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Review Article

Automation in the Discipline of Dentistry: A Visionary Update

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Abstract

Nanotechnology a rising field in science and technology has enormous possibilities to achieve compelling health benefits to the society thereby pioneering extensive research opportunities. A segment of nanotechnology the nanorobots have paved its way in the field of dental medicine to increase precision, quality and safety of various procedures. With its unparalleled precision and its ability to work without fatigue nanorobots are the most pragmatic inventions within the field of technology. The objective of this review article is to provide an insight about the applications of robotics in dentistry.

Clinical Relevance: Nanotechnology may bring boundless changes in dentistry and may be predicted to change dental care in a fundamental way. Nevertheless, such novel development may also give rise to possible risk if misused or abused.

Keywords: *Endo-Micro Robots; Geminoid DK; Nanorobots; Robotic Dental Drill; Simroid; Showa Hanako*

Introduction

The branch of technology concerned with the design, construction, operation, application of robots as well as computer systems for their control, sensory feedback and information processing is known as "Robotics" first introduced by Isaac Asimov in a science fiction book "I Robot" published in the year 1950. Czech Playright Karel Capek in his play Rossom's Universal Robots for the first time in history coined the term "Robot" which means forced labor [1]. Robot Institute of America in 1979 define robot "a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through various programmed motions for the performance of variety of tasks". Robots- machine driven agents that function under the guidance of computer programs when present at or close to microscopic scale of nanometers are known as nanorobots [2].

In the year 1959 Nobel Prize winner Richard Feynman through his work "plenty of room at the bottom" deduced the idea of manipulating and controlling things on a small scale. He recommended the use of regular machine tools to produce smaller machine –tools thus fragmentary leading to the production of molecular machines [2]. Nanotechnology a rising field in science and technology has enormous possibilities to achieve compelling health benefits to the society thereby pioneering extensive research opportunities [3].

Nanodentistry: "The science and technology of diagnosing, treating and preventing oral and dental disease relieving pain and of preserving and improving dental health, using nanoscaled structures." Thereby giving a new aspect to comprehensive dental care concentrating

on preventive intervention rather than curative and restorative treatments [3]. Nanotechnology makes way for advanced diagnostics such as target drug delivery and biosensors furthermore nanorobots will allow instant diagnosis and extermination, individual cell surgery *in vivo* and improvement of natural physiological function. Nanorobots induce oral analgesia desensitise tooth manipulate the tissues to re-align and straighten irregular set of teeth and to enhance the durability of the teeth [4].

Approaches for nanorobots

The manufacturing of robots can be either organic or inorganic. Organic being bio-nanorobots established on the progression of energy source adenosine triphosphate and deoxyribonucleic acid to obtain actuation for nanorobots while the latter is based on either diamondoid materials or fullerenes [5-7].

Concept of nanorobots

The nanorobotic theory states that, nanorobots are microscopic in size and it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks [8]. Nanorobots in medicine are designed with the goal of maintaining and protecting the human body against pathogens [8]. A nanorobot is a tiny machine constructed to operate definite task or tasks time and time again amidst accuracy at nanoscale dimensions [4].

Fabrication and mechanism of action

Principle element carbon present as diamond/fullerene nanocomposite owing to its superior strength and chemical inertness. Others like oxygen, nitrogen may also be included. The external diamond coating which is passive in nature manifest a smooth flawless coating that elicits near minimum reaction from the body's immune system [8]. Nanorobots are powered internally by the metabolism of glucose and oxygen as energy supplies and externally by acoustic energy [4]. Nanorobots possess simple onboard computers capable of performing around 1000 or even fewer computations per second. Transmission with this device can be accomplished with the help of broadcast type acoustic streaming. A navigational network installed in the body provides high positional accuracy to all passing nanorobots thus making their location known [4]. Nanorobots are capable of demarcating between various cell types by scrutinizing their surface antigens. Once their function has ended they excuse themselves through the human excretory channels or via scavenger systems called nanoterminators (Figure 1).

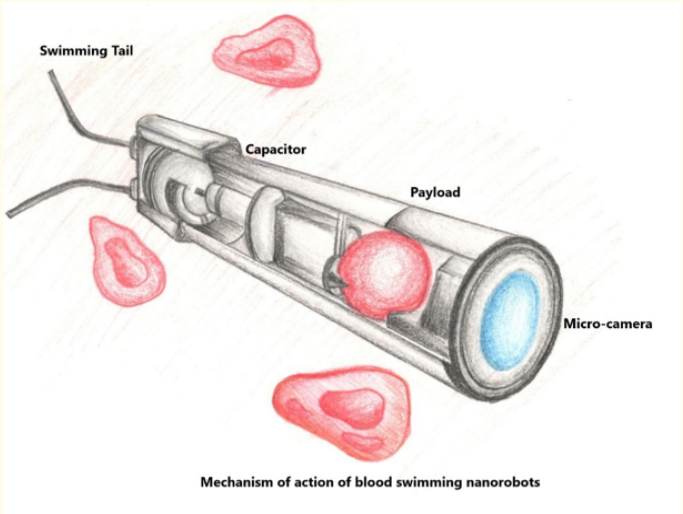

Figure 1: *Mechanism of action of blood swimming nanorobots.*

Robotics in medical field

Robots have managed to pave their way into the field of medicine and now are being used in a number of surgical branches. The first time a robot was used in medical science was in 1985, when the PUMA 500 was used to place a needle for brain biopsy using CT guidance [9]. Guy's and St's Thomas Hospital, London in 1988 employed the MROBOT and thereby prostatic surgery was performed by Dr. Senthil Nathan. Following the developments in industrial robot technology the pioneer complete robot surgery took place at The Ohio State University Medical Center under the leadership of Professor and Chief, Cardiothoracic surgery Dr. Robert E. Michler [10]. A first true robot- a machine-driven instrument simply not mirroring the movement of hands but guided by the pressing of buttons was used in September 2010 for a femoral vasculature performed at the University Medical Centre Ljubljana by a team led by Borut Gersak.

Robots in dental field

Dental patient robot

The skills of dental surgeons are calculated based on their competence and ability which is directly proportional to their experience gained using methods and models that can stimulate the near-real treatment procedures and conditions. Clinical training in dental schools have always being carried out on consenting volunteer patients, fresh pass out dental surgeons lacking sufficient clinical skills and experience in administering treatment have culminated in ethical changes in medicine and dentistry making these trainings not as simple to carry out as there were before. This has given initiative for the invention of the dental training robot-patient robots utilised for training with respect to dental therapy, commonly referred to as phantoms they comprise of a simple yet functional cephalic region with an external arrangement of teeth designed for clinical training [11].

Realistic human-like robots

Tokyo's Showa University contracted robotics company Tmsuk for the construction of a realistic robot Showa Hanako that impels typical patient gestures along with their responses thereby dental students experience a first hand clinical experience even in the absence of a real stimulated environment. March 2010 saw the manufacture of Showa Hanako 2 user friendly in nature and a functional replacement to Showa Hanako 1. Orient industry the makers of "Love doll" suggested the silicon skin that is different from the PVC skin of the first model and the mouth lining which enhance the realistic feel and prevents water getting clogged in the equipment. The Showa Hanako 2 can blink, roll its eyes, sneeze, shake its head, cough, move its tongue and even gets tired when its mouth is kept open for pronged duration of time. Rayton developed a speech recognition technology to carry out conversations along with a gag reflex that could be stimulated during instrumentation.

Geminoid DK

Japan's Advanced Telecommunications Research Institute International built the Geminoid DK led by Professor Hiroshi Ishiguro along with his associates. Remote controlled Geminoid is equipped with advanced motion-capture technology. A variant of geminoid the Geminoid- F mimics human facial expressions to the extent of laughing. HPR-4 – have been programmed to mimic human expressions and sound while singing

SIMROID

A quintessential inclusion is the SIMROID, super-realistic in nature developed at The Nippon Dental University Kokoro with dental equipment maker Morita Manufacturing and an upgrade to the Simuloid build in 2007. A major advancement in this set up is the robots ability to react with lifelike situations with emotional responses. The presence of two cameras oversee students every move with readings from its sensors in and around the mouth allow it to feel pain and discomfort which will allow it to act in a negative manner when in discomfort making students feel conscious about their technique and can act as a source of correction thereby facilitating improvement. Discomforts as minute as when a dentists elbow comes in contact with its breast are also included in the model which can respond and react to question and commands. The motive behind the creation of the Simroid is to improve student patient communication skills by emphasizing attitude rather than technique [12].

Endo micro robot

Clinician's knowledge, expertise and tactile sense and judgement are essential for a successful endodontic treatment. Procedural errors such a perforations, canal ledging, apical foramen transportations, stripping and excessive instrumentation beyond the apex may not provide a favourable prognosis [13]. Advanced endodontic technology innovation has been developed in-order to reduce the potentials errors that can result in mishaps (Figure 2). Several teeth within the patients mouth are mounted with the computer-controlled machine alongside on-line monitoring and intelligent control, the robot performs automated drilling, cleaning and filling of the root canal.

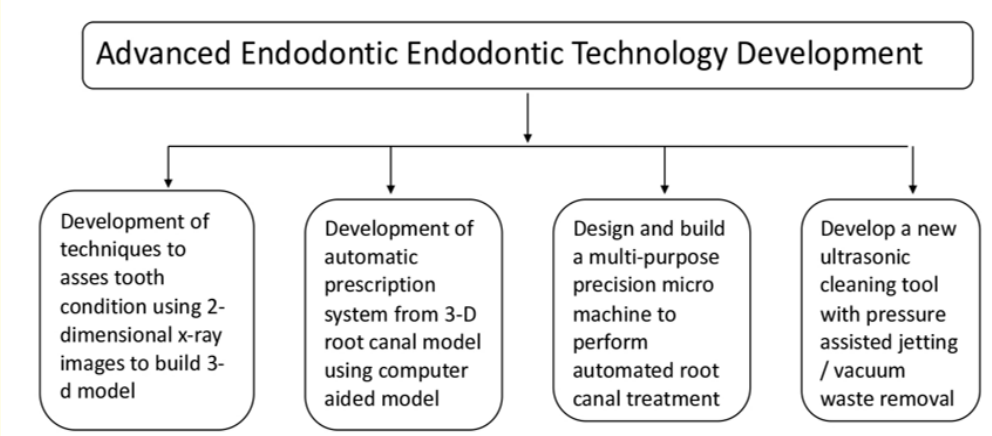

Figure 2: *The Advanced Endodontic Technology Development project consists of four subjects.*

Objectives of the micro-robot design

Micro-robot design aims at reducing the reliance on the contemporary dentist, thereby minimizing human error while maintaining precise diagnosis and treatment.

Dental nano-robots

Nanorobots will allow instant diagnosis and extermination, individual cell surgery *in vivo* and improvement of natural physiological function. Programmed to induce oral analgesia, desensitise tooth manipulate the tissues to re-align and straighten irregular set of teeth and to enhance the durability of the teeth. Their potential to consume bacteria promoting caries or to repair tooth blemishes where decay has crept in employing digital aids to direct these tiny workers in their tasks [14].

Surgical robots

Advancements in maxillofacial surgery have paved way for surgical robots where the surgeon collectively with the robot executes pre-programmed functions [15]. Milling of bone surfaces, drilling of holes, deep saw osteotomy cuts, selection of osteosynthesis plates bending and intraoperative positioning in define position and orthognathic surgery planning and now being carried with the help of robotic designs and techniques [16]. According to Satava, "the operating room of the future will be a sophisticated mix of stereo imaging systems, micro robots, robotic manipulators, virtual reality, telepresence workstation and computer integrated surgery" [17].

Sensor-equipped implant setup

Yomi (FDI Cleared) is robotically assisted dental surgical system for implant placement, which plans its procedure using a patients CT Scan [18]. Not long ago, South China morning post reported a case where a dental robot had placed two dental implants on a female

patient, this was carried out by following a set of pre-programmed commands to install the implants fitted within an error of 0.2 - 0.3 mm (Figure 3) [19].

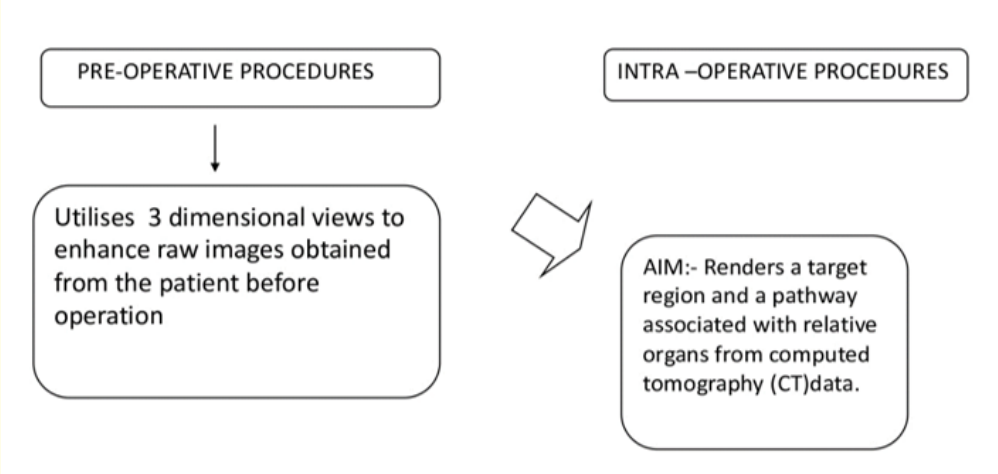

Figure 3: *The mechanism of action.*

Robotic dental drill

Designed to take the complexity out of dental implant work and developed by Tactile Technologies based in Rehovot the robotic dental drill can make the procedure more economical, faster and less traumatic for the patient. A frame is clamped onto the patients jaw and very thin needles penetrate the gum that determines the location of the bone. This data is transmitted via a wireless connection to a PC which combines with a CT scan data to configure a set of drill guides that are attached to a frame and the dentist presses a button to start the drilling in the precise location required. The process is self-guiding though the practitioner can alter the process at stage of the procedure.

Dental robot cerec

iRobot in collaboration with InTouch Health designed a patient friendly robot that wonders into hospital rooms and helps with diagnosis at a preliminary stage with the assistance of a physicians support who may be thousands of miles away. A robot technician enter the dental setup and commands a Cerec machine which takes a digital impression thus forbidding the patient to leave the clinic with a temporary crown in place. The Cerec trained dentist then designs the dental crown on a computer screen and wirelessly emails the design to CAD-CAM, dental robot located in another room. Within 15 minutes a perfectly shaped and coloured dental crown or onlay is magically produced. This can then be luted in a single visit. Robotic dentistry has also branched into Invisalign orthodontics where mal-aligned teeth are digitally recreated and straightened.

Discussion

The field of nano-robotics has witnessed rapid development along with its fair share of controversies over the safety of their application in conjunction with the toxic effects of medical nanorobots on the human being or the medium, giving birth to ''nanoethics" [20,21]. The boon of employing dental nanorobots are diverse as there are countless applications of these minute instruments, hence the potential toxicological risks on the human body are being discussed [22], Scenarios like the disappearances of the *Homo sapiens* on the assumption that nanorobots will not be eliminated from the human body. The progress of nanorobots approaching the capacity of continuous auto-

replication could lead to the disappearance of the biosphere culminating in the appearance of clusters consuming any living creatures on earth leaving behind a useless grey mass (grey-goo scenario).

As of today, nanodentistry faces numerous symbolic challenges in attaining its tremendous potential that must be addressed ahead of with it can make its way into modern medical armamentarium (Figure 4).

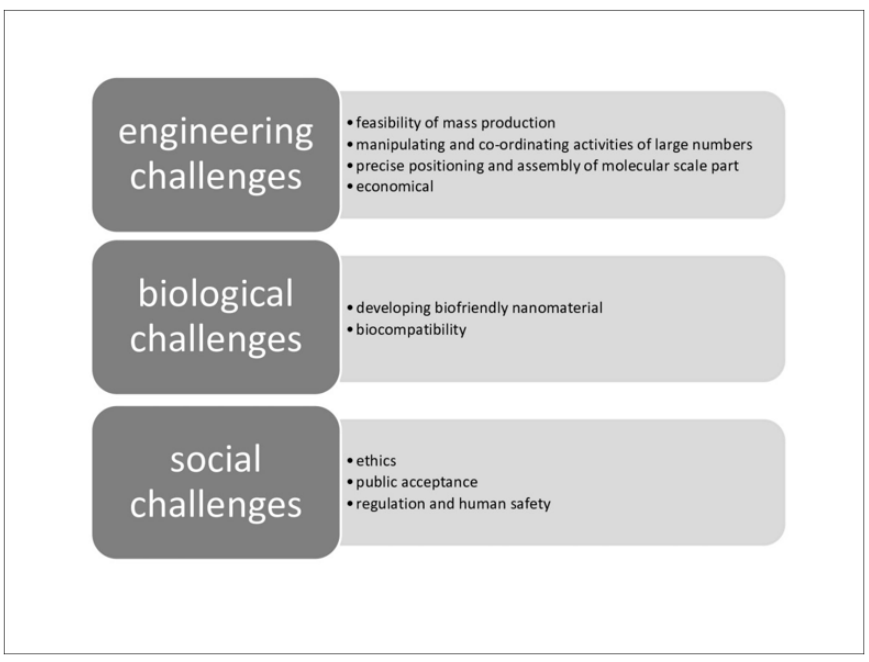

Figure 4: *The engineering biological social challenges.*

The dwindling of self care neglect coupled with the rise of cases with the involvement of cosmetic procedures, acute trauma, rare disease conditions. Customised diagnosis and treatment will be carried out to match the preference along with the genetics of each patient. Bountiful and exciting treatment options will be in demand manifold in comparison to the present which will be considered as the hallmark of the contemporary dentist.

Despite the fact that the robotic world of precision and accuracy is well expressed and implemented in a large number of places there are still some limitations. Although there is invariably a quest for advancement, developing countries still regard robots replacing humans nothing less than a science fiction [23]. Way back in 1950s nanorobots was at the "Fictional stage» now "theoretical stage" but 2020 "decade of the nanorobot" [24]. Nano-robots will radically change the 21st century dental medicine and the role of the dentist will change for ever. The contemporary dentist will now have to have to possess technical capabilities along with a quicken and a correct professional judgement to be able to treat acute facial trauma and rare genetic disease with manifestation at the level of oral cavity. A fiction today, Nano-robots will rationalize dentistry, health care, human life more profoundly than other developments [25].

Conclusion

Robotics within the realms of possibility have the potential to revolutionize dentistry with improved accuracy, predictability, safety, quality of care and the speed of dental treatment. It encourages the concept of minimally invasive dentistry, creating a more dentist

friendly atmosphere and a potential to alter the quality of dental health in a few years from now. If you've ever wondered why robots have not yet been acquainted in the field of dental science then the only plausible explanation is that robotics is an example of disruptive technology that might hamper the sales of dental equipments and a negative impact contributing to the alienation of dentists and possibly dental schools years from now. Our main futuristic objective lies in maintaining a clear vision and feasibility of adapting these technologies in our daily practice be it clinical or teaching. As Paul A Meglitsch has rightly stated "Nearly every great discovery in science has come as a result of providing a new question rather than a new answer".

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