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Review

Future of dentistry, nanodentistry, ozone therapy and tissue engineering

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Future of dentistry has become one of the most unique resources and providers of this oral systemic approach. In determining the patient's unique needs, it is becoming increasingly important for the dentist to work with other cutting-edge, integrative practitioners to fully assess the individual requirements of the patient before, during, and after dental care. Witnessing the beginning of truly groundbreaking advances in technology is a rare opportunity. Skepticism is a natural reaction when we are presented with a radically new method and its potential uses. Skepticism helps us filter the valuable from the worthless, the permanent from the ephemeral, and the rational from the preposterous. The present article describes a brief review on some of the breakthrough advances in dentistry regarding tissue engineering, nanodentistry and ozone therapy.

Key words: Nanodentistry, ozone therapy, tissue engineering.

INTRODUCTION

Patients today are increasingly taking more responsibility for their own health care. They tend to be well-read, educated by previous health-care experiences, and much more discriminating in their own choice of practitioners and treatment methods. As health practitioners struggling with the complex task of helping these patients achieve optimum wellness, we should constantly search for the information that best answers their questions and offers solutions to their health concerns (Kumar et al., 2010).

Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanomaterials, biotechnology including tissue engineering, and ultimately, dental nanorobotics (nanomedicine). When the first micron-size dental nanorobots can be constructed in 10 to 20 years, these devices will allow precisely controlled oral analgesia, dentition replacement therapy using biologically autologous whole replacement teeth manufactured during a single office visit, and rapid nanometer-scale precision restorative dentistry. New treatment opportunities may include dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently-bonded diamondized enamel, and continuous oral health maintenance using mechanical dentifrobots (Sharma et al., 2010).

Most of people possess a fear towards dentistry. On account of this fear, they avoid the dental treatment. Infact, people fear injections and drills that are used in dental clinics. Although, in recent time, dentistry has been experiencing a period of dynamic changes and growth, perhaps like no other time before. The use of ozone in dental treatment is the result of this dynamics and growth. Incorporation of ozone in dental clinic set-ups would eradicate the feeling of pain during dental treatment and also cut off the treatment time, significantly. Ozone has been shown to stimulate remineralization of recent caries-affected teeth after a period of about six to eight weeks. Scientific support, as suggested by demonstrated studies, for ozone therapy presents a potential for an atraumatic, biologically-based treatment for conditions encountered in dental practice (Garg and Tandon, 2009).

A new direction in the field of vital pulp therapy is given by the introduction of tissue engineering as an emerging science. It aims to regenerate a functional tooth-tissue structure by the interplay of three basic key elements: stem cells, morphogens and scaffolds. It is a multidisciplinary approach that combines the principles of biology, medicine, and engineering to repair and/or regenerate a damaged tissue and/or organ (Malhotra et al., 2009).

The present review article describes the future of dentistry and possible different treatment modalities in the future including nanodentistry, ozone therapy and tissue engineering. We hope this mini review article be useful for all dentists and our colleagues and open a new era in field of dentistry.

NANODENTISTRY

The human characteristics of curiosity, wonder, and ingenuity are as old as mankind. People around the world have been harnessing their curiosity into inquiry and the process of scientific methodology. Recent years have witnessed an unprecedented growth in research in the area of nanoscience. There is increasing optimism that nanotechnology applied to medicine and dentistry will bring significant advances in the diagnosis, treatment and prevention of disease. Growing interest in the future medical applications of nanotechnology is leading to the emergence of a new field called nanomedicine. Nanomedicine needs to overcome the challenges for its application, to improve the understanding of pathophysiologic basis of disease, bring more sophisticated diagnostic opportunities, and yield more effective therapies and preventive properties. Molecular technology is destined to become the core technology underlying all of 21st century medicine and dentistry (Mallanagouda et al., 2008).

Nano is derived from the Greek word for dwarf, and usually is combined with a noun to form words such as nanometer, nanotechnology or nanorobot. A nanometer is 10–9 meter, or one-billionth of a meter. Since it is not easy to visualize the scale of a nanometer, a comparison with concepts and objects of appreciable dimensions is helpful. If the height of an average human being were scaled up to stretch from the earth to the moon, then each of the person’s atoms would be about the size of a baseball (approximately 10 centimeters in diameter). A nanometer then would be about five baseballs in a row (Jhaver, 2005).

Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanomaterials, biotechnology, including tissue engineering and ultimately, dental nanorobotics. New potential treatment opportunities in dentistry may include, local anesthesia, dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondised enamel, and continuous oral health maintenance using mechanical dentifrobots (Freitas, 2005; Chen et al., 2005).

When the first micro-size dental nanorobots can be constructed, dental nanorobots might use specific motility mechanisms to crawl or swim through human tissue withnavigational 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. These nanorobot functions may be controlled by an onboard nanocomputer that executes preprogrammed instructions in response to local sensor stimuli (Mallanagouda et al., 2008; Jhaver, 2005).

Inducing anesthesia

One of the most common procedures in dental practice, to make oral anesthesia, dental professionals will instill a colloidal suspension containing millions of active analgesic micron-sized dental nanorobot 'particles' on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1 to 3-micron thick layer of loose tissue at the cementodentinal junction. On reaching dentin, the nanorobots enter dentinal tubules holes that are 1 to 4 microns in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials, and even positional navigation, all under the control of the onboard nanocomputer as directed by the dentist. There are many pathways to choose from, near to cemento-enamel junction (CEJ), midway between junction and pulp, and near to pulp.

Tubules diameter increases as it nears the pulp, which may facilitate nanorobot movement, although circumpulpal tubule openings vary in numbers and size (tubules number density 22,000 mm dentin-enamel junction (DEJ), 37,000 mm square midway, and 48000 mm square near to pulp). Tubules branching patterns, between primary and irregular secondary dentin, regular secondary dentin in young and old teeth (sclerosing) may present a significant challenge to navigation.

The presence of natural cells that are constantly in motion around and inside the teeth including human gingival and pulpal fibroblasts, cementoblasts of the cementum-dentine junction (CDJ), bacteria inside dentinal tubules, odontoblasts near the pulp dentin border, and lymphocytes within the pulp or lamina propria suggested that such journey should be feasible by cell-sized nanorobots of similar mobility. Once installed in the pulp and having established control over nerve impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment. When on the hand-held controller display, the selected tooth immediately becomes numb. After the oral procedures are completed, the dentist orders the nanorobots to restore all sensation, to relinguish control of nerve traffic and to engress, followed by aspiration. Nanorobotic analgesics offer greater patient comfort and reduced anxiety, no needles, greater selectivity, and controllability of the analgesic effect, fast and completely reversible switchable action and avoidance of most side effects and complications (Freitas, 2000).

Tooth repair

Nanorobotic manufacture and installation of a biologically autologous whole replacement tooth that includes both mineral and cellular components, that is, 'complete dentition replacement therapy' should become feasible within the time and economic constraints of a typical office visit through the use of an affordable desktop manufacturing facility, which would fabricate the new tooth in the dentist's office. Chen et al. (2005) took advantage of these latest developments in the area of nanotechnology to simulate the natural biomineralization process to create the hardest tissue in the human body, dental enamel, by using highly organized micro architectural units of nanorod-like calcium hydroxyapatite crystals arranged roughly parallel to each other.

Dentin hypersensitivity

Natural hypersensitive teeth have eight times higher surface density of dentinal tubules and diameter with twice as large as nonsensitive teeth. Reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure (Mallanagouda et al., 2008; Jhaver, 2005; Freitas, 2005).

Tooth repositioning

Orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours (Whitesides and Love, 2001).

Tooth renaturalization

This procedure may become popular, providing perfect treatment methods for esthetic dentistry. This trend may begin with patients who desire to have their; (1) old dental amalgams excavated and their teeth remanufactured with native biological materials, and (2) full coronal renaturalization procedures in which all fillings, crowns, and other 20 th century modifications to the visible dentition are removed with the affected teeth remanufactured to become indistinguishable from original teeth (Freitas, 2005; Chen et al., 2005).

Dental durability and cosmetics

Durability and appearance of tooth may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which have 20 to 100 times the hardness and failure strength of natural enamel or contemporary ceramic veneers and good biocompatibility. Pure sapphire and diamond which are brittle and prone to fracture, can be made more fracture resistant as part of a nanostructured composite material that possibly includes embedded carbon nanotubes (Jayraman et al., 2004).

Nanorobotic dentifrice (dentifrobots) delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day metabolizing trapped organic matter into harmless and odorless vapors and performing continous calculus debridement. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 species of harmless oral microflora to flourish in a healthy ecosystem. Dentifrobots also would provide continuous barriers to halitosis, since bacterial putrification is the central metabolic process involved in oral malodor. With this kind of daily dental care available from an early age, conventional tooth decay and gingival diseases will disappear into the annals of medical history.

Potential benefits of nanotechnology are its ability to exploit the atomic or molecular properties of materials and the development of newer materials with better properties. Nanoproducts can be made by building-up particles by combining atomic elements and using equipments to create mechanical nanoscale objects. Nanotechnology has improved the properties of various kinds of fibers. 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 (Freitas, 2000; Whitesides and Love, 2001; Jayraman et al., 2004).

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 (Freitas, 2000).

Nonagglomerated discrete nanoparticles are homogenously manufactured in resins or coatings to produce nanocomposites. The nanofiller used include an aluminosilicate powder having a mean particles size of about 80 nm and 1:4 M ratio of alumina to silica. Advantages include; superior hardness, flexible strength, modulus of elasticity, translucency and esthetic appeal, excellent color density, high polish, polish retention, and excellent handling properties (Yunshin et al., 2005; Price et al., 2004). Nanosolutions produce unique and dispersible nanoparticles that can be added to various solvents, paints and polymers in which they are dispersed homogenously. Nanotechnology in bonding agents ensures homogeneity and so the operator can now be totally confident that the adhesive is perfectly mixed every time. Nanofillers are integrated in the vinylsiloxanes, producing a unique addition siloxane impression material. Better flow, improved hydrophilic properties, hence fewer voids at margin and better model pouring, enhanced detail precision (Saravanakumar and Vijayalakshmi, 2006).

Ozone therapy

Most people suffer anxieties about being treated for tooth decay or more precisely; they fear the injections and drills, but, now, with ozone treatment, this is all the thing of the past. Studies have shown that 99% of all the bacteria causing tooth decay have been eliminated after 10 s of ozone exposure and even 99.9% bacteria after 20 s exposure. Thus, treating patients with ozone cuts off the treatment time with a great deal of difference, it eliminates the bacterial count more precisely and moreover, it is completely painless, therefore, increasing the patients' acceptability and compliance (Edward et al., 2008; Holmes, 2003; Lynch et al., 2004). Ozone can now be incorporated in various other treatment modalities also, like bleaching of discoloured teeth, root canal treatment, desensitization and treatment of some soft tissue infections (Bogra and Nikhil, 2003; Celiberti et al., 2006). Ozone, definitely, seems to be a promising treatment modality for various dental problems in future.

Studies have shown that: 1) ozone quickly dissipates in water and kills micro organisms via a mechanism involving the rupture of their membranes in such lesions, 2) It is a strong oxidizer to cell walls and cytoplasmic membrane of bacteria, 3) ozone treatment leads to oxidative decarboxylation of plaque pyruvate generating acetate and carbon dioxide as bye product, 4) it oxides volatile sulphur compounds precursor methionine to its corresponding sulphoxide and thus prevents malodour associated with root caries, 5) It also oxidized poly unsaturated fatty acids, and 6) ozone has little influence on the oxidation of dental alloys (Bogra and Nikhil, 2003).

Ozone is a gas composed of three atoms of oxygen and present naturally in the upper layer of atmosphere in abundance. It has got the capacity to absorb the harmful ultra-violet rays present in the light spectrum from the sun. Thus, ozone filters the light spectrum high up in the atmosphere and protects the living creatures from the ultra-violet rays (Nagayoshi et al., 2004). Ozone is an unstable gas and it quickly gives up nascent oxygen molecule to form oxygen gas. Due to the property of releasing nascent oxygen, it has been used in human medicine since long back to kill bacteria, fungi, to inactivate viruses and to control hemorrhages. Medical grade ozone is made from pure medical oxygen because oxygen concentration in the atmospheric air is variable. Atmospheric air is made up of nitrogen (71%), oxygen (28%), and other gasses (1%) including ozone which is altered by processes related to altitude, temperature and air pollution (Baysan and Beighton, 2007).

Very recently, in dentistry, ozone has got its role in various dental treatment modalities. Interest in ozone use in dentistry is due to the infectious diseases associated with the oral cavity. Ozone therapy presents great advantages when used as a support for conventional treatments, for example, to dental caries, periodontal procedures and endodontic treatment (Nogales et al., 2008). The ozone therapy for managing caries is considered a breakthrough that is expected to be a cornerstone of dental care in the near future.

TISSUE ENGINEERING

New advances in stem cell biology and tissue engineering are leading to the development of cutting edge approaches to dentistry both in the repair and replacement of teeth (Koussoulakou and Koussoulakos, 2009).

Caries, pulpitis, and apical periodontitis increase health care costs and attendant loss of economic productivity. They ultimately result in premature tooth loss and therefore diminishing the quality of life. Advances in vital pulp therapy with pulp stem/progenitor cells might give impetus to regenerate dentin-pulp complex without the removal of the whole pulp. Tissue engineering is the science of design and manufacture of new tissues to replace lost parts because of diseases including cancer and trauma. The three key ingredients for tissue engineering are signals for morphogenesis, stem cells for responding to morphogens and the scaffold of extracellular matrix. In preclinical studies, cell therapy and gene therapy have been developed for many tissues and organs such as bone, heart, liver, and kidney as a means of delivering growth factors, cytokines, or morphogens with stem/progenitor cells in a scaffold to the sites of tissue injury to accelerate and/or induce a natural biological regeneration (Nakashima and Akamine, 2005; Lacerda-Pinheiro Set al., 2008)

The pulp tissue contains stem/progenitor cells that potentially differentiate into odontoblasts in response to bone morphogenetic proteins (BMPs). There are two strategies to regenerate dentin. First, is *in vivo* therapy, where BMP proteins or BMP genes are directly applied to the exposed or amputated pulp. Secondly, is ex vivo therapy which consists of isolation of stem/progenitor cells from pulp tissue, differentiation into odontoblasts with recombinant BMPs or BMP genes and finally transplanted autogenously to regenerate dentin (Koussoulakou and Koussoulakos, 2009).

Many strategies have evolved to engineer new tissues and organs, but virtually all combine a material with either bioactive molecules that induce tissue formation or cells grown in the laboratory. The bioactive molecules are frequently growth factor proteins that are involved in natural tissue formation and remodeling. The basic hypothesis underlying this approach is that the local delivery of an appropriate factor at a correct dose for a defined period of time can lead to the recruitment, proliferation and differentiation of a patient's cells from adjacent sites. These cells can then participate in tissue repair and/or regeneration at the required anatomic locale (Baum and David, 2000).

The second general strategy uses cells grown in the laboratory and placed in a matrix at the site where new tissue or organ formation is desired. These transplanted cells usually are derived from a small tissue biopsy specimen and have been expanded in the laboratory to allow a large organ or tissue mass to be engineered. Typically, the new tissue will be formed in part from these transplanted cells (Kim and Mooney, 1998).

With both approaches, specific materials deliver the molecules or cells to the appropriate anatomic site and provide mechanical support to the forming tissue by acting as a scaffold to guide new tissue formation. Currently, most tissue engineering efforts use biomaterials already approved for medical indications by the U.S. Food and Drug Administration (FDA). The most widely used synthetic materials are polymers of lactide and glycolide, since these are commonly used for biodegradable sutures. Both polymers have a long track record for human use and are considered biocompatible and their physical properties (for example, degradation rate and mechanical strength) can be readily manipulated. A natural polymer—type 1 collagen is often used because of its relative biocompatibility and ability to be remodeled by cells. Other polymers familiar to dentistry, including alginate, are also being used (Kim and Nikolovski, 1999).

New technology continually has had a major impact on dental practice, from the development of high-speed handpieces to modern restorative materials. Tissue engineering in the broadest sense unquestionably will affect dental practice significantly within the next 25 years. As an interdisciplinary endeavor, tissue engineering brings the power of modern biological, chemical and physical science to real clinical problems. The impact of tissue engineering likely will be most significant with mineralized tissues, already the focus of substantial research efforts.

These efforts will yield numerous clinical dental benefits, including improved treatments for intraosseous periodontal defects, enhanced maxillary and mandibular grafting procedures, perhaps more biological methods to repair teeth after carious damage and possibly even regrowing lost teeth.

In addition, it is expect to see a range of other tissue-engineering applications that may promote more rapid healing of oral wounds and ulcers, as well as the use of gene-transfer methods to manipulate salivary proteins and oral microbial colonization patterns. Less common, but still a treatment consideration for the dental profession, will be devices such as the artificial salivary gland and muscle (tongue) or mucosal grafts to replace tissues lost through surgery or trauma. This is an exciting time for biomedical science and its application. Clinical dental practice in 2025 will certainly be different (Baum and David, 2000).

CONCLUSION

The visions described in this article may sound unlikely, implausible, or even heretic. Yet, the theoretical and applied research to turn them into reality is progressing rapidly. Genetic engineering, nanotechnology and ozone therapy will change dentistry, healthcare, and human life more profoundly than many developments of the past. As with all technologies, these technologies carry 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 improved health, better use of natural resources, and reduced environmental pollution. These truly are the days of 'Miracle and Wonder'. It is a bright future that lies ahead in dental field, but we shall all have to work very long and very hard to make it come to pass.

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