Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

Robotics in Pediatric Dentistry: A Review

Dr. Jaya Sanjay Bhangdiya[1], Dr. Milind Wasnik[2], Dr. Arunkumar Sajjanar[3], Dr. Gauri Raju Patil[4], Dr. Bhoomika Kulkarni[5], Dr. Neha Yadav Battulwar[6]

[1]Postgraduate student, Department of Pediatric and Preventive Dentistry, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur 411000.

[2]Reader, Department of Pediatric and Preventive Dentistry, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur 411000.

[3]Professor and Head, Department of Pediatric and Preventive Dentistry, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur 411000.

[4,5,6] Postgraduate student, corresponding author, Department of Pediatric and Preventive Dentistry, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur 411000.

(Received: 16 March 2025 Revised: 20 April 2025 Accepted: 15 May 2025)

KEYWORDS

Humanoid robotics, Pediatric dentistry, Anxiety, Behaviour management, Robots.

ABSTRACT:

Dental anxiety is one of the major challenges in pediatric dentistry not only in children but also adults face the problem of anxiety, causing people to avoid dental treatment which consequently, negatively affects their oral and dental health. To overcome these problems there are many conventional ways of behaviour management. But with new generation, Robotics is more advanced and rapidly progressing way to relieve anxiety in children. As children see robots in cartoons and find it more fascinating in real which will help to calm them. The goal of this approach is to reduce unpleasant perceptions, to avoid negative behaviour and escaping from the treatment. This will be a great alternative to advance medical techniques such as sedation and general anaesthesia. It is to direct child's attention from a painful stimulus to more entertaining and amusing direction during their dental treatments by using humanoid robots and by making the therapy session less problematic and more comfortable in order to provide much comfortable treatment environment.

1. Introduction

The term "robot" originated in the 20th century, first appearing in 1920 in the science fiction play *Rossum's Universal Robots* by Czech writer Karel Čapek. The word "robot" was derived from the Czech term "Robota," which translates to "labor" or "drudgery." [1] At a landmark robotics conference in Japan in 1967, Masahiro Mori offered a significant definition, describing a robot as a versatile machine characterized by mobility, individuality, intelligence, versatility, a semi-mechanical and semi-human nature, automatic operation, and servitude. According to the American National Standards Institute, a robot is a programmable mechanical device capable of performing specific operations and mobile tasks autonomously.

As modern science and technology have rapidly advanced, robotics has emerged as a prominent field of research and societal interest. Robots are now employed in various sectors, including machinery, electronics, aerospace, and medicine. The medical field, in particular, has seen a growing focus on robotics, with medical robots categorized into macro, micro, and bio-robots. Macrorobots encompass devices such as rehabilitation robots (including home care robots and smart wheelchairs), surgical robots (used in procedures like brain and eye surgeries), and minimally invasive surgical robots and medical endoscopic devices. Bio-robots, on the other hand, are medical robots designed to mimic human perception, thought, and judgment.

The success of medical robots has also fuelled interest in applying robotics within dentistry, leading to innovative breakthroughs in oral diagnosis and treatment. Addressing anxiety related to dental treatment, especially in children, is crucial. While

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

traditional methods like colourful clothing and entertainment have been employed to alleviate fears, they often prove insufficient. Our study proposes a more comprehensive approach, utilizing multi-sensory stimuli—visual, auditory, and tactile to shift children's attention from pain to a more engaging experience during treatment. Introducing Humanoid Robots into therapy sessions can create a soothing environment, reduce stress, and enhance patient cooperation. Furthermore, automating repetitive tasks, such as pre-treatment communication, through advanced computer technologies can help Pediatric dentists conserve time and energy, streamline processes, encourage positive behavior, and improve treatment outcomes.

The integration of robotics into dentistry opens up exciting possibilities. Robots offer precision, efficiency, and capabilities that surpass those of humans, thereby enhancing the quality and safety of dental procedures. The incorporation of artificial intelligence further optimizes dental care delivery. By embracing robotic technologies, we can create a more comfortable and effective dental care environment, potentially reducing the need for costly and risky interventions like sedation or general anesthesia.[2]

2. History of Robots

Following the developments in industrial robot technology, robotics has found its way into the medical field and is used in a range of surgical disciplines. It has been decades since robots have been in the field of medicine and this technology would not had been true if Leonardo da Vinci would not have created many robot-like sketches and designs in the 1500. It all started way back in 1985, when a robot, the PUMA 560 was used to place a needle for a brain biopsy using CT guidance.[3] In 1988, the MROBOT, was used to perform prostatic surgery by Dr. Senthil Nathan at Guy's and St Thomas' Hospital, London. Further, the first complete robotic surgery took place at The Ohio State University Medical Center under the direction of Dr. Robert E. Michler, Professor and Chief, Cardiothoracic Surgery.[4] Advancements poured July 1998 when a reconnection of the fallopian tubes operation was performed successfully in Cleveland using ZEUS.[5] On May 12, 2008, the first image guided MR-compatible robotic neurosurgical procedure was performed at University of Calgary by Dr. Garnette Sutherland using the NeuroArm.[6] Also, revolution came in when in January 2009, the first all-robotic-assisted kidney transplant was performed at Saint Barnabas Medical Center in Livingston, New Jersey by Dr. Stuart Geffner.[7] In September 2010, the first robotic operation at the femoral vasculature was performed at the University Medical Centre Ljubljana by a team led by Borut Geršak. The robot used was the first true robot, meaning it was not simply mirroring the movement of human hands, but was guided by pressing on buttons.

3. Application of Robotics in Dentistry

Use of robotics in dentistry is caving in with all the necessary technologies which could be further developed and easily adapted. Some of the technologies are already being used in dentistry such as image-based simulation of implant surgery, followed by the use of surgical guides and creating digital impressions of preparations using an intraoral scanner, after which a milling device produces the restoration

I. Dental Patient Robots

For the purpose of clinical training for dentists and dental students, and to develop their clinical skills and experience in a patient, dental patient robots have been designed to mimic real-life treatment scenarios. They are popularly known as "Phantoms" [8]

Showa Hanako is a realistic robot that can perform a variety of patient gestures and reactions such as blinking, sneezing, coughing, rolling of eyes, shaking its head, moving its tongue and even get fatigue for mouth opening for too long. It can simulate gag reflex, making it no different from an actual patient.[8] It was created in Tokyo, Japan by Showa University with assistance from the robotics company Tmsuk.[8]

Geminoid DK was invented in Japan at Advanced Telecommunications Research Institute. It is a remotely controlled robot with advanced motion-capture technology that can do human facial expressions and different head motions dimensional filling of the root canal system.[9] It offers precise treatment with no error giving less stress to the dentist.[9]

II. Dental Nanorobots

Nanorobots, constructed from nanomaterials measured at the scale of nanometers, represent a cutting-edge application of nanotechnology in dentistry.[10] These microscopic robots are designed for a variety of dental

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

procedures, including cavity preparation, restoration, dentin hypersensitivity treatment, local anaesthesia, single-visit orthodontic realignment, and nanorobotic dentifrice (dentifrobots). They also enable targeted local drug delivery and precise tooth repair.[11] The use of these nanoscopic dental robots allows for treatments that are both rapid and exceptionally precise, significantly enhancing the efficiency and effectiveness of dental care.[12]

III. Surgical robots

The integration of robotics into oral and maxillofacial surgery allows surgeons to interactively program the robot in real-time during the surgical procedure. This advanced technology empowers the robot to execute a range of meticulously preprogrammed tasks within the operating theatre. These tasks include intricate operations such as milling and drilling of bones, performing osteotomy cuts with precision, selecting and positioning surgical plates, and even assisting in comprehensive surgical planning. By leveraging robotic assistance, surgeons can enhance the accuracy, efficiency, and overall outcome of complex surgical interventions.[13]

IV. Dental Implantology Robot

The latest advancements in computer-assisted surgery for guided implant placement involve the creation of a highly accurate 3D model of the patient's jaw, generated from cone beam CT imaging data. This 3D reconstruction provides a precise representation of the patient's anatomy, which is crucial for planning the surgical procedure. Using this data, a software planning system determines the optimal implant sites, and the robot is then employed to precisely drill the jaw splint at these predetermined locations. This process results in the creation of a customized surgical guide, ensuring accurate implant placement and improving surgical outcomes.[14]

V. Robotic Dental Drill

Recent advancements developed by tactile technologies utilize ultra-thin needles to precisely penetrate the gum tissue and identify the location of the alveolar bone in an immobilized patient's jaw. This real-time data is wirelessly transmitted to a computer, where it is seamlessly integrated with CT scan imaging. The combined information is then used to generate a precise set of drill guides, optimizing the accuracy of the surgical procedure.[15]

VI. Tooth-Arrangement Robot

In the field of prosthetic dentistry, a single-manipulator robotic system is commonly employed for the fabrication of complete denture prostheses. This system utilizes a 6-degree-of-freedom (6DOF) CRS robot, manufactured in Canada, to precisely execute the fabrication process. The entire procedure is guided by advanced three-dimensional virtual tooth arrangement software, which meticulously plans and controls every aspect of the denture creation, ensuring a high level of accuracy and customization.[16]

VII. Orthodontic Archwire Bending Robot

Robotic technology is employed to automatically bend orthodontic archwires into precise shapes tailored to each patient's needs. This process is carried out by the SureSmile archwire bending robot, which integrates gripping tools with a resistive heating system. The robot works in conjunction with CAD/CAM technology, 3D imaging, and computer systems to fabricate customized orthodontic appliances, ensuring a high degree of accuracy and personalization in orthodontic treatments.[17]

4. Applications of Robotics in Pediatric Dentistry:

According to the principles of attentional capacity theory, distracting stimuli need to be stronger than pain stimulus to attract children's attention.[18] From the viewpoint of the human-robot interaction design, the clinical application of robot technologies to dental services might be good option for modern dentistry. These are few applications of robotics in Pediatric Dentistry:

1. **Distraction and Entertainment:** Robots can engage children with interactive storytelling, games, and other entertaining activities, effectively diverting their attention from dental procedures. This helps alleviate anxiety and discomfort, making the overall experience more pleasant for young patients.[19]
2. **Patient Education:** Humanoid robots can be programmed to adapt to individual preferences and needs, tailoring their interactions based on factors

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

such as age, language, and cultural background. They can serve as educational tools, teaching children about oral hygiene practices and the importance of dental care in a fun and engaging manner, promoting positive attitudes toward oral health and encouraging healthy habits from a young age.[20]

3. **Customized Treatment Planning:** Based on patient assessments and data analysis, Humanoid Robots can assist dental professionals in creating personalized treatment plans tailored to the individual needs of each child. These plans may include recommendations for preventive care, restorative treatments, orthodontic interventions, or behavioral management strategies.[21]
4. **Interactive Waiting Room Experience:** Humanoid robots can conduct initial assessments of Pediatric patients by engaging in interactive conversations and gathering relevant information about their dental history, oral health habits, and any specific concerns or preferences they may have. Using artificial intelligence algorithms, they can analyse the collected data to identify patterns, trends, and potential risk factors, helping develop a comprehensive understanding of each child's dental needs.[22]
5. **Remote Consultation and Monitoring:** In situations where Pediatric patients cannot visit the dental office in person, Humanoid Robots can facilitate remote consultations with dental professionals. They can relay information between the patient and the dentist, allowing for virtual assessments and treatment planning.[23]
6. **Assistance in Procedural Explanation:** Throughout treatment, Humanoid Robots can monitor the progress of Pediatric patients and provide real-time feedback to dental professionals. They can track compliance with oral hygiene routines, monitor the effectiveness of treatment interventions, and identify any emerging issues that may require adjustments to the treatment plan.[21]

5. Humanoid Robots

A **Humanoid Robot** is a robot designed to resemble and mimic human appearance and behavior. Typically, these robots have a body structure similar to a human, with a torso, head, two arms, and two legs. Some humanoid robots are designed with facial features, eyes, and even expressions, enabling them to engage in more natural interactions with people.

Humanoid Robots are often equipped with advanced sensors, cameras, microphones, and artificial intelligence (AI) software to perceive their surroundings, process information, and respond in ways that simulate human-like behavior. They can perform tasks like walking, talking, understanding speech, recognizing faces, and even expressing emotions.

Different Humanoid Robots Used in Behavior Management:

1. **NAO:** The NAO robot is used in education and therapy, acting as an educator and peer to children. It has been employed in classrooms to teach new words, assist in speech therapy, help children learn a second language, improve nutritional education, and deliver motivational interviews. NAO has also been used to enhance social behavior and quality of life in children with autism and to screen for autism in toddlers. Due to its positive interaction with children, NAO is used to guide, distract, and encourage children during dental treatment.[24]
2. **Robokind R25:** The Robokind R25 Humanoid Robot is significant in behavior management within Pediatric Dentistry, offering engaging interaction, positive reinforcement, distraction techniques, personalized communication, and educational support. Its capabilities enhance the patient experience, improve treatment outcomes, and promote lifelong oral health in children.[25]
3. **ASIMO:** ASIMO can recognize moving objects, postures, gestures, sounds, and faces, enabling interaction with humans. It can follow or face a person when approached, interpret voice commands and human gestures, and respond accordingly. ASIMO's ability to distinguish between voices and sounds allows it to identify companions and respond to its name or other sounds. It can answer questions verbally in different languages and recognize

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

and address approximately 10 different faces by name.[26]

4. **PEPPER:** PEPPER evaluates efficiency and response behavior concerning navigation, speech and hearing, and object and face detection. Its functionalities, such as navigation, obstacle avoidance, speech, and dialogue management, have been tested with acceptable results.[27]
5. **iRobiQ:** iRobiQ is a small, autonomous Humanoid Robot with a touch-screen LCD display and multi-color LEDs for communication of emotions. It can show different facial expressions such as happy, sad, surprised, or angry, making it effective in conveying emotions.[28]

6. Limitation of Robotics:

When a novel technology is introduced in a new environment, it inevitably faces various challenges. One significant obstacle is the high cost of technological advancements, particularly in medical and dental applications.[29] Additionally, robotic systems are inherently complex, requiring specialized expertise for their proper operation and functionality. Another critical consideration is the uncertain level of patient acceptance and dentist compliance with these new technologies.[30] Research indicates that male patients are generally more inclined to undergo robotic medical treatments compared to female patients, though the willingness to accept such treatments diminishes across all demographics as the invasiveness of the procedure increases.[30]

The accuracy of data input is also a crucial factor. In contemporary dentistry, there are two key aspects to consider: procedures that are meticulously planned and executed by experienced professionals, and those that are inefficiently managed by less knowledgeable personnel, often leading to poor outcomes. Ultimately, the quality of the results will depend on the expertise of the individual inputting data into the robotic system.

7. Future Recommendations:

The literature consistently suggests that integrating robots into dentistry enhances accuracy, reproducibility, and reliability. However, research in robotic dentistry has been limited due to the scarcity of accessible systems and the lack of expertise needed to program and manage these technologies. Advancing research in this field requires effective collaboration between dentists and engineers, and this dynamic may soon evolve as the robotics community explores new communication strategies and programming paradigms.

Currently, much of the interdisciplinary research combining dentistry and engineering in the context of robotic dentistry is centred on dental implantology. However, the invasive nature of these technologies may hinder their acceptance among both dentists and patients, making them less ideal as pioneering applications. In contrast, research in assistive robotic dentistry holds greater promise for ushering in this new era of robotic technology. Additionally, integrating robotics into dental education within university settings could play a crucial role in overcoming acceptance barriers among future dentists.

The robotic applications discussed in this article from teeth arrangement for complete dentures to dental material testing and tooth preparation have significant potential to advance dentistry into a new era where digitalization supports real-world management. However, the current level of technological readiness is still low, and more research is necessary to establish the value of robotic dentistry. Consequently, the pace of research in this field should accelerate in the coming years.

8. Conclusion:

Dentistry is gradually advancing toward a new era of robot-assisted and data-driven care. However, robotic systems have yet to be fully integrated into dental research, and they still lack the cost-effectiveness and technological maturity needed for widespread adoption in the dental market. While the potential applications of robotics in dentistry such as material testing, orthodontics, prosthodontics, oral surgery, and implant dentistry are promising, significant limitations remain. These include not only the complexity and high cost of robotic systems but also fundamental challenges related to the manipulation, sensory capabilities, and learning abilities of robots.

To truly introduce robotics into dentistry, several key hurdles must be overcome. Enhanced

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(3), 973-979 | ISSN:2251-6727

intuitiveness of robotic systems, the development of more affordable solutions, and extensive educational efforts are crucial. Dentists must become familiar with robots, including mastering both real-world and digital robot-human communication skills.

The future offers numerous possibilities for the integration of dentistry and robotics. The most immediate goal is to develop a functional system that meets essential requirements: large-scale usability, specific initial use-cases, intuitive and reliable manipulation capabilities, effective robot-human communication, human-centred interaction, and ensuring safety.[31] In this context, we emphasize the technological advancements that have made the use of robotics in dentistry possible and encourage further exploration of the opportunities that could arise from the fusion of robotics and dentistry.

References

1. Almurib HA, Al-Qrimli HF, Kumar N. A review of application industrial robotic design. In2011 Ninth International Conference on ICT and Knowledge Engineering 2012 Jan 12;105-112.
2. Dario P, Guglielmelli E, Allotta B, Carrozza MC. Robotics for medical applications. IEEE Robotics & Automation Magazine. 1996 Sep;3(3):44-56.
3. Kwoh YS, Hou J, Jonckheere EA, Hayati S. A robot with improved absolute positioning accuracy for CT guided stereotactic brain surgery. IEEE transactions on biomedical engineering. 1988 Feb;35(2):153-60.
4. McConnell PI, Schneeberger EW, Michler RE. History and development of robotic cardiac surgery. Problems in General Surgery 2003; 20(2):20-30.
5. Versweyveld L. ZEUS robot system reverses sterilization to enable birth of baby boy. Virtual Medical Worlds Monthly Sep. 1999;29.
6. Rawtiya M, Verma K, Sethi P, Loomba K. Application of robotics in dentistry Indian J Dent Adv. 2014;6:1700–6
7. Ishiguro H, Geminoid DK. Geminoid series; 2010 Available from: http://www.Roboticstoday. [Last accessed on 2017 Dec 12].
8. Schulz M J, Shao VN, Yun Y. Nanomedicine Design of Particles, Sensors, Motors, Implants, Robots, and Devices, Artech House, 2009; 10.
9. Dong J, Hong S, Hesselgren G. WIP: A Study on the Development of Endodontic Micro Robot. Proceedings of the 2006 IJME-INTERTECH Conference; 2006.
10. Lumbini P, Agarwal P, Kalra M, Krishna K M. Nanorobotics in Dentistry. Ann Dent Spec 2014; 2:95-6.
11. Lueth T C, Hein A, Albrecht J, Demirtas M, Zachow S, Heissler E, Klein M, Menneking H, Hommel G, Bier J. A Surgical Robot System for Maxillofacial Surgery. IEEE Int. Conf. on Industrial Electronics, Control, and Instrumentation (IECON), Aachen, Germany, 1998; 2470- 2475.
12. Xiaojun W C, Yanping L A Computer-Aided Oral Implantology System. IEEE Engineering in Medicine and Biology 27th Annual Conference, Shanghai, China, 2005; 3312-3315.
13. Palep J H (2009) Robotic Assisted Minimally Invasive Surgery. J Min Access Surgery 5(1):1-7.
14. Zhang Y, Ma J, Zhao Y, Peijun L, Wang Y (2008) Kinematic Analysis of tooth-arrangement robot with serial-parallel joints. IEEE, Hunan, China, 624-628.
15. Rigelsford J (2004) Robotic bending of orthodontic (http://www.emeraldinsight.com/doi/abs/10.1108/ir.2004.04931fad.007?journalCode=ir) archwires. Industrial Robot 31(6): 321-335.
16. McCaul KD, Malott JM. Distraction and coping with pain. Psychol Bull. 1984;95(3):516–533.
17. Kasimoglu Y, Kocaaydin S, Karsli E, et al. Robotic approach to the reduction of dental anxiety in children. *Acta Odontol Scand*. 2020;78(6):474-480.
18. Tanzawa T, Futaki K, Tani C, et al. Introduction of a robot patient into dental

education. *Eur J Dent Educ*. 2012;16(1):e195-e199.

19. Xia Z, Ahmad F, Deng H, Jiang L, Qin W, Zhao Q, Xiong J. Robotics Application in Dentistry: A Review. IEEE Transactions on Medical Robotics and Bionics. 2024 Jun 3.
20. Sivakumar M, Ali S, Rajagopal M, Yaskina M, Drury S, Wright B. The impact of humanoid robot presence in the paediatric emergency department waiting room: A prospective cohort study. *Paediatr Child Health*. 2021;26(8):470-477.
21. van Riet TC, Sem KT, Ho JP, Spijker R, Kober J, de Lange J. Robot technology in dentistry, part two of a systematic review: an overview of initiatives. Dental Materials. 2021 Aug 1;37(8):1227-36.
22. Yelda, K., Simin, K., Şule, B. (2023). The Impact of a Humanoid Robot on Children's Dental Anxiety, Behavior and Salivary Amylase Levels: A Randomized Clinical Trial. The Journal of Pediatric Research, 10(2), 132-141.
23. Schadenberg BR, Reidsma D, Heylen DK, Evers V. Differences in spontaneous interactions of autistic children in an interaction with an adult and humanoid robot. Frontiers in Robotics and AI. 2020 Mar 5;7:28.
24. Vipul Dalal, Upasna Setia, 2017, Humanoid Robot: ASIMO, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) ICADEMS – 2017 (Volume 5 – Issue 03)
25. Mishra D, Romero GA, Pande A, Nachenahalli Bhuthegowda B, Chaskopoulos D, Shrestha B. An Exploration of the Pepper Robot's Capabilities: Unveiling Its Potential. Applied Sciences. 2023 Dec 22;14(1):110-114
26. Kasimoglu Y, Kocaaydin S, Karsli E, Esen M, Bektas I, Ince G, Tuna EB. Robotic approach to the reduction of dental anxiety in children. Acta Odontologica Scandinavica. 2020 Aug 17;78(6):474-80.
27. Jeelani S., Dany A., Anand B., Vandana S., Maheswaran T., Rajkumar E. Robotics and medicine: A scientific rainbow in hospital. *J. Pharm. Bioallied Sci.* 2015;**7**:S381–S383.
28. Milner M.N., Anania E.C., Candelaria-Oquendo K., Rice S., Winter S.R., Ragbir N.K. Patient perceptions of new robotic technologies in clinical restorative dentistry. *J. Med. Syst.* 2020;**44**:1–10.
29. Cheema H.S., Dhillon P.K. Robotics in dentistry. *Dentimedia J. Dent.* 2012;**17**:61–62.