ISSN: 2581 – 3633
PubMed - National Library of Medicine - ID: 101745081

International Journal of Medical Science and Advanced Clinical Research (IJMACR)

Available Online at: www.ijmacr.com

Volume – 5, Issue – 2, March - April - 2022, Page No. : 247 - 252

Robotics in Dentistry

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How to citation this article: Deepak Narang, Prabhjot Kaur, Rajbinder,Tejveer Singh,Amandeep Singh, Manmohit Singh, "Robotics in Dentistry", IJMACR- March - April - 2022, Vol – 5, Issue - 2, P. No. 247 – 252.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

The success of applying robotics to the medical field has opened a new frontier with vast areas for expansion and exploration; more specifically, robotics with dental application is a relatively untraveled area to pursue. It was introduced in the field of medicine and dentistry to increase precision, quality and safety of various procedures.

Robotics is a disruptive technology that will change diagnostics and treatment protocols in dental medicine. Robots can perform repeated workflows for an indefinite length of time while enhancing the overall quality and quantity of patient care. Early robots required a human operator, but robotic systems have advanced significantly over the past decade, and the latest medical robots can perform patient intervention or remote monitoring autonomously.

However, little research data on the therapeutic reliability and precision of autonomous robots are available. The present paper reviews the promise and practice of robots in dentistry by evaluating published work on commercial robot systems in dental implantology, oral and maxillofacial surgery, prosthetic and restorative dentistry, endodontics, orthodontics, oral radiology as well as dental education. In conclusion, this review critically addresses the current limitations of dental robotics and anticipates the potential future impact on oral healthcare and the dental profession.

Keywords: Robotics, Endo-microrobots, Dental Nanorobots, Surgical Robots

Introduction

Robots, the most wonderful invention of human being, have made their way into dentistry. Robotics is the branch of technology that deals with the design,

construction, operation, and application of robots as well as computer systems for their control, sensory feedback, and processing the information. According to the Robot Institute of America a robot is defined as "a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks".[1]

The use of robots in dental clinics, especially in the tasks of dental assistants, may constitute one of the most important arguments for robotic dentistry. A study at Oxford University found the tasks of dental hygienists and dental assistants were more likely to be computerized than the tasks of dentists. Jenkins perceived in 1967 as a robotic dental secretary, and several robot applications in dentistry have since become a reality. Dental professionals may experience physical and mental exhaustion after hours of demanding procedures in ergonomically challenging positions, potentially leading to mistakes in the oral examination, disease diagnosis, and treatment planning.[2]

Apart from serving as dental assistants, robots in conjunction with 3D navigation can be used for invasive dental procedures, including tooth preparation and autonomous dental implant placement. Robotic systems can also play a role in education. Training dental students with the aid of full-body robotics, haptic interface technology, and advanced simulation can teach basic learning needs before interaction with real patients.[1]

History

The pioneering work conducted at the National Aeronautics and Space Administration (NASA) marks the origin of robot-assisted surgery. In the mid-1980s, a remotely controlled robotic system was developed by NASA for surgically operating soldiers on the battlefield as well as astronauts in space. In 2000, the USA Food and Drug Administration (FDA) approved the first robotic system for performing laparoscopic surgery in a doctor-robot setup. In 2001, the validation of the doctor-robot concept was performed via a transcontinental live robotic cholecystectomy. It was the first instance that a team of surgeons operated on a patient elsewhere (Tele presence). Since then, robots have been employed in surgical specialties such as general surgery, gynecology, and urology.[3]

Robots in Dentistry

Robots are not used as extensively in dentistry as in medicine. Dentistry employs a few manual robotic systems that are managed manually via the control interface of the computer. Manual robots can provide safer and more accurate drilling than traditional dentistry. Progress is being made towards autonomous robots in implant dentistry, but the few promising robotic systems are not yet available to dentists. High acquisition cost and innate intricacy of the robotic hardware and methods must be overcome before robots will become commonplace in dental practice.[4]

Dental therapy skills often depend on the competence and ability of clinicians and it is necessary for them to have extensive experience using methods and models that accurately reflect actual treatment procedures and conditions. Recently fresh pass out graduates lack clinical skills and experience in treating patients[1].

Until recently, clinical training was carried out on consenting volunteer patients. However, recent changes in ethical issues related to environmental studies, medicine and dentistry have made such clinical training difficult. Currently so called 'Phantoms' consist of

simple functional cephalic region and arrangement of teeth which is different from actual patients.[2]

Showa Hanako

Tokyo's Showa University engaged robotics company Tmsuk to manufacture the realistic robot which is designed to simulate a number of typical patient gestures and responses, allowing dental students to experience what it's like to work with a real patient. The robot is also capable of simulating a gag reflex, which is frequent during dental procedures, it can blink, roll its eyes, sneeze, shake its head, cough, move its tongue and even get tired when having to keep its mouth open for too long[5].

Geminoid DK

This robot is a realistic android designed for research into human-robot interaction. It is modeled after Danish professor Henrik Scharfe, who remotely operates the android as his robotic surrogate. The Geminoids can be controlled, being equipped with advanced motion-capture technology.

Simroid It is a super realistic dental teaching robot for clinical training at dental schools created by Kokoro Company Ltd. It is actually an upgrade to Simuloid, a less sophisticated dental training robot created back in 2007. This robot is loaded with sensors that give feedback to dental students. It can express pain when poked hard; it grimaces to show pain; and it also moves its hands and eyes to say that it is hurt.[6]

Endo Micro Robot

Success of endodontic treatment depends on the clinician's knowledge, expertise including his/her tactile sense and judgment. To help with this, endo-microrobots were fabricated. It consists of a visually guided robotic system will be mounted on the teeth within patient's mouth, while a robotic controller and a root canal image processor share control over its motion. With online monitoring and positioning control, the multipurpose robotic system will perform automatic treatment procedures, including probing, drilling, filing, cleaning and filling. This robot consists of a micro position and orientation adjustment device, an automatic feed rate and travel distance controller, micro sensors and apex sensors.[7]

Dental Nanorobots

Nanorobots are miniature devices measured on the scale of nanometers (1n equals one millionth of 1 millimeter) constructed with nanoscale or molecular components. A dental nanorobot have a nanocomputer on board which store and performs preprogrammed actions and processes signals and external stimuli. The possible treatment options of using nanorobots may include the application of nanotechnology to local anesthesia, dentition renaturalization, the permanent cure of hypersensitivity, complete orthodontic realignment in a single visit, covalently bonded diamondized enamel, and continuous oral health maintenance using mechanical dentifrobots.[8]

Surgical Robots

The intervention of robotics into surgery has allowed surgeons to create a new kind of environment in the operating room. Robotic technique is being used for milling of bone surfaces, drilling of holes, deep saw osteotomy cuts, selection of osteosynthesis plates, bending and intraoperative positioning in defined position, and orthognathic surgery planning.[9]

Sensor-Equipped Implant Setup

Dental implants are long-lasting tooth replacements that use Titanium screws embedded directly into the alveolar bone. Recently a new system of computer assisted

surgery for implants has been developed consisting of preoperative and intra operative stage. [10]

The preoperative stage, uses the 3D views obtained from the raw images of the patient before surgery followed by the intra operative stage, which it shows 3D orientation of surgical instrument position and trajectories which are displayed on the monitor within a patient's 3D imaging data. "Yomi" (FDA Cleared) is robotically assisted dental surgical system for implant placement. It is used to plan a procedure based on patients' CT scan.[9]

Robotic Dental Drill

It is a recent advancement, developed by Tactile Technologies, consists of immobilizing the jaw of the patient and suspending thin needles which can penetrate the gum and determine the location of the bone. This whole unit is connected with a wireless connection to a PC and joins with the CT scan data thereby producing a set of drill guides. Once activated, these are self directing and can be altered by the clinician as per the requirement.[11]

Dental Implantology Robot

This system mimics the mandibular movements and occlusal contact forces in order to make it possible for various implant designs and procedures to be tested and evaluated before animal testing or clinical human trials. This method consists of forming pre-programmed software which is used to work with CT scanner data.[12]

Neocis, a Precision HealthCare Robotics company, has introduced an FDA-cleared computerized navigational system (robot) intended to assist in both the planning and surgery of dental implants. The YOMI® robotic arm provides an enhanced level of precision and control while using haptic guidance and multisensory feedback to perform dental implant surgery. The robotic arm helps the surgeon to achieve the correct location, angulation, and depth when placing dental implants through its sensors, producing true and unique guidance[11].

Orthodontic Arch Wire Bending Robots

This new bending apparatus is known as "SureSmile archwire bending robot." The apparatus comprises a robot mounted to a base or table support surface with 2 gripping tools. The tools incorporate force sensors which are used to determine overbends to get the desired final shape of the arch wire. They may also include a resistive heating system in which current flows through the wire while the wire is held in a bent condition to heat the wire and thereby retaining the bent shape of the wire.[13]

Micro Sensors, Actuators and Control Systems

This machine design also incorporates sensors for intelligent monitoring of the treatment process. Because the compact features of the sensors, they can be fabricated using a surface micro machine method to produce silicon-on-insulator (soi) wafers, which will be embedded in the micro robot. Six micro actuators are used to control the five axes (five degrees of freedom) and the on/off spindle of the tool. Each actuator is independently controlled by a digital nc controller. The controller should react the sensor signal quickly, typically in a few milliseconds.[14]

Rosy

It is a new computer- aided intra-operative guidance system for implant surgery .For implant planning and surgery with the robot system Rosy; five different work processes are required. Preprosthetic planning consist of preparation of direct mock up with the help of radio-opaque resin on set of pre - operative cast. This mock up is tried on the patient mouth. The cast with mock up is placed on lower support plate of Rosy and a pointer is set in the upper support plate that marks the planned implant entry site and angulation. Using the six step

motors, the lower support plate can be adjusted in all the six degrees of spatial freedom.[15]

Dental Robot CEREC

The joint venture between iRobot, the inventor of the home robot vacuum cleaner called Roombas, and InTouch Health designed a new patient friendly robot that wonders into patient hospital rooms and helps to remotely diagnosis problems with the help of a physician specialist who may be thousands of miles away. [16]

Instead of the patient having to leave the office with a temporary crown, a robot technician is wheeled into the clinic and commands a Cerec machine which takes a digital impression .The Cerec trained dentist then designs the dental crown on a computer screen and wirelessly emails the design to a cad-cam, dental robot located in another room[17].

In about 15 minutes of fascinating buzzing and whirring a perfectly shaped and colored dental crown or onlay is almost magically produced and can be bonded to the tooth in one visit. Invisalign orthodontics is yet another example of robotic type, dental treatment available from your hi tech Gettysburg Invisalign dentist Malaligned teeth are digitally recreated and then digitally straightened, allowing a series of tooth straightening dental aligners to be robotically fabricated[18,19].

Conclusion

The intervention of robotics in the field of dentistry can offer improved accuracy, predictability, safety, quality of care and speed of treatment. With the emergence of new technologies, future of dentistry is unpredictable. Main concern lies in the vision and feasibility of adapting these technologies in day today teaching and clinical practice.

Any new therapeutic innovation is critical to our future health and such an innovation will, at least initially, cost more than the previous therapy. To abandon the search for improved therapies on the basis of cost would represent enormous disservice to our patients and would distinguish attempts to improve patient care from the quest for better automobiles, audio systems, or computers, or from any area of human endeavor.

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