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ORIGINAL RESEARCH

Use of new technologies in dentistry

Uso de nuevas tecnologías en odontología

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ABSTRACT

Nowadays, nanodentistry might seem a dream, nevertheless, science advances through nanotechnology help understand complex interrelated microworlds existing between tooth and colonizing microorganisms, these advances open as well a cosmos of possibilities which could revolutionize the world of dentistry. One of these possibilities could be found in the use of nanomaterials, nanobiotechnology, and the recently proposed nanorobots; all these would foster the maintenance of oral health in minute periods of time. This article is a revision of the applications of molecular engineering techniques to the dental sciences, and how these new techniques are contributing to the development of new dental materials such as nanoparticles, nanotubes and nanocomposites. These new techniques can be directly applied in the clinic and in the dental profession, they offer an array of possibilities of bearing enormous impact in conservative procedures.

RESUMEN

La nano-odontología hoy día pareciera un sueño, sin embargo los avances de la ciencia a través de la nanotecnología, en la comprensión de los complejos micromundos interrelacionados entre órgano dentario y los microorganismos colonizadores, abre un cosmos de posibilidades que podrían revolucionar el mundo de la odontología, como lo es el mantenimiento de la salud oral en un periodo de tiempo diminuto al involucrar el uso de nanomateriales, nanobiotecnología y una propuesta reciente «nanorobots». En este artículo se hace una revisión de las aplicaciones de la nanotecnología en las ciencias odontológicas, y cómo estas nuevas tecnologías están permitiendo un gran aporte al desarrollo de materiales innovadores en odontología como nanopartículas, nanotubos, y nanocompositos, entre otros, que se pueden aplicar directamente en la clínica, y que marcan un abanico de posibilidades de invaluable trascendencia en los procedimientos conservadores de la profesión.

Key words: Nanotechnology, dentistry, nanomaterials, nanoparticles, tissue regeneration.
Palabras clave: Nanotecnología, Odontología, nanomateriales, nanopartículas, regeneración tisular.

INTRODUCTION

Since the very beginning, professional activities in dentistry have mainly targeted rehabilitation and restoration of dental structures. This has arisen as a consequence of the destruction caused by dental caries, which is considered the most frequent and expensive ailment in the world. According to the World Health Organization (WHO) 70% of the world s population is afflicted by caries. In Mexico, the percentage of caries affected population is 90% *(Figure 1)*. The dental profession, since its beginnings has always considered that removal and restoration of demineralized tissue were indispensable procedures to solve the sequels caused by this pandemic.

In response to the demand of restorations where aesthetics are of paramount importance, advances in science and technology have concentrated their efforts to create materials that can restore lost dental tissue and provide an appearance similar to that of the tooth's natural structure. For these reasons, and as a consequence of advances of science in dentistry, we aspire to survey all the applications of nanodentistry in dental sciences, the contributions of these new technologies in the development of innovative materials with nanometric range particles and their daily clinic applications such as nanoparticles, nanotubes and nanocomposites amongst others. We also would like to survey the array of possibilities and contributions which are considered of great importance in the conservative procedures of the profession, which revolutionize ancestral therapies and dental procedures.

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Nowadays, it is hard to conceptualize the area of Dental Sciences, since the best part of research is geared towards the concept of restoration, and the main concerns for a restorative material is stability and aesthetics of the mutilated tooth. Nevertheless, basic science research increases the complexity of dental science since it is one of the few areas focused in the search of strategies to regenerate and or restore the stomatognatic system which in turns comprises an enthralling and enigmatic microcosmos in the human body: «the tooth».

Within this frame of reference, research has shown the regenerative ability of the tooth in cases when it is submitted to elements like fluoride which foster its demineralization. With this, scientific basis are established, and they refute the erroneous conception of dental caries as an irreversible process. It therefore becomes a precedent which positively influences preservation and maintenance of dental structures.

The complexity of dental science is observed when analyzing teeth. The tooth is not only a compound of soft and mineralized tissues, it is a vast world of cellular communications, signals and interactions, beginning at embryonic stages *(Figure 2)*. Moreover, if we incorporate to this tissue interaction the symbiotic interrelationships existing between tooth and colonizing microorganisms (which in these circumstances can turn pathogenic), this complexity is even more intensified.

Nowadays, due to the aforementioned reasons, dental challenges are rooted in the understanding of interrelated microworlds which could allow the finding of successful therapies for direct application in clinical situations, all this with the purpose of creating a favorable atmosphere for the partial and/or total regeneration of dental tissues.

These challenges present in an area considered basic and/or clinic area, also receive the contribution of scientific advances from other areas, like «nanotechnology», or, in simpler words «Molecular Engineering». Nanotechnology is described as science and techniques which control and manipulate matter at nanometric level.

The nano scale corresponds to the billionth part of the meter (1/1,000,000,000) , in other words, one thousandth of a micron. According to its Greek etymology «*νανος*» (nano) means small or tiny *(Figure 3)*.

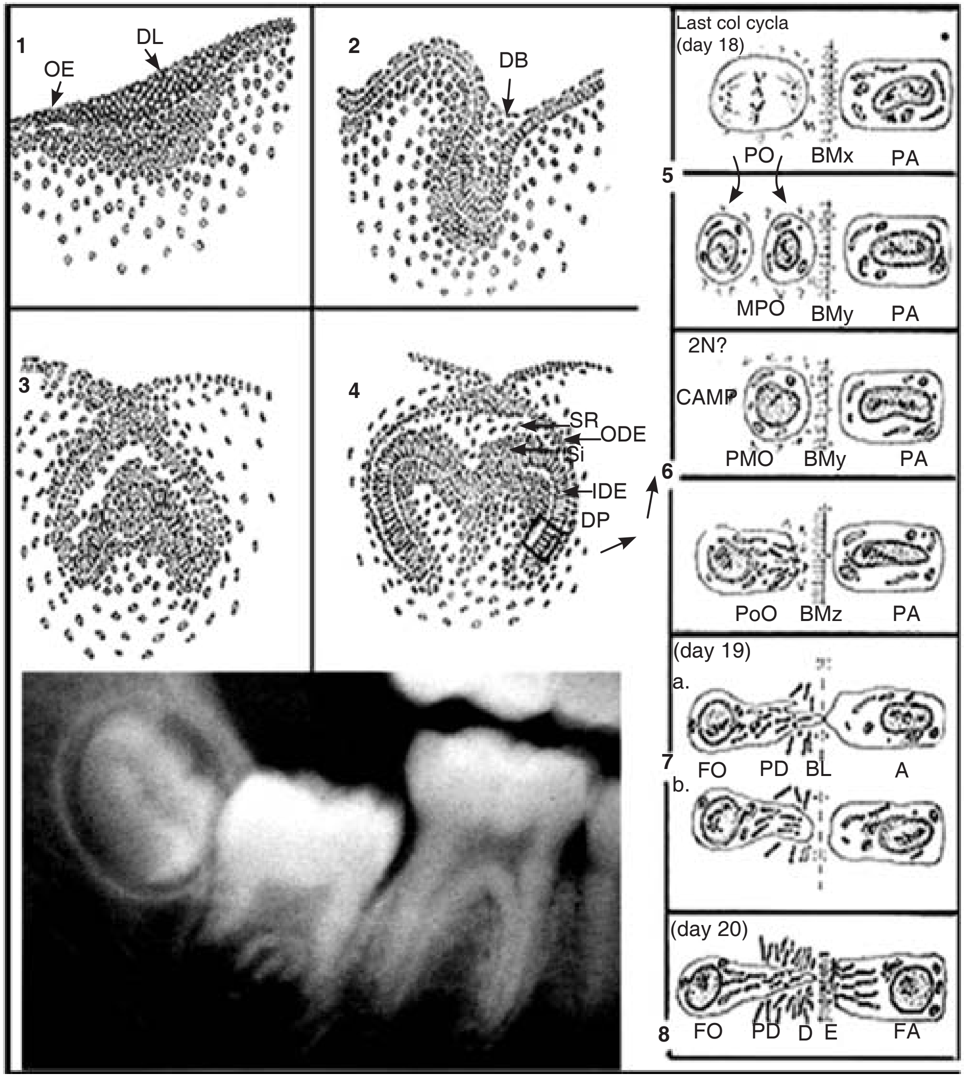
In this tiny world, researchers find a new and wonderful cosmos, which allows for the definite exploration of a sector of technological development, which, up to this date, was in the dark, and can now enlighten the world of dentistry.

Nanotechnology applicability in the dental scope has become a reality in general practice procedures and in various specialties. Nowadays, dentists work with nanomaterials in their private practice. Several companies have undertaken to sell products such as nano-hybrid resins, nano-fillers and nano-adhesivses. These new materials, upon being handled at a «nano» scale, increase their mechanical, physical and chemical properties when compared with conventional materials used in clinical practice *(Figure 4)*.

Nanoparticles have begun to play an important role in medicine and in dentistry. Among their applications we find silver nanoparticles being used as an alternative to dental filling agents.[1-3] The wonderful aspects of these nanoparticles are the new antiwear, antibacterial and antifungicidal properties present in their superficial chemistry. This enables their use in treatments related to the roots of the teeth. These properties have amazed the dental community, since they can combat *Staphylocccus aureus*, *E. coli*, *Enterococcus faecalis* and *Candida albicans*. These new properties doubtlessly offer an array of benefits and possibilities for the patient s health.

When speaking of dentin and enamel regeneration, the combination of tissue bioengineering along with the development of genetically designed trigger nanoparticles, as well as nanoparticles which are biomimetic with mineralized tissues, have begun to bear fruit in the manufacturing of *in vitro* teeth. Example of this is

Figure 1. Dental caries and its future prevention through nanotechnology which seeks restoration and rehabilitation of dental structures with nanorobots directed to the microorganisms causing the dental disease.



1. Dental laminate
2. Dental outline
3. Dental cup
4. Dental bell
OE: Oral epithelium
DL: Dental laminate
SR: Stellate reticulum
SI: Stratus intermediate
ODE: External epithelium of enamel organ
P: Dental papilla,
5-6 Terminal differentiation of Odontoblasts
5. BMx Basal membrane, stage-specific, PO preodontoblast; MPO: mature preodontoblasts which control preameloblasts GAGs synthesis (PA), BMx transforms into BMy
6. GAGs modifications transform MPO into postmitotic odontoblasts (PMO) BMy transforms into BMz. PMO transforms into polarized odontoblasts (PoO)
7-8 Terminal differentiation of ameloblasts
7. Predentin (PD) secreted by functional odontoblasts (FO), BL: basal membrane disappears, giving way to contact between FO and postmitotic ameloblasts (A)
8. Functional ameloblasts (FA) secrete enamel (E)

Figure 2. Diagram which emphasizes successive odontogenesis steps, taken from Ruch et al (1983).

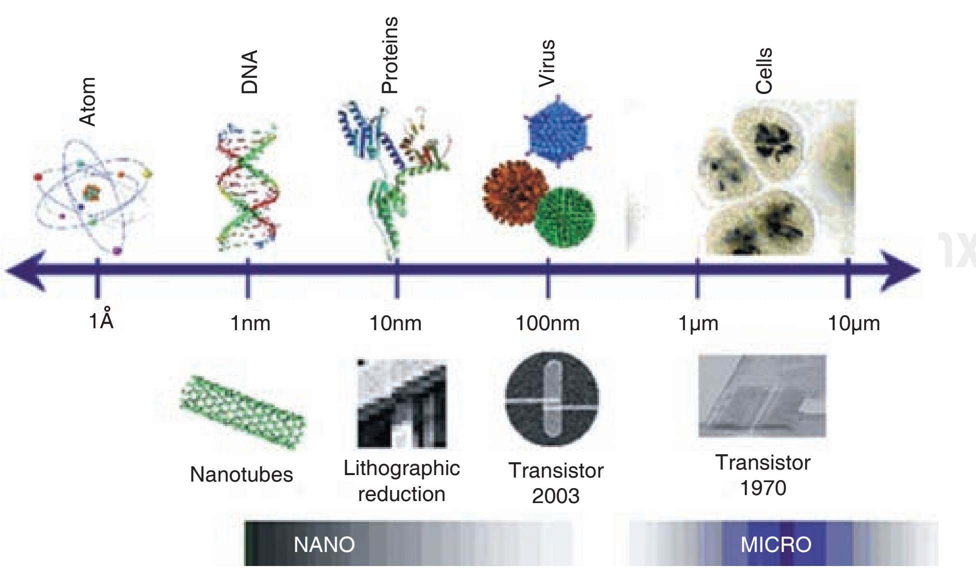


Figure 3. Graphic scheme where nanoscale is located.

the amelogenin gene which has been manipulated to adhere to hydroxyapatite nanoparticles. When these are directly shot to pluripotential cells encapsulated in nanohydrogels they begin to work on the formation of the enamel tissue.[4] Likewise, results obtained when using nanohydrogel in a cellular co-culture with a nanofiber net transporting in their interior particles loaded with the dental sialoprotein gene, indicate that pluripotential cells can be organized in an array of cellular layers which transform into dental and enamel tissue which are similar to tissues found in the natural tooth.[5] This first approach opens the possibility that in the future dental practice might drastically change, allowing the manufacturing of teeth in the dental practice office, and achieving with it one of the most transcendent scientific contributions for the dental profession.

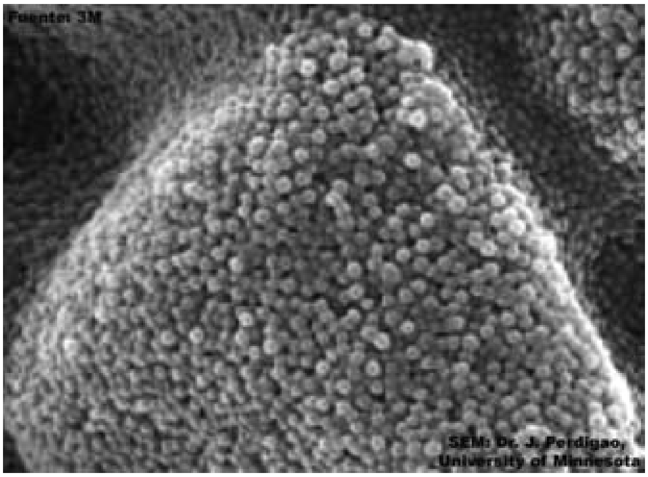


Figure 4. Microphotographs of scanning electron microscope showing size of nanoparticles of Filtek® Supreme XT hybrid resin.

In orthodontics, nanoparticles are being applied to control pain signaling, and increase nerve branching through the use of nanospheres filled with factors which induce nervous tissues regeneration. Nevertheless in this particular area of dentistry, nanotechnology is still a chimera. A daydream is also Dr. Sims proposal who claims that the use of brackets could be replaced by nanorobots programmed to control the bone and periodontal ligament biomechanical response and so achieve dental movement.[6,7]

In the same fashion, implantology will benefit with the development of a material named nanobone *(Figure 5)* which closely imitates the structure and

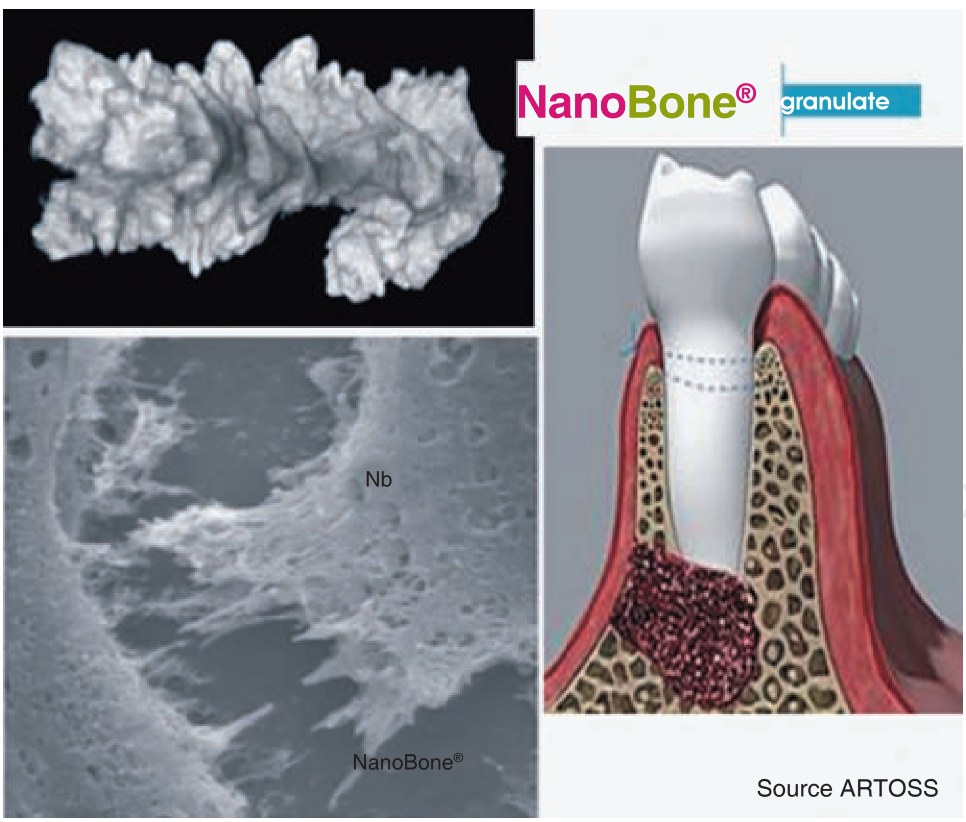


Figure 5. NanoBone® structure has shown great potential as osteoconductor in dental bone tissue regeneration.

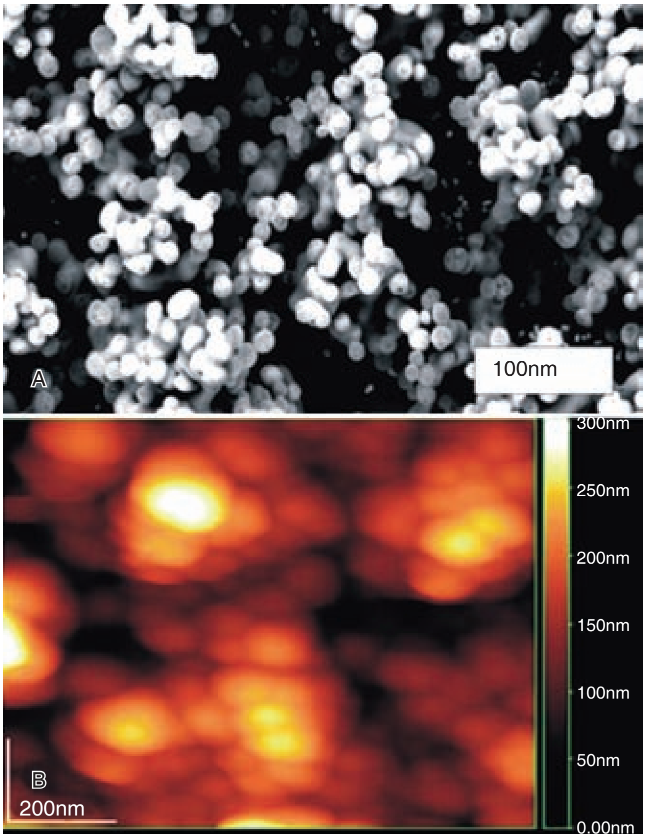


Figure 6. $ZnAl_2O_4$ nanoparticles, whose superficial chemistry shows new anti-wear properties and increases odontogenic response.

composition of real bone. This will turn titanium artificial implants in a matter of the past. This is due to the fact that nanobone implants possess a greater capacity to interact with live tissues, and allows for the self-repair of the body, since the body, upon recognizing it like a similar nanomaterial, tries to develop into it.[8-11]

Bearing this in mind, in the areas of surgery and implantology, scientists are creating «intelligent» implants. These implants are able to detect which type of tissue is developing on them, to communicate this information to a hand device and liberate, drugs as needed to promote tissue development. These implants are designed as well to help avoid complications that can normally be found after a bone implant. These complication can be infections, inflammation (or scar development), loosening of the implant, and, in cases of bone cancer, recurrence of the disease. Scientists have also been studying implants which have intrinsic mechanisms to protect the body from infections or to inhibit cancer development. These implants are made of silver, zinc, zirconium selenium and chrome *(Figure 6)*.[12,13]

Finally we can say that scientific advances are opening new areas of specialization. Such is the case with the new minted term «Biodontics». In this term, results of basic science and clinical research are amalgamated to incorporate contemporary developments of molecular biology, informatics science (DNA and RNA nanochips) nanogenetics, bioengineering and nanotechnology with clinical dentistry. This would bring about the development of new products and technologies that can be patented.

Physician Richard Freyman, 1959 Nobel Prize winner, said *«Principles of physics, such as I understand them, do not negate the possibility of handlings things atom by atom…. Problems of chemistry and biology could be avoided if we develop our skills to see what we are doing, and to achieve things at atomic level».* From this speech, which could have been considered merely rhetorical or a science fiction tale, arose ideas which gave birth, 40 years later, to the bases of a science: «nanotechnology». With this we can see, that advances in this new world are revolutionizing science and technology. They confirm man s visionary aptitude as well as the need to foster research to back dental science.

CONCLUSIONS

According to consulted literature nanotechnology has started to become of extraordinary value in the field of dental sciences, in its application as tissue regenerative material for aesthetic purposes.

The physical-chemical properties attained by dental materials with nanometric particles presence has augmented efficiency of dental restoration materials.

Cellular compatibility characterization of *in vitro* cultures and animal models have demonstrated an increase in cellular response. They have also shown biomimetic characteristics with dental tissues, and they support the development of new materials with applications in the areas of dental implantology. All this will provide a better quality of life to the population.

In our days, research in nanotechnology applied to dental sciences can be catalogued as an innovative project. It has a strong potential to revolutionize diagnosis and treatment of dental diseases, as well as tissue regeneration. Bearing in mind the aforementioned benefits, The School of Dentistry of the National University of Mexico, being an academic and forefront institution feels the need to support research lines that can contribute to the generation of procedures and therapies to benefit society.

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