|| ISSN(online): 2589-8698 || ISSN(print): 2589-868X ||
International Journal of Medical and Biomedical Studies
Available Online at www.ijmbs.info
PubMed (National Library of Medicine ID: 101738825)
Index Copernicus Value 2018: 75.71
Review Article
Volume 4, Issue 3; March: 2020; Page No. 94-98

ROLE OF NANOTECHNOLOGY IN DENTAL SCIENCES: A REVIEW

Ramakoteswara Rao N[1*], Kranthi kiran Reddy E[2], Leena Gahane[3], SV Ranganayakulu[4]
[1]MNR Academy of Higher Education & Research, Hyderabad, India.
[2]MNR Dental College & Hospital, Hyderabad, India.
[3]Anjuman College of Engg. & Tech, Nagpur, India.
[4] Gurunanak Group of Institutions, Hyderabad, India.

Article Info: Received 18 February 2020; Accepted 18 March 2020
DOI: https://doi.org/10.32553/ijmbs.v4i3.1055
Corresponding author: Ramakoteswara Rao N
Conflict of interest: No conflict of interest.

Abstract
Nano technology is the multi disciplinary science and technology, which has emerged as new science exploiting specific phenomena and direct manipulation of materials on nanoscale. Nanotechnology deals with the physical, chemical, and biological properties of structures and their parts at nanoscale dimensions. It's established on the concept by creating functional structures by controlling corpuscles and molecules on a one-by-one basis by different physical and chemical synthesis methods. Developments in materials science and, nano biotechnology is especially forestalled to provide elevates in dental sciences and initiations in oral health-related diagnostic and therapeutical methods.
Keywords: Nano Science, dentistry, Nanocomposite, Nanorobots, Nanomaterials.

Introduction

The term *nanotechnology* is derived from the Greek word *nanos*, meaning dwarf. The nobel prize winner Richard Phillips Feynman, during 1959 in his speech, cited that 'there is a plenty of room at the bottom' to the American Physical Society, had first projected the discovery of dimension of at a billionth meter scale[1]. The term nanotechnology was acquainted by Norio Taniguchi in 1974, when he mentioned a production technique to get extra high accuracy and ultra-fine dimensions[2], later in 1986, K. Eric Drexler contributed to its development by introducing the concept of molecular nanotechnology in his 1986 publication of creation [3]. Applications within this field started within the Eighties with the innovation of the scanning tunnelling microscopes and therefore the discovery of nanotubes and fullerenes [4-6]. Nonetheless, major initiatives started at the starting of this century, thence ushering in the era of nanotechnology.

Development of Nanotechnology

The main objectives of nanotechnology are to enable the analysis of structures at the nanoscale, to empathize the physical attributes of structures at the nanoscale, to fabricate nanoscale structures, with nano-precision, and to establish a linkup nanoscopic and macroscopic creations by fabricating adequate methods. Nanotechnology involves the exploitation of materials, devices, and systems showing properties that is dissimilar from those found in macro and micro scale. In the nano dimension (1-100 nm), the lower limit confined to the size of a hydrogen atom (0.25 nm) and the upper limit embarks on from a size where phenomena different from larger structures start seeming. In layman's terms, if a toddlers marble is compared to a nanometre. A measure would seem as the earth's diameter. This novel scale of engineering induces researchers of various areas including medical specialty and dental medicine. An overview from the general applications of nanotechnology will render to improve the understanding the concept. However, this review will focus on the current applications of nanotechnology in dental medicine, and the novel materials and techniques that have been explicated utilizing its principles for diagnosis, prevention, reclamation, and pulp/ periodontal re-formation.

Nano material research falls under two approaches. The bottoms-up approach deals with the creation and development of new smart materials or devices, wherein various processes are utilized to induce nanostructures to self assemble at a desired scale and then organize into higher macro scale structures.[8,9] Various particles formulated at the nano scale include nanorods, nanotubes quantum dots, fullerenes, and nano capsules. Next one is the top-down approach deals with the enhancement of existing materials, where the existing structures are contracted and miniaturized into the nanorange with their molecules consecutively rearranged to achieve the desired properties.[8,9] Research in the medical sector is directed toward the development and application of nano devices in the sphere of diagnostics, drug delivery and therapeutics.

Nanotechnology in Dental Sciences

The area of dental medicine is receiving unprecedented support from the biotechnological sector in the form of new inventions that include improvised diagnostic aids and treatment devices. Different nanoparticles appropriate for drug and gene delivery are being designed and tested for safety, control, and proper use. Drug delivery system is therapeutical arrangements that can control the discharge of dose drugs and deport the medicines optimally. One such agent is nanotube. It is open-ended barrels that can carry infinitesimal amounts of dose drugs within their 50-100 nm wide drug cells. The open ends of these tubes are covered up with pH or thermosensitive caps which decompose upon arrival conflagrated sites. Likewise, carbon fullerenes and polymeric nanoparticles also are developed as drug delivery vehicles [16, 17]. These carriers own antibody-modified surfaces, which enable drug delivery to specific target sites that are unapproachable to carrier-free dose drugs.[17]

Recently, 2-layered iron compound magnetic nanoparticles were utilized in associate animal study for cancer tissue destruction.[18] , after these nanoparticles are injected into tumors, and a magnetic field is applied, exchange coupling takes place between the two layers, resulting in locally increased temperature which can potentially destroy the cancer tissue. The field of dental medicine is receiving new support from the biotechnological sector, in the form of novel innovations that include improvised diagnostic aids and treatment devices. Bone replacement materials developed via nanotechnology are commercially available [19-20], Bone engrafts with more benevolent features can be developed with the use of nanocrystalline hydroxyapatite. Moreover, it was shown that nanocrystalline hydroxyapatite energised the cell proliferation required for periodontic tissue re-formation.

Prospective applications of tissue engineering and stem cell research in dental medicine include the discourse of oral facial cracks, bone augmentation, cartilage re-formation of the mandibular joint, pulp reanimate, periodontal ligament regeneration, and implant osseointegration showing in figure. Tissue engineering allows the position of implants that eliminate a elongated convalescence amount, ar biologically and physiologically a lot of stable than antecedently used implants, and may safely support early loading.[16,17]

Surveys related to the re-formation of bone tissue comprise a major part of the studies in the tissue-engineering. Nanoscale fibers are similar in shape to the arranging between collagen fibrils and hydroxyapatite crystals in bone. The perishable polymers or ceramic materials that are often preferable in bone tissue engineering, may not have sufficient mechanical survival contempt, their osteoconductive and biocompatible properties in spite of their osteoconductive and biocompatible properties. Studies performed in recent years suggest that nanoparticles can be used to raise the mechanical properties of these materials. The main reason for favouring nanoparticles is that the range of dimension of these structures is the same as that of cellular and molecular constituents. Bone replacing materials acquired via nano-technology are commercially accessible.

Bio - nano based Dental implants

Natural bone surface has a roughness of approximately 100 nm, and such nano details are consequently important on the surfaces of implants. Osteoblast proliferation has been stimulated through the initiation of nano size particles on the engraft surface.Roughing the implant surface at the nanoscale level is essential for the cellular reception that passes in the tissue.[23]

Titanium implants treated with a nanostructured atomic number [20] surface coat were inserted into rabbit tibias, and their effect on osteogenesis was investigated; the nanostructured calcium coat increased the responsiveness of the bone around the implant.[25] Many in-vitro studies have shown that the nanotopography of the implant surface considerably affects osteogenic cells and that the nanoscale surface morphology enhances osteoblast adhesion. Moreover, the nanoscale surface morphology augments the surface area and thus provides an increased implant surface area that can react to the biologic environment.[25-28]

Nanocomposite for artificial teeth

Nanotechnology allows for the product of nano-sized filler corpuscles that are congenial with dental composites; thence, a greater amount of filler can be added into the composite resin matrix.[31] accretionary interest in aesthetical regainings in recent years has led to further developing of material that have the equivalent color as that of teeth.[29] The Newest approach in composite resins is the execution of nanoparticle technology into recuperative materials.[16] Nanoparticles allow the production of composites with a smoothen surface after the smoothing process and confer premium esthetic lineaments to the material. Composite resins comprising such corpuscles are easy to shape and have a high degree of strength and resistance to attrition. Hence, the area of use of resins containing nanoparticles is wider than that of composites holding hybrid and microfill fillers.[29] Bacteria cause plaque accretion and succeeding periodontic disease by cohering to the rough surfaces of restitutions.[35] numerous articles have suggested that importantly smoother surfaces were attained using composites with nanofiller compared to other composites. This is because nanocomposites have very much smaller sizes and contain greater amounts of filler posed. Nanofiller technology has enabled the

assembly of nanofill composites by drawing along the aesthetic options of microfill composites and also the mechanical lineaments of hybrid composites.[29] In-vitro analyses have shown that these composites had preferential physical, mechanical, and esthetical features. Seeing these characteristics, the nanocomposite may be a tangible example of an ideal composite.

Dentifrobots (Nano robotic dentifrice):

Nano computers that have been programmed via acoustic signals utilised for ultra ultrasonography can ensure nanorobotic functions.[11] Nanorobots (dentifrobots) left by gargle or toothpaste on the occlusal surfaces of teeth can make clean organic residuals by moving end-to-end the supragingival and sub gingival surfaces, unceasingly preventing the aggregation of the calculus. These nanorobots can move as fast as 1 to 10 micron/second, are safely inactivated while they're swallowed.

Dental hypersensitivity

Natural supersensitive teeth have eight times higher surface density of dentinal tubules and diameter with double as large as nonsensitive teeth. Rehabilitative dental nanorobots, using native natural materials, could selectively and accurately occlude specified tubules within moments, offering patients a quickly and permanent cure.[51-53]

Orthodontic treatment.

Orthodontic nanorobots might directly manipulate the drugs tissues, permitting fast and painless tooth straightening, rotating and vertical position inside minutes to hours.[54]

Nano Surface engineering in dentistry

Though enamel, cement, and bone are formed by the organized accumulation of apatite crystals with carbon dioxide, enamel tissue has distinct characteristics because it doesn't contain collagen and reconstructing is not possible. Nanoparticles presented plays an important role during enamel bio mineralization, spontaneous self-assembly of the amelogenin protein in nano-spheres plays an important role in controlling the growth of apatite crystals with carbon dioxide. These processes can be applied for making other mineralized tissues such as bone and cement, in which nano-structures were similarly used.

Although enamel, cement, and bone are formed by the organized accumulation of apatite crystals with carbon dioxide, enamel tissue has distinct characteristics because it does not contain collagen and remodelling is not possible. Nanoparticles plays an important role during enamel bio mineralization, spontaneous self-assembly of the amelogenin protein in nano-spheres plays an important role in assuring the growth of apatite crystals with carbon dioxide. This process can be enforced for forming other mineralized tissues such as bone and cement, in which nano-structures were similarly used.

Dental caries; a study that inquired the bacteriostatic effects of silver, zinc oxide, and gold nanoparticles on streptococci variations, which induces dental dental caries, reported that compared to the other nanoparticles, silver nanoparticles had an antimicrobic effect in lower concentrations and with lower toxicity.[48] So, use of toothpaste containing nanosized calcium carbonate enabled remineralisation of early tooth enamel wounds. Thoroughly and effectively cleans the root canal and allow applying material precisely. Afterwards using nano brush rosin sealants can diffuse deep into dentin tubules and lateral channels.

Nanotechnology images in oral and maxillofacial surgery

More advances in digital dental imaging techniques are also expected with nanotechnology. In digital radiographies obtained by nanophosphor scintillators, the radiation dose is diminished and high-quality images are obtained.[4] identified cell manipulation and surgery performed with tools sized at the molecular level will provide great benefits, particularly in tumour tissue surgery.

Applications of Nanotechnology in Dental sciences

Nanotechnology is anticipated to find its application in all the specialisations of dental sciences. A few of its applications as reported in the literature, would include improved diagnosing and discourse of oral cancers, nanorobotic manufacture and installment of a biologically autologous whole replacement tooth, in production of subocclusal-dwelling nanorobotic dentifrices extradited by gargle or toothpaste which would patrol all supragingival and subgingival surfaces at least at one time a day, metabolising entrapped organic matter into harmless and odourless vapors and playacting continuous calculus debridement and in production of a colloidal solution containing billions of activistic analgetic micron-size dental robots to be instilled on the patient's gingiva resultant in anesthesia.

Nanodentistry

Nanodentistry will make conceivable sustenance of comprehensive oral health by applying nanomaterials, including tissue engineering and dental nanorobots. These nanorobot functions may be controlled by an onboard nanocomputer that executes preprogrammed instructions in response to local sensor stimuli. New potential treatment opportunities in medicine could embrace anesthesia, teething renaturalization, and permanent hypersensitivity heal, complete orthodontic realignments during a single office visit, covalently bonded diamondised

enamel, and continuous oral health maintenance using mechanical dentifrobots. When the first micro-size dental nanorobots is formed, dental nanorobots might use specific motility mechanisms to crawl or swim through human tissue with navigational precision, acquire energy, sense, and manipulate their surroundings, achieve safe cytopenetration and use any of the multitude techniques to monitor, interrupt, or alter nerve impulse traffic in individual nerve cells in real time.. Alternatively, the dentist may issue strategic instructions by transmitting orders directly to in vivo nanorobots via acoustic signals or other means.[54,55]

Nanotechnology has improved the properties of various kinds of fibres.[56,57] Polymer nanofibers with diameters in the nanometer range, possess a larger surface area per unit mass and permit an easier addition of surface functionalities compared to polymer microfibers.Polymer nanofiber materials have been studied as drug delivery systems, scaffolds for tissue engineering and filters. Carbon fibers with nanometer diamensions showed a selective increase in osteoblast adhesion necessary for successful orthopedic/dental implant applications due to a high degree of nanometer surface roughness.[57,58]

Challenges

Nanomedicine needs engulfing the challenges for its utilization, to boost the inferring of pathophysiologic basis of illness, bring additional advanced diagnostic probabilities, and yield additional economical therapies and preventive attributes. Molecular technology is destined to become the core technology underlying all of twenty first century medication and medical specialty. Societal emergences of public acceptance, ethics, regulation and human safety with new products are the major disputes to face.

Future perspective

Nanotechnology plays an important role; it will change dentistry, healthcare, and human life more profoundly than many developments of the past. As with all technologies, nanotechnology carries a significant potential for misuse and abuse on a scale and scope never seen before. However, they also have potential to bring about significant benefits, such as better use of natural resources, improved health, and reduced environmental pollution. Hollow nanospheres, core shell structures, nanocomposites, nanoporous materials, and nanomembranes will play a growing role in materials development for the dental business.[59]

- Nanotechnology is foreseen to change health care in a fundamental way
- Development of Novel methods for disease diagnosis and prevention
- Therapeutic selection tailored to the patient's profile
- Drug delivery and gene therapy
- Development of nanoneedles
- Introducing nanoencapsulation techniques and nanorobots.

References:

1. Saravana KR, Vijayalakshmi R. Nanotechnology in dentistry. Ind J Dent Res. 2006;17:62–65.
2. Schleyer TL. Nanodentistry: Fact or fiction? J Am Dent Assoc. 2000;131:1567–1568.
3. Erkoç Ş. Nanobilim ve Nanoteknoloji.1. Baskı, Ankara: ODTÜ Yayıncılık;2007. pp. 1–10.
4. Gumusderelioglu M, Mavis B, Karakecli A, Kahraman AS, Cakmak S, Tigli S, Demirtas TT, Aday S. Doku mühendisliğinde nanoteknoloji. Bilim ve Teknik. 2007;479 Ek.
5. Kong LX, Peng Z, Li SD, Bartold M. Nanotechnology and its role in the management of periodontal diseases. Periodontol 2000. 2006;40:184–196.
6. Mansoori GA. Advances in atomic and molecular nanotechnology. Principles of Nanotechnology. 1st ed. Singapore: World Scientific Publishing Co. Ptc. Ltd; 2005. pp. 1–10.
7. Rieth M. Nano-Engineering – Studies and Conclusions Nano-Engineering in science and technology. 1st ed. Singapore: World Scientific Publishing Co. Ptc. Ltd; 2003. pp. 91–103.
8. Ozbay E. İşe yarar nanoteknoloji. Seminer, Bilkent Üniv. Nanoteknoloji Araştırma Merkezi; Ankara, Turkey: 2006.
9. Poole PC, Jr, Owens FJ. Introduction to Nanotechnology. New Jersey: John Wiley & Sons Inc; 2003. pp. 1–7.
10. Duke ES. Has dentistry moved into the nanotechnology era? Compend Contin Educ Dent. 2003;24:380–382.
11. Freitas RA., JR Nanodentistry. J Am Dent Assoc. 2000;131:1559–1565. [PubMed]
12. Freitas RA., JR . Nanomedicine: Basic Capabilities. Vol. 1. Landes Biosciences; Retrieved online January 3, 2008 from: www.nanomedicine.com.
13. Freitas RA., JR What is nanomedicine? Nanomedicine. 2005;1:2–9. [PubMed]
14. Freitas RA., JR Nanotechnology, nanomedicine and nano-surgery. Int J Surg. 2005;3:243–246. [PubMed]
15. Caruthers SD, Wickline SA, Lanza GM. Nanotechnological applications in medicine. Current Opin Biotechnol. 2007;18:26–30. [PubMed]
16. Stephen CB. Dental Biomaterials: Where Are We and Where Are We Going? J Dent Educ. 2005;69:571–578. [PubMed]
17. Roberson MT, Heymann OH, Swift EJ., JR . Biomaterials Sturdevant's Art and Science of Operative Dentistry. 5th ed. Mosby Co; 2006. pp. 137–139.
18. Ashammakhi N, Ndreu A, Yang Y, Ylikauppila H, Nikkola L, Hasırcı V. Tissue engineering: A new take-off using nanofiber-based scaffolds. J Craniofac Surg. 2007;18:3–17
19. Strietzel FP, Reichart PA, Graf HL. Lateral alveolar ridge augmentation using a synthetic nano-crystalline hydroxiapatite bone substitution material (Ostim®) Clin Oral Impl Res. 2007;18:743–751. [PubMed]
20. Wagner V, Dullart A, Bock AK, Zweck A. The emerging nanomedicine landscape. Nature Biotechnology. 2006;24:2–9. Retrieved online February 2, 2008 from: www.nature.com/nbt/ [PubMed]
21. Kasaj A, Willershausen B, Reichert C, Röhrig B, Smeets R, Schmidt M. Ability of nanocrystalline hydroxyapatite paste to promote human periodontal ligament cell proliferation. J Oral Sci. 2008;50:279–285. [PubMed]

22. Tetè S, Mastrangelo F, Traini T, Vinci R, Sammartino G, Marenzi G, Gherlone E. A macro- and nanostructure evaluation of a novel dental implant. Implant Dent. 2008;17:309–320. [PubMed]

23. Braceras I, De Maeztu MA, Alava JI, Gay-Escoda C. In vivo low-density bone apposition on different implant surface materials. Int J Oral Maxillofac Surg. 2009;38:274–278. [PubMed]

24. Ellingsen JE, Thomsen P, Lyngstadaas P. Advances in dental implant materials and tissue regeneration. Periodontol 2000. 2006;41:136–156. [PubMed]

25. Suh JY, Jeung OC, Choi BJ, Park JW. Effects of a novel calcium titanate coating on the osseointegration of blasted endosseous implants in rabbit tibiae. Clin Oral Impl Res. 2007;18:362–369. [PubMed]

26. Meirelles L, Currie F, Jacobsson M, Albrektsson T, Wennerberg A. The effect of chemical and nanotopographical modifications on the early stages of osseointegration. Int J Oral Maxillofac Impl. 2008;23:641–647. [PubMed]

27. Chiang CY, Chiou SH, Yang WE, Hsu ML, Yung MC, Tsai ML, Chen LK, Huang HH. Formation of TiO(2) nano-network on titanium surface increases the human cell growth. Dent Mater. 2009;25:1022–1029. [PubMed]

28. Park JW, Kim HK, Kim YJ, An CH, Hanawa T. Enhanced osteoconductivity of micro-structured titanium implants (XiVE S CELLplus) by addition of surface calcium chemistry: a histomorphometric study in the rabbit femur. Clin Oral Implants Res. 2009;20:684–690. [PubMed]

29. Türkün LŞ, Uzer Çelik E. Antibakteriyal adeziv ile uygulanan kompomer ve nanofil kompozit restorasyonların bir yıllık klinik performansı Gazi Üniv Diş Hek Fak Derg. 2007;24:1–8.

30. Papadogiannis DY, Lakes RS, Papadogiannis Y, Palaghias G, Helvatjoglu-Antoinades M. The effect of temperature on viscoelastic properties of nano-hybrid composites. Dent Mater. 2008;24:257–266. [PubMed]

31. Jung M, Sehr K, Klimek J. Surface texture of four nano-filled and one hybrid composite after finishing. Oper Dent. 2007;32:45–52. [PubMed]

32. Ernst CP, Brandenbusch M, Meyer G, Canbek K, Gottschalk F, Willershausen B. Two- year clinical performance of a nanofiller vs a fine-particle hybrid resin composite. Clin Oral Invest. 2006;10:119–125. [PubMed]

33. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. J Am Dent Assoc. 2003;134:1382–1390. [PubMed]

34. Yesil ZD, Alapatı S, Johnston W, Seghi RR. Evaluation of the wear resistance of new nanocomposite resin restorative materials. J Prosthet Dent. 2008;99:435–443. [PubMed]

35. Joniot S, Salomon JP, Dejou J, Grégoire G. Use of two surface analyzers to evaluate the surface roughness of four esthetic restorative materials after polishing. Oper Dent. 2006;31:39–46. [PubMed]

36. Davis N. A nanotechnology composite. Compend Contin Educ Dent. 2003;24:662–670. [PubMed]

37. Curtis AR, Palin WM, Fleming GJP, Shortall ACC, Marquis PM. The mechanical properties of nanofilled resin-based composites: The impact of dry and wet cyclic pre-loading on bi-axial flexure strength. Dent Mater. 2009;25:188–197. [PubMed]

38. Pinnavaia TJ, Beall GW. Polymer-Clay Nanocomposites. West Sussex, England: John Wiley & Sons Ltd; 2000. pp. 1–8.

39. Watanabe H, Khera SC, Vargas MA, Qian F. Fracture toughness comparison of six resin composites. Dent Mater. 2008;24:418–425. [PubMed]

40. Schirrmeister JF, Huber K, Hellwig E, Hahn P. Two-year evaluation of a new nano-ceramic restorative material. Clin Oral Invest. 2006;10:181–186. [PubMed]

41. Suzuki S. In vitro wear of nano-composite denture teeth. J Prosthodont. 2004;13:238–243. [PubMed]

42. Ghazal M, Hedderich J, Kern M. Wear of fekdspathic ceramic, nanofilled composite resin and acrylic resin artificial teeth when opposed to different antogonists. Eur J Oral Sci. 2008;116:585–592. [PubMed]

43. Ghazal M, Albashaireh ZS, Kern M. Wear resistance of nanofilled composite and feldspathic ceramic artificial teeth. J Prosthet Dent. 2008;100:441–448. [PubMed]

44. Loyaga-Rendon PG, Takahashi H, Hayakawa I, Iwasaki N. Compositional characteristics and hardness of acrylic and composite resin artificial teeth. J Prosthet Dent. 2007;98:141–149. [PubMed]

45. Imamura S, Takahashi H, Hayakawa I, Loyaga-Rendon PG, Minakuchi S. Effect of filler type and polishing on the discoloration of composite resin artificial teeth. Dent Mater J. 2008;27:802–808. [PubMed]

46. Lee SY, Kwon HK, Kim BI. Effect of dentinal tubule occlusion by dentifrice containing nano-carbonate apatite. J Oral Rehabil. 2008;35:847–853. [PubMed]

47. Nakashima S, Yoshie M, Sano H, Bahar A. Effect of a test dentifrice containing nano-sized calcium carbonate on remineralization of enamel lesions in vitro. J Oral Sci. 2009;51:69–77. [PubMed]

48. Hernández-Sierra JF, Ruiz F, Pena DC, Martínez-Gutiérrez F, Martínez AE, Guillén Ade J, Tapia-Pérez H, Castañón GM. The antimicrobial sensitivity of Streptococcus mutans to nanoparticles of silver, zinc oxide, and gold. Nanomedicine. 2008;4:237–240. [PubMed]

49. Mupparapu M. New nanophosphor scintillators for solid-state digital dental imagers. Dentomaxillofac Radiol. 2006;35:475–476. [PubMed]

50. Troulis MJ, Ward BB, Zuniga JA. Emerging Technologies: Findings of the 2005 AAOMS Research Summit. J Oral Maxillofac Surg. 2005;63:1436–1442. [PubMed]

51. Mjör I.A, Nordahl I. The density and branching of dentinal tubules in human

52. teeth. Arch Oral Biol. 1996;41 (5): 401-12.

53. Sumikawa DA, Marshall GW, Gee L. Microstructure of primary tooth dentin. *Paediatric Dentistry*. 1999;21 (7): 439-44.

54. Whitesides GM, Love JC. The Art of Building Small. *Scientific American.* 2001;285 (3): 33-41.

55. Freitas RA. Nanomedicine // Basic Capabilities, Georgetown, TX: Landes

56. Bioscience. 1999; I: 345-347.

57. Freitas, RA. Nanodentistry // American Dental Association. 2000;131: 1559-66.

58. Jayraman K, Kotaki M, Zhang Y. Recent advances in Polymer nanofibers. *J. Nanosci and Nanotech.* 2004;4(52): 65-67.

59. Price R.L., Ellison K., Haberstroh K.M. Nanometer surface roughness increases select osteoblasts adhesion on carbon nanofiber compacts. *J. Biomed Mat.* 2004;70(129): 38-40.

60. Reifman E.M. Diamond teeth. In: Crandall B.C., editor. Nanotechnology: Molecular speculations on global abundance. Cambridge, Mass: MIT Press. - 1996. P.81.

61. Anna V. Rybachuk, Ivan S. Chekman, Tetyana Yu. Nebesna Nanotechnology and Nanoparticles in Dentistry. *Pharmacology and Pharmaceutics*. 2009;1: 18-21.