the medicine field and dentistry via nanotechnology. This will simplify health care facilities in the leaping future and ease off treatment modalities for the welfare of the humanity. Nanodentistry will bring about revolutionary outcomes in the diagnostic & treatment modalities for the patients seeking dental care. Although the research is in the initial process, years from now nanoscience will evolve to be new normal in the world of medical science.

4. Conflicts of Interest

All contributing authors declare no conflicts of interest.

5. Source of Funding

None.

References

1. Freitas RA. Nanomedicine. In: Basic capabilities. vol. 1. Landes Bioscience: Georgetown, Texas; 1999.
2. Freitas R. Nanodentistry. *J Am Dent Assoc*. 2000;131(11):1559–65. doi:10.14219/jada.archive.2000.0084.
3. Jhaveri HM, Balaji PR. The future of dentistry a review. *Jr I Prosthetic*. 2005;5:15–7.
4. Cavalcanti A. Robots in Surgery. *Euro Nano Forum*. 2005;.
5. Wang. can man made machines compete with nature biomotors. *ACS Nano*. 2009;3(1):4–9.
6. Feynman R. There is plenty of room atthe bottom. *Sci*. 1991;254:1300–1.
7. Biology JR. Drexler, and nanotechnology. *Nanotoday*. 2005;8(8):56.
8. Freitas RA. Exploratory design in medical nanotechnology: a mechanical artificial red cell. *Artif Cells Blood Substit Immobil Biotechnol*. 1998;26(4):411–30.
9. Freitas RA. Microbivores: Artificial Mechanical Phagocytes Using Digest and Discharge Protocol; 2001.
10. Freitas RA. Clottocytes: artificial mechanical platelets. *Foresight*. 2000;41.
11. Freitas RA. Pharmacytes: An Ideal Vehicle for Targeted Drug Delivery. *J Nanosci Nanotechnol*. 2006;6(9):2769–75. doi:10.1166/jnn.2006.413.
12. Freitas RA. The Ideal Gene DeliveryVector: Chromallocytes, Cell RepairNanorobots for Chromosome Replacement Therapy. *J Evol Technol*. 2007;16:1–97.
13. Cavalcanti A, Rosen L, Kretly CL. Nanorobotic challenges in biomedical applications , design and control. IEEE ICECS International Conference on Electronics, circuits and systems, Tel-Aviv, Israel; 2004.
14. Nagpal A, Kaur J, Sharma S, B A, Sachdev P. Nanotechnology - the era of molecular dentistry. *Indian J Dent Sci December*. 2011;3(5):134–6.
15. Vijayalakshmi R, Kumar SR. Nanotechnology in dentistry. *Indian J Dent Res*. 2006;17(2):62–9. doi:10.4103/0970-9290.29890.

16. Verma SK, Prabhat KC, Goyal L, Rani M, Jain A. A critical review of the implication of nanotechnology in modern dental practice. *Natl J Maxillofac Surg*. 2010;1(1):41–4. doi:10.4103/0975-5950.69166.
17. Shetty NJ, Swati P, David K. Nanorobots: Future in dentistry. *Saudi Dent J*. 2013;25(2):49–52. doi:10.1016/j.sdentj.2012.12.002.
18. Abhilash M. Nanorobots. *Int J Pharma Bio Sci*. 2010;1(1):1–10.

Author biography

Shivani Sachdeva, Reader

Amit Mani, Professor and HOD

Shubhangi A Mani, Professor

Hiral R Vora, Post Graduate Student

Sonali S. Gholap, Post Graduate Student

Jasleen Kaur Sodhi, Post Graduate Student

Cite this article: Sachdeva S, Mani A, Mani SA, Vora HR, Gholap SS, Sodhi JK. Nano-robotics: The future of health and dental care. *IP Int J Periodontol Implantol* 2021;6(1):6-10.