Dental Robotics –Beginning Of The End Of An Era In Dentistry?

Dr Aarathi Vijayan [*], Dr Jayanth Jayarajan [**]

[*] Professor And HOD, Dept Of Public Health Dentistry, Azeezia Dental College, Kerala, India
[**] Professor And HOD, Dept Of Orthodontics And Dentofacial Orthopaedics, Azeezia Dental College, Kerala, India

DOI: 10.29322/IJSRP.13.03.2023.p13546
http://dx.doi.org/10.29322/IJSRP.13.03.2023.p13546

Paper Received Date: 15th February 2023
Paper Acceptance Date: 15th March 2023
Paper Publication Date: 30th March 2023

***Abstract*-** Dentistry is one of the many professions that witness new technologies develop at finger snapping speed. The latest and the fast evolving one is the development of robots in dentistry. Robots are developed for many purposes from assisting dental students to nurture their dentistry skills to helping disabled dentists to practice dentistry. However, conventional robotics research is usually related to supporting surgical procedure and to help doctor's ask questions to patients during interviews. There are many researchers working in the development of an ideal robot that can assist dental students and dentists in their clinical skills. If this is established successfully then it can be considered as a great boon in the field of dentistry. This great achievement can help the patients a great deal as they need not be served as "guinea pigs" to the budding dentists in dental colleges. This technology can mark the beginning of the end of an era in Dentistry.

***Index Terms*-** Patient robots, Dentistry, training of dental students

I. INTRODUCTION

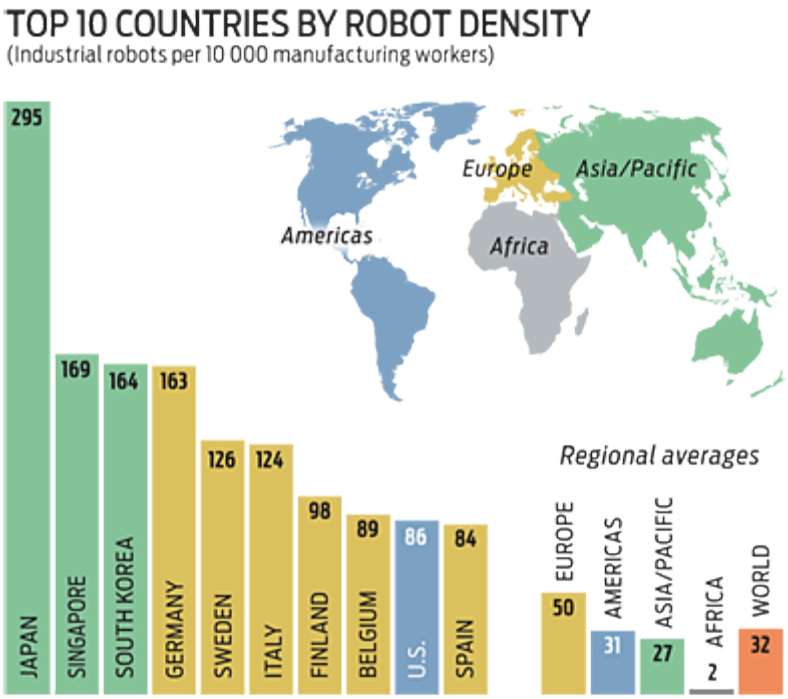
Recent dental school graduates of universities are said to lack clinical skills and experience in treating patients.[1]The main reason is attributed to inadequate clinical training. Currently, so-called 'phantoms' consisting of a simple functional cephalic region and an arrangement of teeth are used for clinical training but these models are considerably different than actual patients. Clinical trainings are 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 in many places. Thus the potential danger of declining clinical skills is a problem in dental therapy training, and in spite of the well known lack of skills of dental students, universities are still producing graduates based on knowledge instead of hands on, clinical ability.

It is common to use static models for therapeutic training in medicine. However, training based on the use of such models is inadequate due to differences between the models and actual patients.

Further, the development of simulators is being widely pursued in the field of dental therapy training but there are few examples of research on robots. Presently, there has been a lot of research regarding machine to measure human's mastication movement and machine to measure food's texture.[2,3] However, these machines only have one particular function and not able to expand their potential to several function. Due to many reasons it has became mandatory for the development of a Dental Robot that assist Dental students and Dentists. Therefore this review article aims to shed light on the robots that could be used by dental students as well as Dentists.

II. DENTAL ROBOTS

Robots are being developed all over the world and different countries have excelled in this profession. However, Japan is one country that is light years ahead in this field.[4]



ROBOTS CURRENTLY USED IN DENTISTRY

Dental Robotics Group in Takanishi Laboratory, Waseda University had developed mastication robot since 1986 which has the ability to mimic human's mastication movement.[3]

Polish researchers have constructed an artificial oral cavity and a robot on a 4:1 scale, so that intra- and extraoral cameras and servomechanisms could be used. Images from the cameras can be transmitted via the Internet to another building, where dentists could see pictures from two movable viewpoints inside the "mouth." The dentists can use joysticks and virtual reality glasses to operate handpieces and materials to prepare caries for restoration, perform endodontic therapy and prepare tooth surfaces for bridges. Dentists who tested this said that they found it easy to guide the handpiece using the joystick and to control its position using the cameras.[2]

However it was three Japanese universities (Waseda, Kogakuin and Showa) and robot maker Tmsuk that developed Hanako, a robotic dental patient who can behave like a human patient (to some extent). The robot, who is supposed to be female, can converse with doctors ("Please examine me!", "That hurts!" etc.), discharge robotic saliva, sneeze, open and close her mouth, etc. Standing 157cm tall, Hanako's body is the work of Tmsuk, while the "medical features" were developed by the dental faculties of the universities involved in the development of the robot. There are nine joints in her body, for example in her jaw, tongue and even in her eyelids.[5-9]

The main goal is to offer dentists or dental students a way to practice "real-life" procedures on a robot before taking care of human patients (at Showa University, dental students actually have to take tests using Hanako). Hanako reacts to mistakes by verbally expressing pain, rolling her eyes or even simulating a vomiting reflex, because of the touch sensors in her mouth. To add to the realism, Hanako can also move her eyes and eyelids, jaw and tongue. She even discharges a saliva-like liquid and slowly slackens her jaw muscles to simulate the gradual "fatigue" of a real patient Hanako is the world's first that has been used to evaluate the skills of dental students on a large scale, according to Showa University and a hundred or so Japanese students have tested it already.

Tokyo, Japan showed off its cutting-edge robots at the country's largest robotics convention, a dazzling display of the technologies that make it a world leader in both service and industrial robotics. The dental-training robot, dubbed Simroid for "simulator humanoid," has realistic skin, eyes and a mouth fitted with replica teeth on which students practice drilling. A sensor fitted where the nerve endings, raises an alert when they drill too close, triggering a yell from the robot. Dr. Naotake Shibui, of the Nippon Dental University in Tokyo, collaborated with technicians at Kokoro Co. to develop the robot.[10-14]

This robot, “simroid” resembles a small Japanese women wearing a pink sweater along with red PVC heels. The Simroid's full set of white teeth are fitted with sensors and the robot will yell “aww that hurts” when the dentist's equipment touches the virtual nerves. The engineers have also included a "breast sensor" to determine if that area has been touched inappropriately during training.

The performance of the patient robot was evaluated by 32 members of Showa University (two clinical interns, 29 students in the 5th year who had completed basic clinical training using phantom heads; and one veteran doctor). Questionnaires were

distributed to evaluate the effectiveness of the robot as a dental patient. The results showed that almost all the students considered the robot was indeed an effective tool as a patient.

The different features of a dental robot are:-[1]

External structure

The patient robot has a height of approximately 165cm. The skeleton is made of metal and FRP(Fibre-reinforced plastic or fibre-reinforced polymer is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually fibreglass, carbon, or aramid, while the polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic) is used for the skull. The teeth in the conventional model used for direct therapy training, can be polished and can be easily replaced. The artificial outer skin is made from a special vinyl chloride based gum reproducing the form and sensation of actual skin. The robot has a total of 36 degrees of freedom (DOF), with patient movements being achieved by low pressure compressed air from an air cylinder as in. The other joints are passive components. Further, by implementing almost human-like joints, it is possible to install the robot in an actual dental therapy unit.

Actuation system

An air cylinder is used in the drive sections. The main pressure is set at 0.7 MPa and differential pressure to 0.35MPa. Further, blinking of the eyes and tongue movement are achieved by a diaphragm with a simple structure. Due to the high density of mechanical parts housed in the cephalic region, a wire is attached internally to the tongue which has 3-DOF, and the tongue is moved by pulling on the wire using a diaphragm attached to the body of the robot.

Control system

The patient robot is controlled by electro pneumatic regulators and electromagnetic valves using an air cylinder. Since it is possible to control the electro pneumatic regulator by minute changes in pressure, feedback from a PC enables fine movement of the neck and mouth. An electromagnetic valve is used for simple ON-OFF movements such as arms and eye lids. Feedback control is achieved by setting a potentiometer in parts where electro pneumatic regulators are used.

Interface

The patient robot is controlled using a PC. Position control of the patient robot's mouth and neck is achieved using voice recognition software that reacts to the trainee's instructions as in. This is mainly used for assessing the skills of dental students. The supervising doctor can manipulate the interface to produce movements due to coughing and reactions to pain to which trainees as expected to respond. After the robot exhibits sudden movements, a five level point rating is displayed above the interface and the supervisor can grade the trainee's response in real time. A record of the type and timing of sudden movements and their evaluation is stored as a table. This table can be used in conjunction with video footage of training sessions by trainees to check their performance.

Image recoginition

The patient's eye is simulated by a small camera embedded into the patient robot's right eye. The camera has been successfully used to recognize and track trainees and instruments used during treatment. Imaging recognition is achieved using the RGB (Red. Green, Blue) colours of video images where the colour of the trainee's hair is electronically recognized and the robot's line of sight shown to the trainee . By this procedure, it is possible to carry out therapy under conditions where the trainee is being watched by the patient.

Also, the voice recognition software is useful for creating more realistic conditions to simulate actual conversation with patients during training programmes. Further, the psychologically induced backward movement of the head when endodontic instruments appear in the patient's line of sight is also reproduced.

Force sensor for drilling and grinding of teeth

Force sensing is achieved by monitoring the load of drilling during surgery by a sensor embedded in one of the 2nd molar teeth on the left side. The sensor consists of a strain gauge sandwiched in gum, which is attached to the teeth arrangement model. In this way, when the spring is compressed under the action of a load, a screw is pushed and the strain gauge sandwiched in the gum is bent. During this procedure, the voltage of the strain gauge is recorded which is a measure of the load acting on the tooth.

Effusion of bleeding

For dental students and trainees, the effusion of blood is one of several unexpected situations. Thus, in order to train students to react calmly to unexpected bleeding during surgery, the patient robot is designed to reproduce the effusion of blood as well. The main locations for bleeding in the oral cavity are regions inside of both cheeks and areas ranging from the surface to below the tongue. The main reason for bleeding in these regions is due to accidental contact of the air turbine with the cheeks or tongue during surgery of the 2nd molar, when patients are prone to move their tongue. For these reasons, the patient robot is also designed so that bleeding results under the above conditions from both cheeks and the tongue regions as described. This is implemented as a three layered structure, consisting of red pigmentation sandwiched between two silicone resin plates. This structure is only a mere 0.4mm thick, and suitable for fitting into the oral cavity.

Saliva

The ease of performing dental surgery is affected by the amount of saliva. In particular, it is desirable that the surface of teeth be dry when inserting fillings. If the volume of saliva is large then the moist surface hinders adhesion of the fillings.hence there is a fitted saliva mechanism to the patient robot. Since 2/3 of saliva secretion is exuded from the parotid gland, the saliva is produced from the parotid gland of the patient robot. The tube from an externally connected air pump is placed into a water tank, an air pump is used to push into the tube which flows out at the location of the parotid gland inside the oral cavity. The saliva flow volume for a patient at rest is 0.3 ml/min. External stimulation results in this volume increasing to between 1.0~1.7 ml/min. The patient robot is able to produce 7.7 ml/min, which reproduces the saliva flow patients undergoing surgical procedures.

Uvula

The robot usually have a uvula sensor that simulates human vomiting reflex. So a touch sensor is installed in the oral cavity. The robot vomits when something touches it. In the training situation, supervisor clicks the vomiting button to evaluate the trainee's reaction for the robot's vomiting.

CURRENT LIMITATIONS

Robots are undoubtedly one of the most exciting of all the inventions in the field of dentistry. The Robot can be of great help to the dental students as well as practising dentists. However there are obvious limitations to this as well.

No matter how good the robot is, it cannot achieve the clinical skills of a dentist acquired through years of practice, and the decision making ability that comes naturally to a dentist with experience. The price and availability of the robots is another negative aspect. Japan being the pioneers in the field of Dental Robots was able to successfully include a Robot for the training of dental students. However, the deep economic plunge the country is facing presently in the stock markets due to the tsunami and earthquake triggered disasters has reduced the chance of more development in this field in the coming years.

CONCLUSION

A patient robot with an oral cavity mimicking unexpected movement of vomiting, pain, functions to induce bleeding and saliva flow can be a great tool in developing dentistry skills in dental students. The students will get an exposure on how patients might react to the different treatments done in the oral cavity, and also this will encourage the students to be more confident in the treatment aspect as the mistakes committed will not cause any harmful effects as they are not performed on humans. This will also help the students to learn from their mistakes and correct it. The students will get better exposure and a feel of treating real patients that a phantom head cannot provide. General practitioners also can benefit from this development, because a dental robot can assist them in clinical practise from answering different questions asked by the patients to assisting in clinical procedures.

There are high expectations in the development of animated patient robots for use in medical training as well. Dental Robots that assist dentists in clinics are also a great boon in dentistry, saving the dentist from having to lean over, that could lead to employment opportunities for dentists with spinal disabilities and physical weakness.[2] The transmission of disease between the dentist and the patient is impossible when a robot is used.

For dawn of Dental robotics in India calls for the need of more studies in this field, and if the results turns out to be positive it can be considered as an important milestone in Dentistry.

REFERENCES

[1] T Hideaki. Dental Patient Robot. Medical Robotics, Book edited by Vanja Bozovic, ISBN 978-3-902613-18-9;443-456.

[2] JADA NEWS. J Am Dent Assoc. 2019;132:1094-1096.

[3] Dental Robotics Groupe. http://www.takanishi.mech.waseda.ac.jp/top/research/jaws/index.htm

[4] Where Are All The Robots? http://boingboing.net/2019/01/09/where-are-all-the-ro.html

[5] Japan unveils willing dental patient -- a robot. http://www.physorg.com/news188718511.html

[6] Practice robot for dentists winces, gags and drools just like a person. http://dvice.com/archives/2010/03/practice-robot.php

[7] Robotics In Dentistry. http://www.robotshop.com/gorobotics/medical/robotics-in-dentristry

[8] "Robot Say Ahhh". Robots Helps Produce Better Dentists. www.robots-dreams.com/2010/03/robot-say-ahhh.html

[9] Robot Dental Patient Can Take My Place Anytime. http://www.danshope.com/news/post/190/Robot-Dental-Patient-Can-Take-My-Place-Anytime

[10] Japans latest invention: The dental training robot that can feel pain. www.dailymail.co.uk/news/article-498530/Japans-latest-invention-The-dental-training-robot-feel-pain.html

[11] Latest Invention: A Dental Training Robot. http://2tech.org/07931/latest-invention-a-dental-training-robot/

[12] Japan's new robot used for dental training. http://seattletimes.nwsource.com/html/nationworld/2004041409_robots29.html

[13] Simroid robot lets dental students know what hurts. http://www.engadget.com/2007/11/28/simroid-robot-lets-dental-students-know-what-hurts

[14] Wild imaginations create robots; Robots laugh, solve puzzles and get dental treatment at exhibit. http://www.niagarafallsreview.ca/ArticleDisplay.aspx?archive=true&e=796853

AUTHORS

First Author – Dr AARATHI VIJAYAN, Professor And Hod Dept Of Public Health Dentistry, Azeezia Dental College, Kerala, India, aarathivijayan123@gmail.com
Second Author – Dr JAYANTH JAYARAJAN, Professor And Hod, Dept Of Orthodontics And Dentofacial Orthopaedics, Azeezia Dental College, Kerala, India, Jayan100@yahoo.com