DENTAL NANOROBOTS – SMALL INSTRUMENTS WITH LARGE POTENTIAL

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ABSTRACT
Science of miniaturization (nanotechnology) is manipulating matter at nanometer level. Using nanotechnology, in the latest 10 years a new field of research appeared: dental nanomedicine, which will use new tools, nanorobots. **Aim** This paper aims to provide the recent information about some application of nanorobots to dental problems, especially in orthodontics. **Materials and methods** We addressed some queries to the electronic data bases including „Google Scholar”, „Google Books” and MEDLINE, using the key-words: „nanotechnology”, „dental nanomedicine”, „nanodentistry” and „dental nanorobots”. We have taken into consideration the articles and monographies in the field of nanomedicine and nanotechnology issued in English until the 31st of December 2010. From the collected materials, we have conceived a summary of the data about the design and architecture of nanorobots, as well as their applications in dental nanomedicine. **Results** The dental nanorobots will be invisible for human eye and could have different shapes as they will have to do different tasks. They will be manufactured out of thousands of mechanical parts, made out of diamondoid materials. The most important part of the architecture of a nanorobot will be the nanocomputer on board which will be under the control of the dentist. The dental robots could accomplish numerous tasks: inducing local anaesthesia, desensitize teeth, correct positioning of periodontal tissue and poorly aligned teeth, restorative dental procedures, and curative preventive procedures at oral cavity level. Though there will be numerous benefits of using nanorobots in dental medicine, some scientists consider that there will be also some risks, including the disappearance of every living being on Earth if the nanorobots will evolve towards the capacity of continuous auto-replication. **Conclusion** Nanorobots will be the next big treatment revolution in dentistry. Scientists appreciate that the years 2020 will be called “the decade of the medical nanorobots” as in those years these “intelligent” instruments will be at work. The role of the dentist working with such instruments will change, but also the types of the dental problems of the patients who will address to him will change.

**Key words**: dental nanomedicine, dental nanorobots, applications, benefits, risks

INTRODUCTION
More than half a century ago, at the annual *American Physical Society* meeting (1959), the physicist Richard Feynman, Nobel Prize winner in Physics, presented his work “Plenty of Room at the bottom” which dealt with the matter of manipulating and controlling small scale things, a field which he thought would have “a great deal of technical applications”. He proposed the construction of “submicroscopic computers” that would enable us to manipulate atoms and molecules, thus opening new technological possibilities. The physicist suggested that using regular machine tools can produce other machine-tools, only smaller, and so on, step by step, till the production of molecular machines [1].

The true founder of nanotechnology was, though, Eric Drexler, who published in 1986 the book *Engines of Creation. The Coming Era of Nanotechnology*, in which he
introduces the molecular technology which he also calls nanotechnology. He states that in the near future this kind of technology will be used to assemble atoms and molecules in order to build nanocircuits and nanomachines. “The way average instruments can build average machines out of compound pieces, molecular instruments will create connections between molecules in order to create pinions, engines, manipulating arms and minute covers that will be assembled into complex machines” [2].

The prefix “nano” refers to the scale of these constructions, the word coming from Greek where it means “dwarf”, a nanometer being the billionth part of a meter. The first scientist who described the medical applications of nanotechnology and nanorobots was Robert Freitas Jr. In an article published by the Journal of American Dental Association, he defined nanomedicine as the “science and technology of diagnosing, treating and preventing disease and traumatic injury; of relieving pain; and of preserving and improving human health, through the use of nanoscale-structured materials, biotechnology and genetic engineering, and eventually complex molecular machine systems and nanorobots”. In the same article, Freitas introduced the concept of nanodentistry, which he defines as the science and technology that “will make possible the maintenance of near-perfect oral health through the use of nanomaterials, biotechnology, including tissue engineering, and nanorobotics” [3].

In this article we will present the most recent data of the medical literature about the architecture and potential use of nanorobots in nanodentistry, as well as possible advantages and risks connected to their use.

MATERIALS AND METHODS

We have searched the electronic data bases including “Google Scholar”, “Google Books” and MEDLINE, using the key-words: “nanotechnology”, “dental nanomedicine”, “nanodentistry” and “dental nanorobots”. We have taken into consideration the articles and monographies in the field of nanomedicine and nanotechnology issued in English until the 31st of December 2010. Adding to that, the articles quoted in the articles and monographies found in the first research have been added to the review. From the collected materials, we have conceived a summary of the data about the design and architecture of nanorobots, as well as their applications in dental nanomedicine.

RESULTS

The field of dental nanomedicine implies the use of three classes of molecular structures: nanomaterials, non-biological nanoparticles, materials and instruments based on biotechnology and non-biological instruments including nanorobotics, all for diagnosis and therapy purposes. The most effective domain of the three classes of the dental nanomedicine technology is considered to be the one of the nanorobotics [4].

The first step of this research field dates back in the 1980s, when the scanning tunneling microscope and also the atomic force microscope were invented. Those microscopes enabled the identification for the first time of individual atoms. In the years 2000 the devices necessary for building nanorobots began to be manufactured (micro-engines, micro-impellers, micro-pumps, micro-sensors, manipulating micro-arms and even molecular computers [4, 5]. In 2008, C. Edeler, research scientist of the Department of Microrobotic Engineering of the Oldenburg University from Germany announced the creation of a mobile platform where nanorobots are already being manufactured [6].

Nanorobots architecture

Medical nanorobots represent microscopical objects artificially
In the body and which can interact with human body cells or can manipulate them, with a nanometric resolution ($10^{-9}$ m) in order to fulfill tasks in the medical field. As a regular robot, a medical nanorobot can be manufactured out of thousands of mechanical parts, made out of nanomaterials such as carbon nanotubes, metallic nanoconductors and diamondoid materials [4, 7]. Unlike regular robots, medical nanorobots will have invisible dimensions to the human eye, respectively from 0.1 to 10 μm, but the compound parts will have molecular sizes (1-10 nm) [4, 7, 8, 9].

The dental nanorobot (Fig. 1) will have a nanocomputer on board which will stock and execute planned missions, will receive and process signals and external stimuli, will communicate with other nanocomputers and will respond to external control and monitoring devices and will possess the contextual knowledge in order to ensure the correct functioning of the nanomechanical devices [3, 5].

The researchers have taken into account various shapes for the design of medical nanorobots bearing in mind both the biomimetism and the place of action. Freitas considers that intravascular nanorobots should probably have a sphere shape, resembling blood cells and leucocytes [10, 4]. Martel et al. appreciates that, for a good movement through the blood flow, the best design shape for medical nanorobots should be that of flagellated bacteria [12].

Dental nanorobots should have a spider like body as they need to be quick in fulfilling their tasks [13]. They will be manufactured out of diamondoid structures (Fig. 2), disposed into nanotubes, as the super-sleek surfaces should reduce to a minimum the possibility of activating the immune system of the organism [4, 14, 9, 11, 10]. Diamondoid molecules are circular saturated hydrocarbons with a diamond like structure. Diamondoids have unique properties due to the exceptional atomic structure. They are chemically and thermically stable, can self-assembly, are more resistant, but lighter than steel [15, 16].

Fullerenes have also been analysed in view of their use in manufacturing dental nanorobots, due to their special physical and chemical properties. They are a class of aromatic carbon compounds, of a somewhat sphere shape in which the carbon bonds form pentagons and hexagons. The diameter of a C60 fullerene molecule is of 0.7 nm, and that recommends it as an important member of the nanomaterials family [17].

![Fig. 1. The architecture of the dental nanorobot (an adaptation of Sujatha et al., 2010)](image1)

![Fig. 2. The molecular structure of diamondoids](image2)
Once inside the human body, nanorobots ensure their movement energy not only from internal sources (such as the energy released by the radioactive particles attached to the nanorobot body or a solar cell reduced to nanoscale), but also out of external sources (such as the patient's body heat or the electrolytes and the metabolism of the glucose in the blood flow) [18, 13, 11].

According to present day theories, dental nanorobots should have at least two means of communication: both with the doctor who coordinates it, and with the other nanorobots he teams up with. Two possible ways of communicating between nanorobots are being considered: either by means of light signals – through optical nanosensors [4], or by chemical signals – through chemical nanosensors (i.e. nanorobots monitoring glucose level) [19, 13].

As to the possible ways of communication between nanorobots and the doctor who coordinates them, research scientists incline towards acoustic signals, allowing rapid rates of data transfer, or electromagnetic radio waves, considered useful in detecting the current status of the nanorobots inside the patient [3, 4, 13].

Applications of nanorobots in dental nanomedicine

Research scientists appreciate that dental nanorobots could accomplish numerous tasks: inducing local anesthesia, desensitize teeth, correct positioning of parodontal tissue and poorly aligned teeth, restorative dental procedures, and curative preventive procedures at oral cavity level [3, 13, 20].

Inducing local anesthesia

As local anaesthesia used now in dental medicine is a painful procedure which causes the patient discomfort and can be sometimes accompanied by complications, manufacturing anaesthetic dental nanorobots will have a large impact on patients as a result of the numerous advantages. A colloidal suspension containing millions of anesthetic dental nanorobots will be applied to the patient’s gum. They will reach the pulp in approximately 100 seconds and will interrupt the traffic of the nervous impulse, under the control of the dentist through the intermediate of the nanocomputer aboard the nanorobots [20]. After finishing the oral procedures, the dentist will be able to command the nanorobots to redo the nervous traffic of the selected tooth and to exit the tooth the way they entered [3, 20]. Using anaesthetic nanorobots will have numerous advantages: a larger comfort for the patient by reducing the anxieties and needle phobias, a larger base of selection and a quick complete reversible action, as well as the disappearance of side effects and complications of the current anesthesia [3, 21].

Treatment of dentine hypersensitivity

A relatively frequently encountered pathology in dental practice is the dentine hypersensitivity characterized by a diffuse symptomatology, slightly painful, caused by the pressure, hydrodinamically transmitted to the pulp, through the dentinal tubes of the exposed dentine. It seems that in this condition, the hypersensitive teeth have a density of dentinal tubes 8 times bigger, and they have a diameter twice the size of dentinal tubes of non-sensitive teeth [13, 20, 8].

In the era of nanomedicine, dental nanorobots will selectively and precisely occlude the selected dentinal tubes in a few minutes, using biocompatible materials and offering the patient a quick and permanent treatment of the hypersensitivity [20, 13].

Orthodontic treatment

Nowadays, orthodontic treatment has a lot of disadvantages among which the need to wear the orthodontic appliance for weeks or months being the most important, to which we can add the unaesthetic aspect of the smile, as well as the discomfort of the patient in terms of speaking and eating. In the era of the
orthodontic nanorobots, they will be able to manipulate directly the parodontal tissues, including gums, parodontal ligament, cementum and alveolar bone, allowing a quick and painless straightening, rotating or vertical positioning within minutes or hours [20, 13].

Aesthetic dental treatment

Nowadays, aesthetic dental medicine uses the tooth implant placed inside the maxillary bone or the mandibular bone (on the spot of a former dental root), in order to help replacing one or several missing teeth. This is followed by a period of osteo-acceptance and another metal piece (a prosthetic joint) is attached to the implant on top of which the doctor can place the crown, the bridge or the prosthetic, that will replace the missing tooth (teeth). This restoring technique has a lot of advantages, but, on the other side, a lot of disadvantages, being a surgical procedure inducing discomfort to the patient as it requires several sessions stretched along several months, and the implant can be rejected by the organism. The reconstructive nanodental techniques will imply genetic engineering procedures, tissue engineering, nanorobotic manufacturing for the growth of a new tooth in vitro, followed by its installation in the dental alveoli with the help of reconstructive dental nanorobots. The nanotherapy of complete replacement of the dentition with biological teeth, including both mineral and cellular compounds, will have the advantage of being possible in the dental practice in one session [3, 20, 13, 8].

Reconstructive dental nanorobots will maintain the natural tooth and will improve its aesthetic aspect (in terms of color and texture) and durability by means of replacing the upper layers of the enamel with artificial biocompatible materials, such as sapphire and diamond, with a hardness of 20-100 times larger than the natural enamel and thus, a larger resistance to fracture [13, 20]. The numerous reconstructive dental nanorobots, controlled from a distance and working together will be able to excavate old amalgam restorations and will be used to prepare the cavities and restore the teeth with biological materials, so that the newly formed teeth could not be differentiated from the original tooth [13].

Treatment for the oral cancer

The fight against the oral cavity cancer will be fought with the help of nanomedical destrorobots, which will be nanotechnological objects capable of researching and destroying in due time the presence of the oral cavity cancer. As in oral cavity cancer there are numerous feeding blood vessels, the destrobot could penetrate the tumor and could use focalized lasers, microwaves or ultrasonic signals in order to attack neoplasm cells which they will destroy without breaking the cell wall, as they work by increasing the pressure or intracellular temperature to high values [7].

Maintaining an almost perfect oral hygiene

This will be possible with the help of dentifrobots playing an important part in preventing cavities and parodontal diseases. Their daily application will be used by means of mouthwash or toothpaste. Being capable of reaching places a tooth brush can’t reach, dentifrobots will identify and destroy pathogen bacteria in the subocclusal area while allowing the harmless bacterial flora from the mouth to develop in a healthy ecosystem. Dentifrobots will patrol all the surfaces above and beneath the gums and will metabolize the rests of organic matter transforming it into odourless vapours. They will be programmed to avoid the occlusal areas and will be deactivated if chewed [13, 20, 21]. As putrefaction is the central metabolic process involved in the odour of the oral cavity, due to their cleaning activities, dentifrobots will ensure a continuous barrier against halitosis [3].
Benefits vs risks in the use of dental nanorobots

Rapid development in the field of nanorobotics in the last two decades has generated controversies over the safety of their application as well as the toxic effect of the medical nanorobots on the human being or the medium [22] and it seems we are witnessing the birth of a new discipline: nanoethics [23].

The benefits of using dental nanorobots could be as numerous as there could be probably as many applications of these minute instruments as there are needs in dental medicine.

The possible toxicological risks on the human body are being also discussed [24], the possible disappearance of homo sapiens sapiens if the nanorobots will not be eliminated from the human body, but also the possible disappearance of the biosphere if the nanorobots will evolve towards the capacity of continuous auto-replication, resulting in the appearance of clusters consuming any living creature on Earth, leaving behind a useless gray mass (the so-called gray-goo scenario) [25].

CONCLUSIONS

In the 1950s, nanorobotics was at a fictional stage, now we are at the theoretical stage, but the years 2020 will be called “the decade of the medical nanorobots”. Nanorobots, considered even now as revolutionary instruments are being expected with a lot of enthusiasm and hopes, but also with some fear as they will radically change the 21st century dental medicine. Once widely used, the role of the dentist will change visibly. More than ever, he will have to possess technical capabilities and a quick and correct professional judgment. He will have to treat especially acute facial trauma and rare genetic disease with manifestations at the level of the oral cavity. Besides, patients will ask for more aesthetic dental treatments. As a result, dental nanorobots, today somewhat fictional, will bring significant benefits in oral health, contributing to achieving painless, quick and high precision dental treatments.

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