ROBOTIC TECHNOLOGY USED IN PROSTHODONTICS

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➢ INTRODUCTION:

Robots are human inventions that help to decrease manual labor in dangerous working settings, improve the accuracy and precision of the task being done, and reduce manual labor overall. Mechanical engineering, electrical engineering, computer science, and other interdisciplinary fields of engineering and science are all included in the field of robotics. Robotics is the study of the creation, advancement, usage, and control of robots as well as the use of computers for robotics' command, control, sensory feedback, and information processing. Robotics has entered the medical profession as a result of advancements in industrial robot technology and is employed in a variety of surgical specialties, including applications in dentistry.

Instead than serving as a substitute for human surgeons, robotic systems are designed to be intelligent surgical tools. They contribute to improving the accuracy, standard, and safety of surgical procedures (Lea et al. 1995). Their ability to establish a communication link between preoperative surgical plans and the operating room may be their most valuable capability. The Programmable Universal Manipulation Arm (PUMA 560) robotic system was utilized in a neurosurgical biopsy in 1985, which is the first instance of a robot-assisted surgical treatment that has been reported (Lanfranco et al. 2004). The success of PUMA 560 gave more confidence in using such robotic devices for minimally invasive surgery.

The same PUMA system was utilized in transurethral resection, a robotic operation, in 1988. The first robotic system to be authorized by the Food and Drug Administration (FDA) for use in endoscopic surgery was the Automated Endoscopic System for Optimal Positioning (AESOP) system in 1994 (Lanfranco et al. 2004, Unger et al. 1994). AESOP was created to control an endoscope while it was being maneuvered inside the patient's body. The surgeon's verbal commands or computer commands cause the camera to move.

Due to the system's adaptability, movements can be performed with more precision, and a smaller incision can be used to enter the endoscope into the patient.

In order to help with the control of blunt dissectors, retractors, graspers, and stabilizers during laparoscopic and thoracoscopic procedures, the ZEUS surgical system replaced the AESOP system (Satav 2003; Leal Ghezzi and Corleta, 2016).

The development of the Da Vinchi Surgical (DVS) system, which was approved by the FDA in 2000 (Leman and Cadiere. 1998; Hagen et al. 2014), represented a significant advance in the use of robots for surgical procedures. This technology, which a surgeon operates from a console, was created to make complex surgery possible using a minimally intrusive technique. The most recent DVS system version also offers a twin console option that enables two surgeons to collaborate. This makes it possible for surgeons to receive more effective training, especially those who are new to robotic-assisted surgery. According to Leal Ghezzi and Corleta (2016), the DVS system is being used for a wide range of surgical interventions, including general, thoracic, cardiac, colorectal, gynecological, and urological procedures.

Even if the necessary technologies have already been invented and could be readily implemented, robotics in dentistry is still in its infancy. Robots are mostly used in dental implantology and partial and total denture tooth arrangement in prosthodontics (Jiang et al. 2014).

Below is a description of the specific robotic systems used in such prosthodontic operations.

TEETH ARRANGEMENT ROBOT:

A Canadian-made CRS robot (6° of freedom) is being used in the development of a solo manipulator robotic system for the manufacture of dentures. Construction, teeth-arrangement method, and motion control of a single manipulator teeth-arrangement robot system are examined. [1–3]. Fig1 depicts a single manipulator tooth-arrangement robot system for afull denture, which consists of the following elements: a denture base, a light source device, a light-sensitive glue, a 6DOF CRS robot, an electromagnetic gripper, a computer, a central control system with robot control software for tooth-arrangement, and tooth-arrangement software.

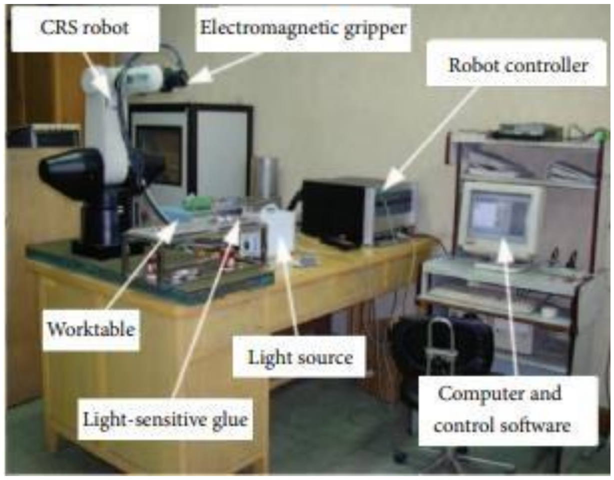

Fig 1: Robot system with a single manipulator for full dentures.

VC++ and OpenGL are used to construct software for virtual tooth arrangement in 3-dimensions. The following are some of the characteristics of the virtual teeth arrangement programme

(1) Select or build the patient's medical history data, design the jaw arch and dental arch curves based on the patient's jaw arch characteristics, and make reasonable adjustments to the dental arch curve.

(2) Provide designed dentitions with a virtual observation environment, highlight virtual dentitions in three dimensions on the screen, and allow interactive adjustment of each tooth position. The software for controlling robots is created using the RAPL programming language.

The capabilities of the robot control software are utilised to calibrate the beginning position of the teeth-arrangement robot, control data profile for the robot's real tooth-arranging activities, and operate the robot. The maximum weight for this robotic system is 3 kg, the top line speed is 4.35 m/s, and the repeated positioning accuracy is 0.05 mm.

Based on the MOTOMAN UP6 robot, the teeth-arrangement multifinger hand realisation system was created. The tooth-arrangement multifinger hand's anatomy, grasping theory and simulation, and workspace analysis are investigated [6–9]. Three fingers make up this multi-finger hand, and each finger has a total of 3° of freedom. Theoretically, this multifinger hand can satisfy the teeth-arrangement criteria based on workspace analysis and motion modelling.

Artificial teeth, on the other hand, have exceedingly complex shapes that make it difficult for a multifinger hand to correctly grab and handle them.

The multi-manipulator robot with 84 DOFs for teeth arrangement, as seen in Fig 2. The dental arch curve has 14 independent manipulators. To meet the criterion for each tooth's position on the dental arch curve, each one might advance along its own path. These manipulators provide six degrees of freedom (three rotations and three movements) to the controllers, allowing them to modify each tooth's position in the X, Y, Z, lingual, rotation, and near far-medium directions. Each tooth is supported by a tooth-arrangement assistant. 84 motorspower this robot system. This robot can achieve any posture in the area around the prosthetic teeth when used with the tooth-arrangement assistant.

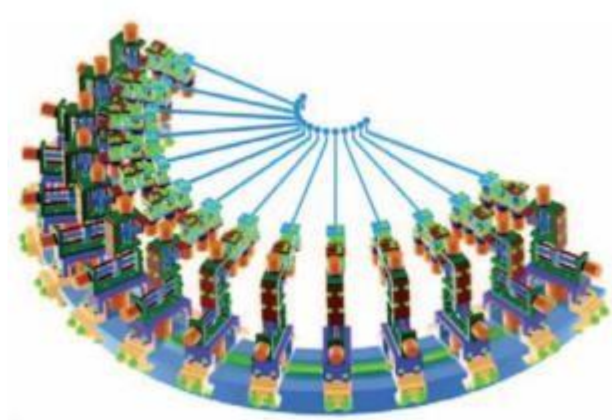

Fig 2: The 84DOF multi-manipulator robot's teeth-arrangement structure.

It may also resolve numerous issues that a single robot finds challenging, such as identifying fake teeth through teeth-arrangement procedure [10], without directly gripping the artificial teeth. Because there are 84 driven motors in robot with 84DOF multi manipulators for teeth arrangement, this is challenging to implement regulate and kinematic calculations for this robotic system. To address these issues, the teeth-arrangement helper and dental arch curve generator are combined to form the suggested teeth-arrangement method [11].

The 50DOF multi-manipulator teeth arrangement robotic system is presented in Fig3. In addition to 14 different manipulators, it contains a slipway mechanism and dental arch generator. A dental arch arc that closely resembles the one from a patient's oral cavity is created using the dental arch curve generator. With 1 fixed point and 4 moving points, it achieves 5-point control via the slipway mechanism.

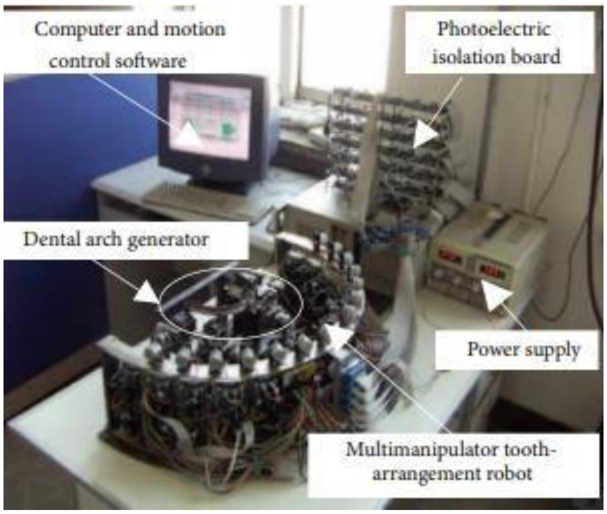

Fig 3: Robotic system for teeth alignment with 50 DOF of motion

The flexible dental arch curve generator has 14 manipulators. To fulfill the need for each tooth to rotate, they can all move along separate trails. In these manipulative devices, every single tooth is held in place by a tooth adjustment helper. The controls also have a maximum of three degrees of freedom to move teeth in the Z, lingual, & near-far-medium orientations.

Two upright bolt rods that are perpendicular to each other and coupled to bendable steel shafts that are driven by stepper drives maintain each operator. The bendable shaft is connected to the stepper motor via a connector, which also turns the bolt bar. When the two bolt bars rotate equally, the rotating frame rolls up and down with the revolving axis in the near-far-medium position. It travels in tandem with the teeth. This method achieves one travelling mobility due to the teeth arrangement assistance's dowelled connection to the shaft that rotates.

The rolling frame rotates when the two bolt bars rotate incoherently, carrying with it the rotation of the tooth-arrangement helper and enabling realization of the ligula direction. A flexible shaft connects the near-far-medium rotating shaft, which is powered by a stepping motor. It can drive the rotation of the tooth-arrangement helper, which results in the near-farmedium direction. The manipulator may move with three degrees of freedom as previously mentioned. As a result, there are now 50 driven motors. The method is also straightforward, nimble, and simple to manage. The coordinated control of a dental arch generator [12], high precision synchronous control of a 50DOF multimanipulator tooth-arrangement robot based on software timer [13], and kinematic analysis and planning [14-18] are all relevant researches that are examined. With the help of this robot technology, a complete denture may be produced in just 30 minutes.

The accuracy of the robotic system is assessed. For a single manipulator, repeated positioning precision is 0.07 mm, and for the full robotics system, it is 0.10 mm. Fig. 4 depicts the entire denture produced by the 50DOF multi-manipulator teeth-arrangement robotic system.

Fig 4: Complete denture made by the 50DOF multi manipulator tooth-arrangement robot system.

On the basis of TRIZ theory, a concept for a professional and miniature Cartesian type robot for teeth-arrangement is proposed in order to address the issue of conventional complete denture manufacturing methods. Robot for teeth arrangement of Cartesian type is designed in three dimensions. ADAMS is used for the kinematic simulation and analysis [19,20]. Fig.5 depictsa virtual prototype for a Cartesian-style tooth-arrangement robot.

Fig 5: Robotic teeth arranger of the Cartesian kind, digital model.

ROBOTS FOR DENTAL IMPLANT SURGERY:

Robotic surgery is now a reality, not just a science fiction story. Robotic systems shouldn't be utilized to replace human surgeons; rather, they should be employed as intelligent surgical utensils that help to improve the accuracy, quality, and security of surgical techniques.

From preoperative surgical planning through the operating room, Ecole des Mines de Paris in France and Umea University have built a robotic implant denture workbench.

The following tasks should be performed by the robot for implantology: preoperative 3D rebuilding, path preplanning, and real-time intraoperative image navigation. The robot's structure should be aware of the flexible image-guided insertion angle and position adjustment inthe constrained workspace. [22,23,25,27]

The first recorded instance of a surgical operation aided by a robot occurred in 1985 during a neurosurgical biopsy using the (PUMA 560) Programmable Universal Manipulation Arm robotic system. This achievement provided further knowledge on the application of such robotic systems in surgical procedures that are minimally invasive. The Yomi implantology robotic system [Fig. 5], created by Neocis Inc. in the USA and authorised by the FDA in 2017, is the first commercially accessible robotic system for dental implantology. [23]

Fig. 5: Robotic dental implantology Yomi

The preoperative planning and the robotically assisted dental surgical system are the two key parts. Navigation during surgery [Fig.6]. Based on the patient's CT data that are presented, the surgeons have a different perspective in the preoperative planning system. An infrared light-based navigation camera is used by the surgical navigation system to determine where the surgical tool should be placed.

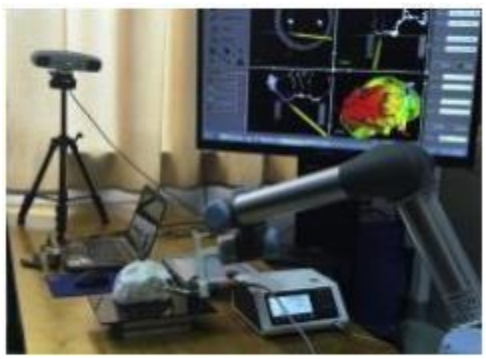

Fig. 6: The surgical robotic equipment includes an optical tracking device, a robot arm, and a surgical navigation system.

These robots, which are made to continuously watch the patient's motions and provide control over the drill as the dentist moves closer to the tissue, may help the surgeon achieve good accuracy. The program keeps an eye on the patient constantly to prevent any surgeon. The process is monitored and shown using real-time 3D graphics. thus it is possible to instantly plan and carry out the dental surgery at the dental office. The advantages of using these robots include quicker healing times and usually safer procedures for dentists when drilling with greater precision. [25,26,27] Fig. 7 depicts the collaborative human-robot operator used in implant dentistry surgery.

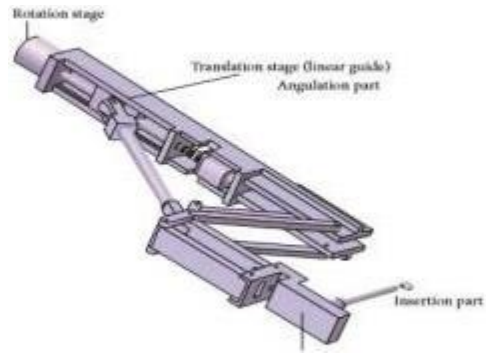

Fig 7: cooperation human-robot manipulator for implant dentistry

In south China [22/09/2017], a robot doctor placed two dental implants for a woman in the first fully automated dental implant operation ever performed [Fig. 8]. The entire treatment was overseen by human doctors who did not take any direct action. [28]

Fig.8: The first totally automated robot implant procedure

ROBOT-ASSISTED MANUFACTURE OF SURGICAL TEMPLATES:

When compared to surgical templates that were prepared traditionally, robot-assisted fabrication of surgical templates has shown better clinical results.

Manufactured surgical templates with robotic assistance may completely direct implant trajectory, are discovered to be less expensive, are less invasive, and reduce the likelihood of human error in clinical practice.[25]

DENTAL MASTICATORY ROBOTS:

Robots that can do some specific masticatory activities is referred to as a "masticatory robot." [29] There are numerous tools and equipment for assessing human masticatory movements. But these tools and technologies fall short of simulating the whole rangeof intricate actions and movements needed in the masticatory process. This paved the door for the realistic and controllable robotic replication of jaw movements for a variety of applications, including dentistry instruction, jaw simulation, and speech therapy.

Robot Simulator Dento Munch is an illustration of a dental masticatory robot. A 6 DOF robotic dental testing simulator is what it is.

It consists of the compliance module and artificial jaws. The jaws were reverse engineered to resemble a human with maxillary and mandibular artificial teeth. They can be used to assess the efficacy of restorations and to mimic material wear on dental parts, such as single tooth, dental crowns, dental bridges, or a whole set of teeth. [30]

MOUTH TRAINING ROBOTS:

Patients with TMJ problems have been trained using robots derived from the Waseda-Yamanashi series. The patient's mandible is opened and closed by this robot as part of an instructional session for opening the mouth.

The WY-5 and WY-6 versions are the most sophisticated. The WY-5 robot measures the biteforce imposed on it from three translational components of the force from the person.

The robot can be controlled remotely by a doctor robot with two degrees of freedom (DOFs) (for open or close and forward or backward movements) or 3 DOFs (for open/close, forward/backward, and right/left motions). The WY robot uses muscular EMG measurements to monitor any alterations in the individual's jaw muscles and assess the efficacy of robotic treatment. [29]

WJ (WASEDA JAW) SERIES ROBOTS:

The WJ robot is employed as a patient robot in order to understand the individual's chewing movements and forces of resistance throughout jaw opening and closing training. TMJ dysfunctions may alsobe assessed for and treated with the aid of this robot. These robots implement artificially manufactured clenching and grinding trajectories and have three DOFs, two artificial TMJs, andtwo TMJs. The robot is powered by eleven artificial muscle actuators (AMA), each of which consists of a pair of DC motors, encoder, cable, and force sensor. The AMA was created to duplicate the forces produced by muscle contraction..

The motor pulls the opposite ends of tendons, which is connected to one end of the robotic mandible. [29]

ROBOTS FOR TREATING TMJ DISORDERS:

Waseda University in Japan created the oral-rehabilitation robot known as WAO1 (Waseda Asahi Oral-rehabilitation robot No. 1). It consists of a headrest-equipped body, two plunger-equipped 6 DOF arms, a control box, a computer, and an automated massage trajectory generating system. This robot device massages the patient's face by pushing or stroking it with a plunger whose action is automatically computer-controlled.

The WAO1 robot is the first to massage a patient's facial tissues, mastication muscles (masseterand temporalis), and saliva-producing oral structures, such as the parotid gland and duct. As a result, it may be used to treat TMJ disorder and dry mouth. [31]

HUMANOID PRACTICE ROBOT:

The ethical difficulty of using human subjects for clinical instruction in dental education is a major barrier. Humanoid practice robots were introduced to solve this problem. These robots can be mounted on a dentist chair and are full-body models. Through computer control, they behave like actual patients and even mimic the gestures and speech of a real patient.

When the students receive dental training, they may end up doing ineffective operational procedures, and these reactions, such as pain response, emesis reflex, cough reflex, and irregular pulse, replicate accidents that may happen during treatment. Simroid is an illustration of a humanoid practice robot. [26,32]

SPEECH ROBOTS:

This was created in 2005 at the Canadian province's university. The two TMJs one at each endof the jaw are driven by two 3-DOF parallel manipulators. It has been designed to examine how jaw motions affect how we perceive and comprehend face-to-face communication. However, no specifics of this study have yet been published. [29]

MICROROBOTISED DENTAL IMPLANT SURFACES:

In comparison to traditionally treated implant surfaces, microrobotized dental implant surfaces can be used to achieve a better bone-to-implant ratio and improved biomechanical attachment between the bone and implant.[33, 34]

NANOROBOTS:

Producing robots at or close to the minuscule scale of a nanometer—1 nm is equal to one millionth of a millimeter—is known as nanorobotics. In the application of nano impression materials with nano-filler in prosthetic dentistry is accessible. To improve polyvinylsiloxane's flow, reduce the amount of voids, and so provide higher precision in the recorded impression and better model pouring, nano fillers are incorporated into the substance. In cosmetic dentistry, nano robots can also be utilized for dental renaturalization procedures. They remove outdated amalgam fillings and recreate teeth using biological materials that are identical to the original teeth. [35]

- **DENTAL ROBOTS HAVE A NUMBER OF BENEFITS AND DRAWBACKS**.

They have **ADVANTAGES**, including: Extremely high accuracy and precision Stability and untiringness, allowing for continuous use without rest

DISADVANTAGES, No assessment of the circumstance, making it unable to make use of any qualitative information. Since these gadgets are still fairly costly and beyond the means of the common person, they must always be under the constant supervision of a professional dentist.

- **CONCLUSION:**

In the upcoming years, robotic aid in prosthodontic applications will continue to be a hotly debated subject. Utilizing the benefits of robotics for several dental applications has made enormous strides. Robotics are mostly used in prosthodontics for implantology and the design and production of complete dentures. Use of highly developed and customized robots helps increase the precision and accuracy of various prosthodontic procedures under expert supervision. However, it is not possible to totally rule out human intervention. Clinical judgment and skilled competence are indispensible.

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