(International Print/Online Journal)

SJIF IMPACT FACTOR: 5.565
PUBMED-National Library of Medicine ID-101739732

ISSN (Print): 2209-2870
ISSN (Online): 2209-2862

International Journal of Medical Science and Current Research (IJMSCR)
Available online at: www.ijmscr.com
Volume 6, Issue 2 , Page No: 782-788
March-April 2023

IJMSCR

Artificial Intelligence In Dentistry: Dental Robotics

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Type of Publication: Review Paper
Conflicts of Interest: Nil

Abstract

Artificial intelligence [AI] is a next-generation technology that has formerly aided the medical field in achieving new frontiers. AI has given lives to machines that are now more able than a surgeon to operate on a living being. The use of such living machines in Dentistry has enhanced the accuracy and precision of the treatments and has reduced the chances of errors. Robotic systems are one of them which is emerging. Robotics technologies provide valuable real-time information, to the clinician allowing for more thorough examinations, accurate diagnosis, and supporting clinical decision-making throughout dental procedures. Robotic systems represent the most technologically advanced approach in minimally invasive surgery (MIS) and its application has precipitously gained acceptance in several surgical Fields, like cardiac space, orthopedics, elective urology, gynecology, digestive, and hepato-bilio-pancreatic surgery. In dentistry, the use of robots is caving in with all the necessary technologies which could further be developed and could be easily adapted and it shows promise in material testing, orthodontics, prosthetics, oral and maxillofacial surgery, and implantology. But robotic systems have not been acquainted with dental research nor have they achieved cost adequacy and modern repute to be fused into the dental market. In this review, we discussed Robotics and their combined utility in diverse fields of dentistry.

Keywords: Robots in dentistry, micro-robots in endodontics, robotics in dentistry, artificial intelligence in dentistry, and robotics in various fields of dentistry

Introduction

Robotics is a Next-generation technology that's specialized in designing, construction, and operation. With the development of current technology, robots at the moment are used in each field of technological know-how.[1] A robot performs a variety of tasks and it is designed to move materials, parts, tools, or specialized devices through various preprogrammed motions.[2] It aids in completing sports that are difficult for a dental clinician to complete. These systems with navigational steerage give progressed accuracy and precision in dental treatment with streamlined work processes and better workflows.[2] Robotic arms mimic the dexterity of a surgeon's hands and assist them in dental surgery. Dentistry together with robots can help to minimize errors and enhance the overall quality and quantity of patient care. Robots in conjunction with 3D navigation can be used for invasive dental procedures, including

tooth preparation and autonomous dental implant placement and they also serve as dental assistants.[3]

Methodology:

For data, a collection search was carried out online on various sites: PubMed, Medline, Research Gate, and EBSCO. For search words and phrases –robots in dentistry, micro-robots in endodontics, robotics in dentistry, and artificial intelligence in dentistry were used in various combinations. The selected items comprised research and review articles.

The intervention of robotics in the field of dentistry can offer improved and precise treatment with good quality work in less time. There are various robots used in divergent environments and for multiple uses. Dentistry employs a few manual robotic systems that are managed manually via the control interface of the computer. Nanotechnology is part of a predicted future in which dentistry may become more high-tech and more effective looking to manage individual dental health on a microscopic level. Microrobots/nanorobots (also called micromotors/nanomotors) have attracted considerable attention over the last decade because of their unique capabilities of self-propulsion in diverse liquid environments to target specific tasks at the microscale/nanoscale.[4]

Nanorobots:

The nanorobots or nanites or nanomachines are theoretical microscopic devices that deal with the manipulation of nanoscale objects by the usage of micro or macro devices, and the construction and programming of robots with overall dimensions that of the nanoscale.[5]

Mechanism of action of nanorobots :

The powering of nanorobots is by metabolizing the action of local glucose, oxygen, and externally supplied acoustic energy. A navigational network is installed in the body which provides high positional accuracy to all passing Nanorobots and keeps track of various devices in the body. They can distinguish between different types of cells by checking their surface antigens which are accomplished by the use of chemotactic sensors that are keyed to the specific antigens on the target cells. When the task is completed, it can be retrieved by allowing them to effuse itself via the usual human excretory channels. Active scavenger systems also remove these.[5]

Applications in various fields of dentistry

Applications in Prosthodontics:

a. Dental Implantology Robots:

YOMI [fig.1a] is the world's first computerized navigation robotic system, and it provides physical guidance of the drill depth, orientation, and position, thereby avoiding the custom fabrication of surgical guides and hand deviation of the operator. A 3D model of the patient's jaw is made from cbct imaging data which helps in computer-assisted surgeries for guided implant settlement. Implant fixtures are placed and an accurate robot is then used to drill [fig.1b] a jaw splint in the predetermined locations by software planning systems to make a surgical guide.[6] Flexibility, stability, and accuracy of implant placement, are increased by Robot-assisted implant surgery. Real-time surgical tracking is used for accurate implant placement. It uses a volume-decomposition-based system to place a root-shaped dental implant .[3]

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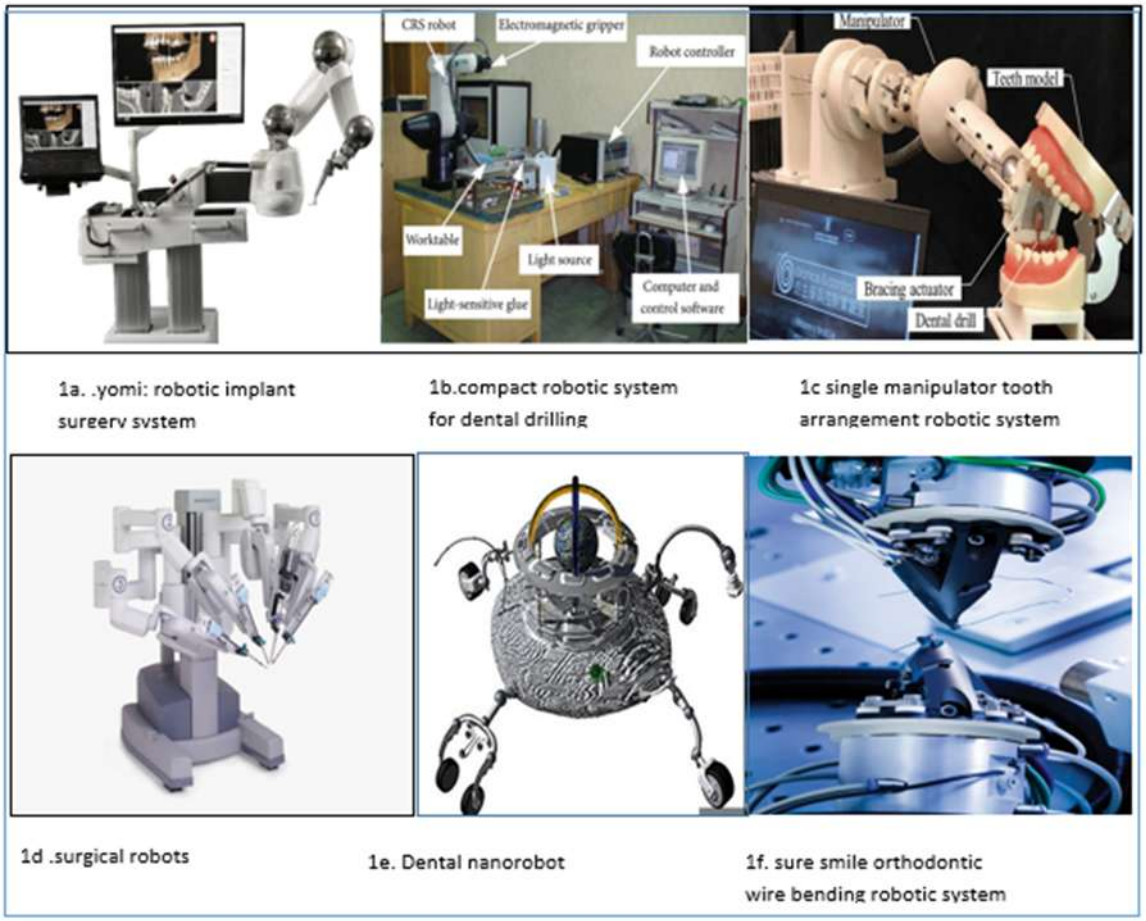

1a. .yomi: robotic implant sureery system

1b.compact robotic system for dental drilling

1c single manipulator tooth arrangement robotic system

1d .surgical robots

1e. Dental nanorobot

1f. sure smile orthodontic wire bending robotic system

b. Tooth–Arrangement Robots:

Tooth-Arrangement Multi-Finger Hand (TAMFH) robots or Cartesian robots [fig.1c] fabricate whole denture prosthesis via 6 DOF (Degree of Freedom) using a single manipulator robotic system. The whole procedure is commenced by a virtual 3d tooth plan programming software that is based on the MOTOMAN UP6 robot.[7]

c. Robot-controlled laser system used for tooth preparation :

For automated tooth preparation, and automated three-dimensional ablating of the crown of interest, a robot-controlled laser is used.[3]

d. Parallel Robot for Dental Articulation

This is used to eradicate the technical difficulty of duplicating the positions and motions of the patient's jaw in dental practice.[7]

Applications in Oral and Maxillofacial Surgery:

a. Surgical Robots

Robots [fig.1d] are used to perform procedures like Milling of bone surfaces, Drilling holes, Deep sawing osteotomy cuts, Selecting osteosynthesis plates Bending and intraoperative positioning of them in a defined position, Orthognathic surgery planning, Cleft palate repair.[8]

b. Rehabilitative Robots in Management of TMD

Massaging robots and mouth training robots are used for maxillofacial massage and exercises to treat patients with myofascial pain and limited mouth opening by decreasing muscle stiffness significantly.[8]

Applications in Periodontology:

Nanorobotic dentifrices to reduce halitosis and calculus debridement:

Configured nanorobots [fig.1e] identify and destroy pathogenic bacteria existing in the plaque which cause halitosis and these mechanical devices crawl at

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1 to 10 microns/sec. They are preprogrammed with automatic deactivation if swallowed.[5] Sub occlusal dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces, performing continuous calculus debridement.[8]

Applications in Orthodontics:

Sure smile system [Orthodontic Wire Bending Robots]:

Bending orthodontic arch wires to a precise shape automatically is achieved by this robotic technology [fig 1f.] Eg: MOTOMAN UP6 robotic system.[8]

Applications in Oral Radiology:

A robotic system with an inbuilt 6-DOF position sensor and a robot arm with an X-ray source and sensor film is used for dental subtraction radiography. These robots help to reduce radiation exposure to the clinician.[3]

Applications in Endodontics:

In endodontics, these systems are used to perform various procedures: Disinfection of the canal, root canal treatments, intracanal medicament, drug delivery, biofilm control, & regenerative procedures.

a. Magnetic Microrobots assisting Root Canal Treatment:

The microrobot system is made up of iron oxide nanoparticles and can be used as a swarm that can enter the tooth, disrupt biofilms, and removes bacterial samples for later investigation. It can be manipulated using magnetic fields. It can help in biofilm disruption, drug delivery, and sample retrieval, within the restrictive space of the root canal.[9,10]

b. Endodontic Micro Robot Mechanical Design:

Multi-purpose micromachine for root canal preparation has five axes of motion in its design.[11]

2a. Endo micro robot assisting root canal

2b. Endo micro robots

The components of the endo robot are [fig.2a, 2b]:

1. Micro position and orientation adjustment equipment – this ensures that the tool starts at a precise point,

2. A travel distance controller- to ensure that the tools can reach the required canal depth and stop at an In-built point,

3. In-built Microsensors to monitor the probing and drilling/reaming process,

4. Automatic feed rate,

5. Apex sensors- to prevent root perforations or the potential to overshoot (exceeding the apex of the canal),

6. Flexible drill- files to allow for cleaning and shaping the curved canal,

7. Vacuum attachments - capable of sucking the debris or loose tissue from the root canal and/or pressurized solution jets to flush the chips away.

c. Femtosecond laser-enabled intraoral robotic device for laser treatments:

It is a Miniature device that clamps onto the tooth and can be controlled remotely. Precise laser treatments of teeth and dental restorative materials are possible with a focusing and scanning system. It will liberate dentists from repetitive manual operations, physical strain, and proximity to the

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patient's oropharyngeal area that potentially contains infectious agents.[11]

d. 3D-printed helix-shaped robots for drug delivery:

They are embedded with iron oxide nanoparticles. They can deliver drugs and antibiotics to help fight infection in the root canal.[2] Micro robots unique with characteristics like self-propulsion in various liquid environments which target specific tasks at Nano or microscale are being used and their active motion can result in more efficient drug delivery.[2]

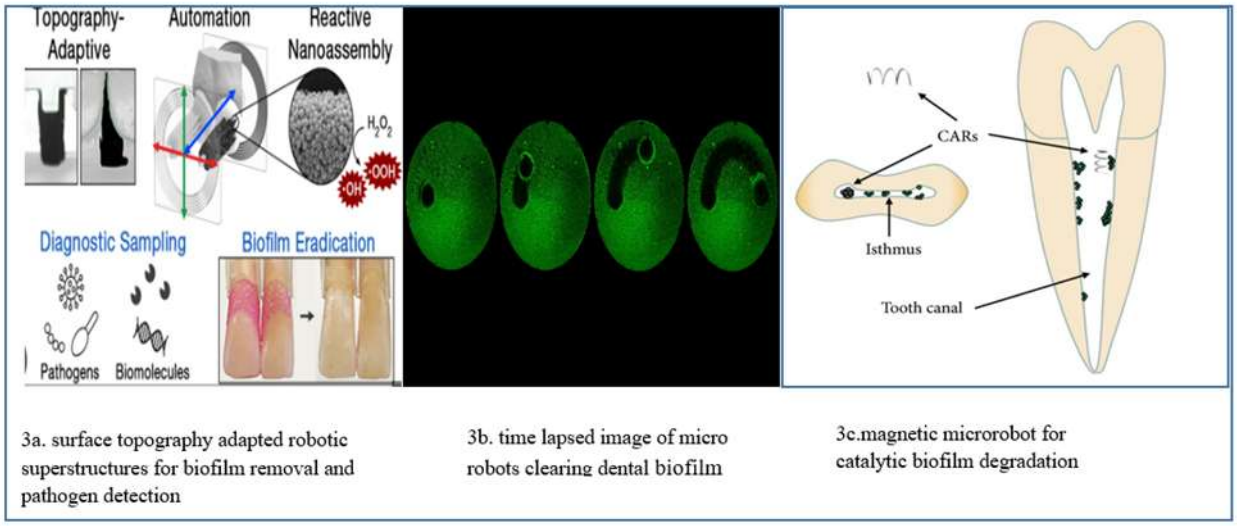
e. Nanosized robots for root canal disinfection:

Nano-sized robots are manipulated using a magnetic field that can help to kill the bacteria deep inside dentinal tubules and boost the success of root canal treatments. These tiny bots help in the deep cleaning of teeth.[12]

f. Surface Topography Adaptive Robotic Superstructures [STARS] for biofilm removal:

STARS [fig.3a,3b] are used for precision-guided biofilm removal and diagnostic sampling. It is a magnetic field-directed assembly of nanoparticles into the surface. They help in efficiently disrupting a synthetic biofilm. It is composed of a mixture of dental strains by the combination of an autonomous generation of microbubbles with the in situ formation of reactive species, such as hydroxyl radicals, on the biofilm surface.[13]

Self-propelled tubular microrobots for biofilm disruption [fig 3a,b,c]:



3a. surface topography adapted robotic superstructures for biofilm removal and pathogen detection

3b. time lapsed image of micro robots clearing dental biofilm

3c.magnetic microrobot for catalytic biofilm degradation

Applications in general dental practice:

They are used in regenerative procedures, disinfection in a hospital setting, and training dental students.

Nanorobots for regenerative procedures

In vitro-grown natural teeth are implanted into extraction sockets and neurovascular networks are established with the help of nanorobots.[14]

Dental training robots [for dental education]

They help to train students in various medical emergency conditions in clinical settings. They are introduced in the dental study to help the students experience dentistry on human-like machines, which proved much better than the earlier used mummies. Dental students can be trained with the help of full-body robotics, haptic interface technology, and advanced simulation to teach basic learning needs before interaction with real patients.[10]

a. Dentaroid [robotic patient]:

The robot patient comprises autonomous moving parts with 8 DOF (eye, lids, eyeballs, jaw, tongue, and neck) and passive moving parts (shoulder, arm, el, bow, waist, hip joint, knee, and ankle). These parts are driven by a compressor located externally to the robot patient. The robot is equipped with various reactions and movements that simulate accidents occurring during treatment, such as reactions to pain, cough reflex, vomiting reflex, and irregular pulse. It makes irregular movements under various situations

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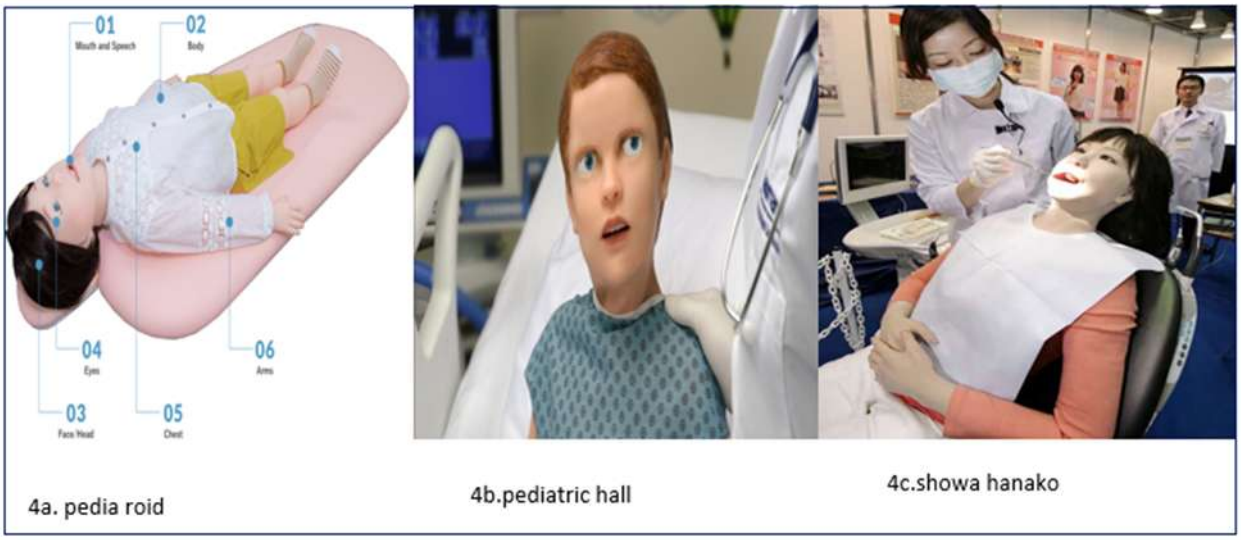
to help students to gain experience in a clinically realistic environment.[4]

b.Pedia roid robot [fig.4a]:

This robot is used for simulating young children during dental treatments, and it is equivalent to a five-year-old. The sight and sensation of a local anesthetic injection and the dental drill are the potential triggers for dental anxiety in children crippling the quality of interaction with the dentist and the subsequent treatment. The use of training robots helps clinicians to get acquainted with the clinical conditions of the children.[3]



4a. pedia roid 4b.pediatric hall 4c.showa hanako

c. Pediatric hal [fig.4b]:

It is the world's most advanced pediatric patient simulator and can simulate life-like emotions through dynamic facial expressions, movement, and speech .it helps in training pediatric clinicians.[3]

d. Robotutor [dental education robotic system]:

It is an alternative system to a dentist for showing tooth-cleaning procedures (i.e., tooth brushing) to patients. It is an attractive technique for dental education. The most effective way of learning fundamental motor skills for dental students is by virtual reality training combined with human instructor verbal feedback and haptic feedback.[3]

e. Simroid [dental patient simulator]:

It is created to give dentists and dental students in training more emotional feedback. It can react more lifelike and provide emotional responses just like a real patient. Sensors fixed in and around its mouth allows the robot to feel simulated pain and discomfort which the robot can express by gestures making students more conscious about their techniques. It is also equipped with better speech recognition capabilities which allows it to respond and react to questions or commands.[6]

f. Dental Patient Robots [phantoms]:

They are used for the clinical training of dentists and dental students, to advance their clinical skills and practice with patients.[6]

g. Showa Hanako [fig 4c]:

It can mimic a wide range of patient actions and reactions, including blinking, coughing, sneezing, moving its tongue, shaking its head, rolling its eyes, and even becoming tired from having its mouth open mimicking a gag response.[6]

h. Geminoid DK

It can accurately replicate head movements and simulate human facial emotions with cutting-edge motion-capture technology.[6]

Robots for disinfection in the Hospital environment:

They are based on an AI algorithm that permits interaction between the disinfection machine and the site to be disinfected. The AI disinfection robot uses

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sensors to identify dynamic disinfection zones.[1] It is controlled with a laptop or tablet and it uses an electrostatically charged nozzle to spray positively charged chemicals onto negatively charged surfaces for highly effective cleaning. It has greater reach because of the 6-axis arms. The machine aims to prevent and reduce the spread of infectious diseases, viral and bacterial, and other types of harmful organic microorganisms by breaking down their DNA structure. The UV-Robot has been designed to be used with minimal input making it user-friendly.[15]

Anesthetic Dental Nanorobotics:

A suspension of Nanorobots is dispatched into the quadrant of interest, which can reach the pulp via the gingival sulcus, lamina propria, and dentinal tubules .they help in blocking the action potentials of sensory nerves on activation by the dentist.[8] It can be controlled by the dentist to block the sensory nerves from transmitting pain sensation and unblock the nerves and deactivate them after the dental procedure is completed.[5]

References:

1. Kumar PY, Dixit P, Kalaivani V, Rajapandian K. Future advances in robotic dentistry. J Dent Health Oral Disorder Ther. 2017;7[3]:278–80.
2. Lumbini P, Agarwal P, Kalra M, Karthik KM. Nanorobotics in dentistry. Annals of Dental Specialty. 2014;2[3]:95-6.
3. Ahmad P, Alam MK, Aldajani A, Alahmari A, Alanazi A, Stoddart M, et al. Dental Robotics: A Disruptive Technology. Sensor. 2021;21[10]:1-15.
4. JH Rohl, S Hellmers, R Diekmann & A Hein. Concept of an Observation-driven Android Robot-Patient with Individualized Communication Skills, 2022 9th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob). 2022, pp. 1-7. doi: 10.1109/BioRob52689.2022.9925488.
5. Bhat BD, Bhandary S, Naik R, Shetty D. Robotics in dentistry: Fiction or reality. J Dent Res Rev. 2017;4:67-8.
6. Syed S, Dawadi TB, Zaheen Khan M. Robotics Using Artificial Intelligence in Dentistry. DTC Journal of Computational Intelligence. 2022;1[1]:1-14.
7. Jiang J, Zhang Y, Wei C, He T, Liu Y. A Review on Robot in Prosthodontics and Orthodontics. Advances in Mechanical Engineering. 2015;7[1]:1-12.
8. Adel S, Zaher A, El Harouni N, Venugopal A, Premjani P, Vaid N. Robotic Applications in Orthodontics: Changing the Face of Contemporary Clinical Care. Biomed Res Int. 2021;2:1-11.
9. Rawtiya, Manjusha & Verma, Kavita & Sethi, Priyank & Loomba, Kapil. Application of Robotics in Dentistry Quick Response Code. Indian J Dent Adv. 2014;6[4]:1700-6.
10. Joseph Johny, Sinitha Sreedharan, Timy S Alex, Jyothisree Kuniyedathchalil, Radhika V Sunil. Robot: next table turner in dentistry. Tanta Dental Journal. 2023;19[1]:52-6.
11. Rapp L, Madden S, Rode AV, Walsh LJ, Spallek H, Nguyen Q, et al. Anesthetic-, irrigation- and pain-free dentistry? The case for a femtosecond laser enabled intraoral robotic device. Front Dent. Med. 2022;3:976097.
12. Yunzhou Fan, Yu Hu, Li Jiang, Qian Liu, Lijuan Xiong, Jing Pan et al . Intelligent disinfection robots assist medical institutions in controlling environmental surface disinfection. Intelligent Medicine. 2021;1[1]:19-23.
13. Katherine Villa, Jitka Viktorova, Jan Plutnar, Tomas Ruml, Lan Hoang, Martin Pumera. Chemical Microrobots as Self-Propelled Microbrushes against Dental Biofilm. Cell Reports Physical Science. 2020;1[9]:1-12.
14. Chandra Kanth B, Chandradeep, Swapna Manepalli. Artificial intelligence and robotics: The enhanced pediatric dentist. International Journal of Advance Research, Ideas and Innovations in Technology. 2020;6[6]:66-9.
15. Zhao Z, Ma Y, Mushtaq A, Rajper A, Shehab M, Heybourne A, Tse Z. Applications of Robotics, Artificial Intelligence, and Digital Technologies During COVID-19: A Review. Disaster Medicine and Public Health Preparedness. 2021;16[4]:1634-44.

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