NANODENTISTRY: THE BENEFITS OF NANOTECHNOLOGY IN DENTISTRY AND ITS IMPACT ON ORAL HEALTH

Peola Jayne Ellis
Maple High School, (Vaughan, Ontario) Summer Mentorship Program (SMP)

ABSTRACT

Nanotechnology is a multidisciplinary field that covers a variety of technological advancements. This branch of technology operates on objects that are less than one billionth of a meter which is equal to one nanometer, therefore focusing its job at the molecular and atomic level. The application of nanotechnology was primarily used in medicine however the emergence of nanodentistry has enabled dental technicians to modify various nanotechnologies to specify them to the field of dentistry. These advancements greatly impact the way dentists go about diagnosing patients, and in doing so using the proper material in order to improve patient treatment. Nanodentistry provides dentists with a new alternative approach that can be applied in their dental practice to treat oral health related problems with a higher degree of specificity.The applications of nanodentistry are designed to achieve maximum therapeutic efficacy with minimal side effects. There are several devices that are used to treat periodontal related illnesses, perform tissue regeneration and bone grafting. Some of these devices include: nanoparticles, nanoassemblers and nanocrystalline hydroxyapatite. These technological devices play an imperative role in helping dentists and dental technicians to analyze information and make precise judgments in the treatment of patients to improve their oral health and wellbeing while identifying ineffective current methods.

La nanotechnologie est un domaine pluridisciplinaire qui couvre une variété de progrès technologiques. Cette division de la technologie règle des objets de moins d'un milliardième de mètre de largeur (égale à un nanomètre) et se concentre sur les niveaux moléculaires et atomiques. La nanotechnologie est principalement utilisée en médecine, cependant, l'émergence de la nanodentisterie a permis aux techniciens dentaires de modifier diverses nanotechnologies pour les adapter au domaine de la dentisterie. Ces progrès ont un impact significatif sur la façon dont les dentistes diagnostiquent les patients et utilisent le matériel approprié pour améliorer le traitement des patients. La nanodentisterie fournit une nouvelle approche aux dentistes qui peut être appliquée dans la pratique dentaire pour traiter les problèmes de santé bucco-dentaire avec un degré plus élevé de précision. Les applications de nanodentisterie sont conçues pour atteindre une efficacité thérapeutique maximale tout en minimisant les effets secondaires. Il existe plusieurs dispositifs utilisés pour traiter les maladies parodontales et effectuer la régénération tissulaire et la greffe osseuse. Certains de ces dispositifs incluent les nanoparticules, les nanoassembleurs et la hydroxyapatite nanocristalline. Ces dispositifs technologiques jouent un rôle impératif en aidant les dentistes et les techniciens dentaires à analyser l'information et à faire des jugements précis lors du traitement des patients. Ils peuvent améliorer la santé bucco-dentaire et le bien-être des patients tout en identifiant les méthodes courantes inefficaces.

KEY WORDS

Nanotechnology; nanodentistry; dentistry; periodontal

INTRODUCTION

There is a growing interest in the dental applications of nanotechnology, leading to the emergence of a new field called nanodentistry (Solanke et al. 2014). Nanodentistry specifically pertains to the issues concerning of periodontal related illness at the molecular level. This includes nanoparticles, nanoassemblers, nanocapsules and nanoshells (Gupta, 2010). Dental technicians program these technological devices by using nanocomputers that have been previously programmed with acoustic signals (Ozak and Ozkan, 2013). In order to complete the transmission of information between the device and the individual using it, the device uses an echoing technique that differentiates different densities within

the body to control nanorobotic functions (Ozak and Ozkan, 2013). The precision of these devices make it easier for dentists to assess the patient accurately and implement the most appropriate treatment plan. Furthermore, nanodentistry is a field that brings promise to patients by ensuring that tissue and bone in the periodontal region are repaired more efficiently by using a variety of nanotechnologies. The technologies pertaining to this task are nanocrystalline hydroxyapatite, orthodontic nanorobots, nanofillers and nanotubes (Zong et al. 2006). The listed technologies work to emulate the natural structures they are designed to replace. These newer methods are more efficient than traditional methods because they are less invasive and often provide sustainable long-term results. This is demonstrated through the improvement of fillers over time. The field of dentistry has expanded from drilling fillers into the gum to using newer methods of nanofillers that help to emulate the natural structure with minimal pain. Patients have constantly relied on these technologies for the entire spectrum of dental diseases. Furthermore, these advancements in nanodentistry have helped to improve human life by allowing dentists to make more precise judgements, as well as providing promise in the repairing of tissue and bone in the periodontal region[1] as opposed to the use of stem cells. Although there is great promise in the research of stem cells it has been proven that chemotherapy may be an important mechanism of resistance which could cause detrimental problems (Dean et al. 2005). The advancements in nanodentistry enable dentists to be more precise when treating periodontal related illnesses. Nanotechnology is beneficial in the world of dentistry and the patients receiving care because it is technology that improves the treatment mechanisms for periodontal diseases.

MATERIALS AND METHODS

This article was designed to answer the following questions: What is nanotechnology?; How is nanotechnology applicable to dentistry?; How are technological devices programmed and how do they work to complete their task?; Why do nanotubes hold more promise for tissue and cell regeneration as opposed to stem cells?

A sifting technique was used to conduct database research. Through meticulous research, inclusion and exclusion factors were considered to retrieve specific information pertaining to nanodentistry. Keywords such as “nanotechnology and its application in dentistry” and similar term combinations were used to find articles relevant to the field of nanodentistry.

The sources were further analyzed and compiled to evaluate the beneficial properties of nanodentistry while enabling dentists to use technology that maximizes efficacy while using less invasive methods.

DISCUSSION

Multi-functionality is the key advantage of nanoparticles over traditional approaches, this attribute includes targeting specific molecular imaging (Mantri and Mantri, 2013). These particles have highly favorable optical and chemical properties for biomedical imaging and therapeutic applications (Gupta et al. 2013). These key features are applied in the field of dentistry to target oral pathogens in the crevices of the gum that are often overlooked. The technique used to get rid of oral pathogens is very efficient because the nanoparticles perform this task with a high degree of specificity. Nanoparticles are molecular units that behave as a whole unit in terms of its transportation properties, in which it moves as one body (Gupta, 2010). These unique nanoparticles are known for their solubility that enables mobility and accuracy for their assigned tasks. Nanosolutions that contain nanoparticles are also used in bonding agents such as Single Bond Plus which increase the quality and durability of orthodontic brackets without the use of liquid (Satyanarayana and Rai, 2011). This solution ensures homogeneity and that the adhesive is perfectly mixed every time (Kumar and Vijayalakshmi, 2006). The process of creating orthodontic brackets while using nanoparticles not only reduces the time of the bonding procedure but it also helps to provide further testing as to how the orthodontic brackets can supersede features such as improved flexibility and durability. This will increase patient comfortability and well as, ensure that it is still straightening the individual’s teeth. Nanoparticles have also been used as a sterilizing solution in the form of molecular units between the size of 0.1 and 100 nanometers (Gupta, 2010). This solution contains opaque oil droplets that attack the specific region they are assigned and then identifies and destroys the oral

[1] This region includes the anatomy of the gums and teeth and diseases concerning specific tissues and bones in the mouth

 DOI: 10.13034/jsst.v10i2.218

pathogen (Gupta, 2010). As mentioned previously, there are many promising qualities of nanoparticles that make it easier to get rid of oral pathogens. However, in order to eliminate pathogens effectively, nanoparticles are often combined with nanoassemblers.

Nanoassemblers are another nanotechnology that are programmed to pinpoint foreign particles that are invasive to the periodontal region (Solanke et al. 2014). The similarities that nanoparticles and nanoassemblers share, increase the atomic precision used to attack foreign bodies. The structure of some nanoassemblers may be smaller than a cell's nucleus but they are very useful when it comes to destroying bacteria in the mouth that can cause tooth decay (Solanke et al. 2014). When they detect an invasive body they attach themselves to the site and undergo chemical processes to destroy the bacteria produced by the oral pathogen. Nanoassemblers are able to repair spots on the teeth where decay has set in by preprogrammed guided chemical reactions with atomic precision (Solanke et al. 2014). These chemical reactions involves a series of redox reactions that are designed by the lab technician to complete the task. Both nanoparticles and nanoassemblers provide detailed results that make it easier for dentists to make better analysis by clearly identifying foreign bodies. This allows dentists to find the most efficient and effective way to get rid of the problem. Periodontal illnesses can cause inflammation of the gums that result in pain. However, nanocapsules that are saturated with triclosan, an antibacterial and antifungal agent can be used to alleviate inflammation (Solanke et al. 2014).

Nanocapsules are molecular units that have been used in novel vaccines, antibiotics and drug delivery with reduced side effects according to the South West Research Institute (Solanke et al. 2014). This institute conducted an experiment testing whether triclosan, an antibacterial and antifungal agent found in toothpaste, could be infused in nanocapsules to alleviate inflammation. They targeted release systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects (Solanke et al. 2014). This confirmed some of the useful properties triclosan could bring to field of dentistry. Effective treatment of oral pathogens using nanocapsules is a breakthrough for dentists but diseases such as cancer in the mouth pose a very different challenge because cancerous cells have to be approached with a mechanism that selectively destroys solely the cancer cells.

Nanoshells is another form of nanotechnology that are particles of silica (glass) completely coated with gold that are used to detect and treat cancerous tumors (Rajendran, 2009). This specific nanotechnology has outer metallic layers of nanoparticles that selectively destroy cancer cells while leaving normal cells intact (Satyanarayana and Rai, 2011). Nanoshells are coated in nanoparticles and are placed close to or within the tumor to destroy it (Satyanarayana and Rai, 2011). Nanoshells are able to slip through vascular leaks created by the defective blood vessels[2] used to feed the tumor (Rajendran, 2009). This nanotechnology releases chemicals that attack the tumor (Satyanarayana and Rai, 2011). The effective use of nanoshells and nanoparticles will become more beneficial to dental patients in a world where technology is evolving rapidly and cancer related illnesses have been increasing. The mentioned technologies have helped improve the overall understanding of dentistry and will inspire new innovations in the future to improve patient care.

Nanocrystalline hydroxyapatite is an invention that has impacted the lives of patients because of its remarkable capabilities of bone grafting and ability to stimulate cell generation (Solanke et al. 2014). Nano crystals have a loose microstructure with nanopores situated between the crystals and the surface of the pores (Shetty et al. 2013). Nanopores are small holes that enable DNA passage one strand at a time, therefore making DNA sequencing highly efficient (Bhardwaj et al. 2014). The precise shape of the nanocrystals play a large role in their function. In the past, the traditional method used to replace a tooth involved physically drilling the false tooth into the gum. This method is very invasive, and damages the torn tissue of the gum. The method using nanocrystalline hydroxyapatite to emulate the natural structure present on bone is better than the traditional method because it is faster and does not replace the tooth structure but rather stimulates growth (Solanke et al. 2014). This procedure is often followed by two main steps which include; the induction of osteoblast proliferation. This process results in the

[2] Tumors create many blood vessels to feed their growth this is known as neoangiogenesis

[3] The place in the bone in which the structure develops

expansion of osteoblast cells which are essential to complete the bone forming process. Hydroxyapatite crystals are then deposited in the matrix[3] , to decrease the time it takes to form the bone. This process is very effective as it allows the process of bone generation to happen right away. Likewise, orthodontic nanorobots can be used with nanocrystalline hydroxyapatite to treat bone defects because of their ability to manipulate periodontal tissues (Solanke et al. 2014). These orthodontic nanorobots target the assigned areas and use receptors to transmit signals to repair them. They also allow rapid and painless tooth straightening, rotating and vertical repositioning, as well as, tissue repair (Solanke et al. 2014). After the oral procedures are complete, the dentist orders the nanorobots to restore all sensation to stop controlling the nerve traffic, this action to relieve pain is very patient friendly (Chandki et al. 2012). This technique is very efficient, and effective for both the patient and the dentist as it alleviates anxious patients who are normally afraid of needles, and similarly allows dentists to complete their tasks faster. Therefore benefitting dental hypersensitivity (Aeran et al. 2015). This is a common condition of tooth pain that varies from person to person. Although, orthodontic nanorobots are used in tissue repair nanofillers play a significant role in the treatment process.

Nanofillers play a substantial role in producing fillers that are useful. These fillers are very different from traditional fillers because traditional composite produces large particles as opposed to nanofillers that can be reduced to the size of 100 nanometres (Zong et al. 2006). This technology is beneficial because smaller particles enable nanofillers to target teeth to a higher degree of specificity. Nanofillers are easy to shape and have a high degree of strength and scratch resistance (Zong et al. 2006). The technological skills used to design nanofillers indicate that they are more durable than traditional fillers. Nanofiller technology has also enabled the production of nanofill composites which brings together the aesthetic features of microfill composites and the mechanical features of hybrid composites (Zong et al. 2006). Nanofillers also offer advantages in optical properties that enables the clinician to construct a wide range of shades and opacities thus providing highly aesthetic restorations (Mitra et al. 2003). This technology has given patients more options that can provide them with fillers that have longer durability. Despite the fact that nanofillers are so important in the filling process, nanotubes also work to give a natural appearance of dental enamel.

Nanotubes are a type of nanotechnology typically used to mimic the natural biomineralization process to create the hardest tissue in the human body, dental enamel (Gupta, 2010). Tissue engineering concepts are focused on the utilization of synthetic scaffold for cell delivery purposes (Gupta, 2010). Nanotubes are one of the most promising technologies of tissue engineering and researchers may try to invest in nanotubes as opposed to the growing research of stem cells. Stem cells bring great promise to tissue and cell regeneration however, problematic cells such as cancer cells can acquire resistance to chemotherapy by a range of mechanisms including mutation, over expression of the drug target, inactivation of the drug target and the elimination of the drug from the cell (Dean et al. 2005). The listed mechanisms may cause numerous problems to the body that may do more harm than good including, such as the regrowth of a tumor after chemotherapy. Conversely, nanotubes are more accessible and can be programmed at a much faster rate than stem cells. Nanotubes technologies bring hope to future generations as they will need tissue and bone regeneration for various illnesses. This futuristic insight opens doors to future research opportunities in this field of growing technological improvements to address illness and diseases in dentistry.

CONCLUSION

Nanotechnology is a field that covers a variety of technological devices that have improved the treatment of periodontal diseases. Applications of nanodentistry have helped to target periodontal issues with a higher degree of specificity, thus improving the overall oral health of dental patients. The breakthrough in nanodentistry has proven to be a worthwhile field that stimulates new research and encourages dental technicians to increase the efficiency and productivity levels of these devices. This field of nanotechnology is very promising because substantial research has been done to prove that it not only operates in favor of the dentist but it also takes into consideration the needs of the patient. These technological devices must be made with great precision to ensure that it is compatible with the human body. Unlike stem cells that may not complete its assigned task appropriately because of

 DOI: 10.13034/jsst.v10i2.218

various counteractions (Dean et al. 2005). Nanoshells show great promise in the field of nanodentistry. There is an increasing number of cancer patients throughout the world and many of their bodies have developed resistance to certain drugs used in cancer therapeutics. Dental technicians have the ability to design nanoshells that will attack tumors and will have a lesser chance of being rejected by the body. This in itself will help to decrease the size of tumors and potentially eliminate them. Perhaps in the future, nanoshells could be used to treat babies with cancer. This would be very effective in targeting specific areas in their bodies because it is much less invasive and has minimal side effects. This technology holds great promise in the development in the imaging of the cancer without any potential for heavy metal toxicity (Laidlaw). Therefore, making the experience less stressful for parents because it uses methods that are better than traditional methods used to treat cancer. Although, these advancements are beneficial to both patients and dentists, future generations should enhance these technologies by continually exploring new concepts to improve dentistry in the 21st century

REFERENCES

1. Abou Neel, E. A., Bozec, L., Perez, R. A., Kim, H.-W., & Knowles, J. C. (2015). Nanotechnology in dentistry: prevention, diagnosis, and therapy. *International Journal of Nanomedicine, 10*, 6371–6394. http://doi.org/10.2147/IJN.S86033
2. Aeran, H., Kumar, V., Uniyal, S., & Tanwer, P. (2015). Nanodentistry: Is just a fiction or future. *Journal of Oral Biology and Craniofacial Research, 5*(3), 207–211. http://doi.org/10.1016/j.jobcr.2015.06.012
3. Bhardwaj, A., Bhardwaj, A., Misuriya, A., Maroli, S., Manjula, S., & Singh, A. K. (2014). Nanotechnology in dentistry: Present and future. *Journal of International Oral Health : JIOH, 6*(1), 121–126.
4. Chandki, R., Kala, M., Kumar, K. N., Brigit, B., Banthia, P., & Banthia, R. (2012). "Nanodentistry": Exploring the beauty of miniature. *Journal of Clinical and Experimental Dentistry, 4*(2), e119–e124. http://doi.org/10.4317/jced.50720
5. Dean, M., Fojo, T., & Bates, S. (2005). Tumour stem cells and drug resistance. *Nature Reviews Cancer, 5*(4), 275-284.
6. Gupta, S., Rakesh, K., Gupta, O. P., Khanna, S., Purwar, A., & Verma, Y. (2013). Role of Nanotechnology and Nanoparticles in Dentistry: A Review. *Int. J. Res. Dev, 1*, 95-102.
7. Gupta, J. Nanotechnology applications in medicine and dentistry. *University of Toronto Libraries [online] 2010, 1,* 1-16. http://getit.library.utoronto.ca/index.php/oneclick?ctx_ver=Z39.88-2004. (Accessed July 16, 2016)
8. Kumar, S. R., & Vijayalakshmi, R. (2006). Nanotechnology in dentistry. *Indian J Dent Res, 17*(2), 62-65.
9. Laidlaw, George. (2010). Exploring the advancements in nanotechnology which are leading to the new ways of diagnosing and treating cancers. https://medlink-uk.net/wp-content/uploads/pathprojectsnanotechnology2011/LaidlawG.pdf.
10. Mantri, S. S., & Mantri, S. P. (2013). The nano era in dentistry. *Journal of Natural Science, Biology, and Medicine, 4*(1), 39–44. http://doi.org/10.4103/0976-9668.107258
11. Mitra, S. B., Wu, D., & Holmes, B. N. (2003). An application of nanotechnology in advanced dental materials. *The Journal of the American Dental Association, 134*(10), 1382-1390.
12. Ozak, S. T., & Ozkan, P. (2013). Nanotechnology and dentistry. *European Journal of Dentistry, 7*(1), 145–151.
13. Rajendran, R. (2009). The Holy Grail of medicine: Era of rejuvenation therapy. *The Saudi Dental Journal, 21*(3), 101-102.
14. Satyanarayana, T; Rai, R. Nanotechnology: The future. *University of Toronto Libraries* [online] 2011, 1, 1-6. http://getit.library.utoronto.ca/index.php/oneclick?ctx_ver=Z39.88-2004. (Accessed July 17, 2016)

15. Shetty, N. J., Swati, P., & David, K. (2013). Nanorobots: Future in dentistry. *The Saudi Dental Journal, 25*(2), 49–52. http://doi.org/10.1016/j.sdentj.2012.12.002

16. Solanke, A; Ajayi, D; Arigbede, A. Nanotechnology and its application in dentistry. *University of Toronto Libraries* [online] 2014, 1-8. http://getit.library.utoronto.ca/index.php/oneclick?ctx_ver=Z39.88-2004. (Accessed July 13, 2016)

17. Zong, L.M.; Peng, Z; Li, S; Bartold, P. M. Nanotechnology and its role in the management of periodontal diseases. *University of Toronto Libraries* [online] 2006, 1-4. http://journals2.scholarsportal.info.myaccess.library.utoronto.ca/pdf/09066713/v40i0001/184_nairitmopd.xml. (Accessed July 17, 2016)