



Robotic Dentistry – Application of artificial intelligence in dentistry.

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Conflict of Interest: None

ABSTRACT:

With the advancement of technology in all fields of medicine, a lot of techniques and opportunities have been unraveled. The dental field has also made some invincible developments with the use of robots; just that this path is still untraveled in a lot of directions. Robotics in dentistry aims to increase precision, quality of work and safety. At the same time it can decrease time consumption and minimizing human errors thus ensuring utmost accuracy and predictability. The main aim of this review article is to provide an insight on the latest robotic technologies being used in the field of dentistry. The literature of this article has been pooled from reference articles which were found using PubMed, Google Scholar, Medline etc. The articles were included based on predetermined criteria in the field of robotic dentistry.

Keywords: Robotics, artificial intelligence, use of robots in dentistry

INTRODUCTION:

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 information processing. The term 'robotics' was introduced by Isaac Asimov in 1950⁽¹⁾. The word robot is derived from a Czech word 'robota' which means forced labor. A robot is a machine that is designed such that it can carry out complex series of actions automatically⁽¹⁾.

The history of robotics' development dates back to NASA's pioneering research with robot-assisted surgery. In 1980s NASA developed remotely operated robotic systems for military and space bound surgery. This is how the

medical field started getting familiarized with the use of robots as a part of artificial intelligence. A beginning base was laid for the applications of robotics in dentistry⁽²⁾.

The usage and application of artificial intelligence (AI) is not just restricted to one or two disciplines in dentistry. Every field of dentistry has their own advancements in technology and has some sort of involvement or application of robotics assisted dentistry. Fields like restorative dentistry, maxillofacial surgery, prosthodontics, endodontics, implantology, orthodontics etc. have found the robotics' niche in their respective way.

Robotic systems are widely used in the medical field, such as the 'Da Vinci' robot which is well known for assisting in various surgical procedures. In this robot, the hand movements of the surgeon are transferred to the robot and are reproduced on a smaller scale⁽³⁾. Even in the dental field, there are some well known robotic systems used like the archwire bending robot of one of the Orthodontic systems⁽⁴⁾. Similarly a robot of high advancement being used today in the dental field is the implantology robot called 'Yomi'©.

This article will shed some light on the various robotic systems being used in different fields of dentistry.

Application of robotics in various fields in dentistry:

ENDODONTICS:

Endodontic microrobot:

Endodontics is a field that requires great precision and skills. And a good treatment requires the practitioner's knowledge, expertise, hand dexterity, tactile sense and judgment. This is to avoid errors like perforations through the root, canal ledging, improper canal preparation, excessive instrumentation and instrument separation⁽⁵⁾. To improve the quality of endodontic procedures and decrease human errors, advanced endodontic technology is a necessary evolution⁽⁶⁾⁽⁷⁾.

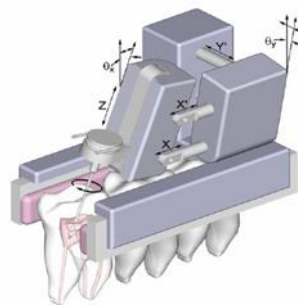


Fig.1 Endodontic microrobot⁽¹⁾

The endodontic micro robot is a computer controlled machine. That is mounted on several teeth of the patient within the patient's oral cavity⁽¹⁾. By the help of online monitoring and use of artificial intelligence, the robot carries out procedures like drilling, cleaning, and obturation or filling of the root canal⁽¹⁾. The objectives of the micro robot are reducing reliance of dentist's skills, minimizing human error and offering a method for precise diagnosis and treatment⁽⁸⁾.



Fig.2 application of microrobot in the oral cavity⁽¹⁾

Nanorobots:

Nanorobots are robots of nanometric resolution that can have various applications in endodontics. They are robots that are close to microscopic scale of two nanometers (2nm)⁽¹⁾. They are made out of nanomaterials such as carbon nanotubes, metallic nanoconductors and diamondoid materials in thousand mechanical parts⁽¹⁾.

These robots use artificial intelligence by which they can be programmed using computers to perform a particular procedure. Nanorobots are designed with such technology that they can artificially diffuse inside the body and interact with human cells or manipulate them to fulfill the tasks at a nanometric resolution⁽¹⁾. Multiple nanorobots in unison can work on a tooth and can be invisible to the naked eye. They can carry out procedures like cavity preparation (of demineralized enamel and dentin to ensure maximum conservation) and restoration of teeth⁽⁹⁾.

ORAL AND MAXILLOFACIAL SURGERY & IMPLANTOLOGY

Yomi:

Yomi is the first commercially available implant robot⁽¹⁰⁾. The robotic system is manufactured by Neocis Inc and has received FDA approval⁽¹¹⁾⁽¹²⁾. Yomi is a robotic system that provides haptic feedback so that it can provide proper physical guidance and constraints in orientation, position and depth of the drill⁽¹⁰⁾. Practitioners have the liberty to change the plan in real time based on the different surgical circumstances and expected outcomes⁽¹⁰⁾.

Yomi offers physical guiding that eliminates the need for the surgeon to fabricate bulky surgical guides⁽²⁾. While using vibrational feedback for implant surgery which requires osteotomy, precise and predictable navigation is achieved.

Perhaps the reason why it is not widely used yet⁽²⁾ is that it cannot perform procedures autonomously due to ethical concerns. The other reason for low market penetration currently is the price factor that puts it out of reach of most general dental practitioners).

This technology is currently being evaluated and integrated into the core undergraduate DDS curriculum, as New York University (NYU) – College of Dentistry one of United States' premier educational institutions that has been on the forefront of this pathbreaking endeavor⁽¹³⁾.

Fig.3 Yomi⁽¹⁴⁾

Robotic dental drill:

It is a robot that is created for ease and accuracy in placing dental implants. It also makes the procedure cheaper, quicker and less painful⁽¹⁾. A clamping frame is placed on to the patient's jaw and then very thin needles penetrate the gum to determine the location of the bone where the implant is to be placed. The data gets wirelessly transmitted to a PC, which gets combined to that of the CT scan data and then a set of drill guides are configured. The guides are attached to the frame. The dentist then presses a button so that drilling begins in the precise location on the jaw bone as required. The drill itself is self-guiding but the dentist or operator can alter it at any time⁽¹⁵⁾.

Temporomandibular Dysfunction (TMD):

Temporomandibular pain is associated with temporomandibular dysfunction. It causes limited mouth opening and temporomandibular joint (TMJ) bounce with sound⁽¹⁶⁾. A conservative therapy is to give massage as treatment to the TMJ having TMD. When compared to the traditional massages, the massage given by a robot saves human endeavor, and its programmed and standardized massages give effective and better treatment to the patients. The oral rehabilitation robot called WOA-1 was used by Arijji et al to massage 26 TMD patients with different conditions three times with each time being a session of ten minutes⁽¹⁷⁾. Out of which 75% of the patients were relieved of myofunctional pain and 40% of them had 5mm increase in mouth opening.

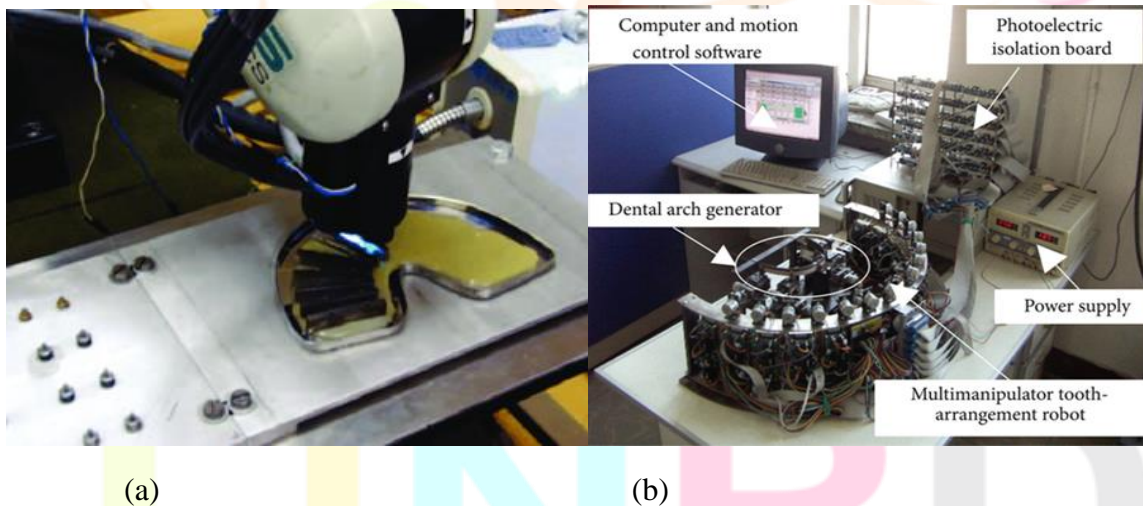
According to Nadjmi, **palatorrhaphy** surgeries can be carried out using the Da Vinci surgical robot⁽¹⁸⁾.

PROSTHODONTICS

A miniature laser manipulation robotic device was created by Yuan et al and Wang et al called **LaserBot** for tooth crown preparation⁽¹⁰⁾⁽¹⁹⁾⁽²⁰⁾. This was done to solve the problem of the shape of prepared teeth not being ideal because of the trembling of hands and limitations of clinician's skills due to narrow oral space. A special laser can automatically be controlled by the robot to cut the teeth in three dimensions. The accuracy of the robot can reach clinical requirements.

Fig.4 LaserBot⁽¹⁰⁾

A single-manipulator robotic system has been created by Lu et al and Jiang et al based on **CRS-450 robot**, which can perform tooth placement in the manufacturing of complete dentures⁽¹⁰⁾⁽²¹⁾⁽²²⁾. It can finely adjust the placement and position of artificial teeth through mechanical claws⁽¹⁰⁾. The software in the robot can display dental arches, dentition in a 3D model and occlusal curves.



(a)

(b)

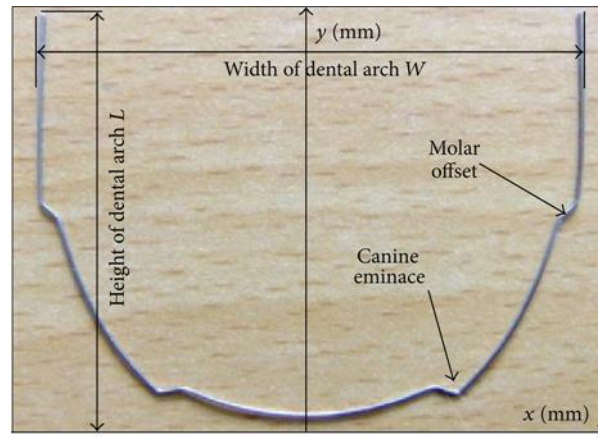
Fig.5 & Fig.6 Single-manipulator tooth-arrangement robot system for complete dentures. (a) Structure of the robot. (b) The robot arranging teeth⁽¹⁰⁾

ORTHODONTICS

An archwire-bending robot called the **SureSmile archwire-bending** robot has two-handed jaws which bends archwire automatically and accurately. It was created by Butsher et al in 2004⁽¹⁰⁾⁽²³⁾.

In 2009, Zhang et al and Du et al created an archwire bending robot that could bend four different types of wires⁽²⁴⁾⁽²⁵⁾.

Jiang in 2013 has constructed an archwire bending robot that uses the third order 'S addition and subtraction curve' controlling method⁽²⁶⁾.

Fig.7 Archwire bent using robot⁽¹⁰⁾

OTHER ROBOTIC DEVICES THAT ARE COMMON TO MULTIPLE FIELDS IN DENTISTRY ARE:

Geminoid DK:

Geminoid DK was created at Japan's Advanced Telecommunications Research Institute International by Hiroshi Ishiguro and his colleagues. Geminoid is an Android robot that is designed to search for answers to fundamental questions. It is remote controlled and equipped with advanced motion-capture technology. It is a replica of Professor Henrik Scharfe of Aalborg university⁽¹⁾. The machine mimics facial expressions and precisely imitates head motions⁽¹⁾.

Fig.8 Geminoid DK⁽¹⁾

Simroid SH:

The simroid is actually an upgrade to Simuloid that was a dental training robot created back in 2007⁽¹⁾. Simroid is a realistic dental training robot. It gives more emotional feedback to the trainer as compared to the Simuloid robot. Artificial intelligence allows it to react towards human emotional responses. With the help of sensors that are in and around the mouth, it is simulated to feel pain and discomfort and thus gives a negative response which allows the

practitioner to become conscious of the treatment. Even when the practitioner's elbow comes in contact with the breast, the robot shows discomfort so that there is room for correction in all possibilities.

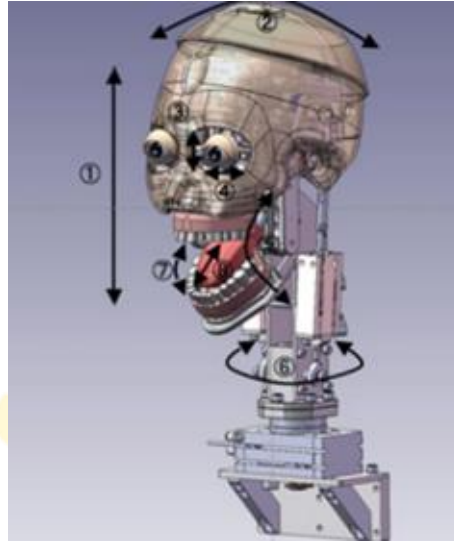


Fig.9 Simroid SH

Showa Hanako:

Showa Hanako is a realistic robot that is designed to mimic a number of patient gestures and responses. This gives the dental students a real patient like working experience which prepares them for better management and handling of the patients in real life practice. The Japanese robot can perform multiple actions such as blinking and rolling of the eyes, sneezing, shaking its head, coughing, moving its tongue and even getting tired if the mouth is open for too much time. Showa Hanako's advanced technology enables it to get a gag reflex (which is common during dental procedures)⁽¹⁾. Also, speech recognition technology has been used by Japanese engineers. It was developed to facilitate conversation capability by Raytron⁽¹⁾.



Fig.10 &11 Showa Hanako

WILL ROBOTS REPLACE HUMANS IN THE FUTURE?

This is a topic of considerable subjective debate. The use of robots is being outspread in almost all countries of the world and are now ubiquitous in our daily lives. Robotics changes the operating techniques for a particular procedure in many ways. It is true that robots are machines designed for better accuracy, minimizing human errors and to be time friendly; but the fact that the ability of humans to reason under certain circumstances and difficult situations can still not be provided by a robot.

A robot may be reliable for certain techniques but not all. And no matter how perfect it might be, robotic working always requires human supervision.

On the other hand when it comes to precision and better treatment a robot is said to check every box of interest and practice when compared to manual work.

So it is for a practitioner to decide whether their practice can be taken over or enhanced by the use of robotic devices because at the end of the day a robot is also man-made.

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