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Robotics in Dental Implantation

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Abstract

This paper presents the application of robotics in the process of Dental Implantation process. The paper presents a prototype of a robotic arm, which can assist the dentist in the drilling the drill site for the dental implantation. The prototype robotic arm developed is a basic model, which given the location of the drill site would reach the particular location. It utilizes the given location coordinates, actuates the motors through the drivers to give the necessary movement for the robotic arm to approach the drill location. The robotic arm traverses to the required co-ordinates and drills a hole of required depth at the destination. The construction specifications and design are discussed in the paper along with the challenges this model has to overcome to replicate the manual implantation procedure.

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Keywords: Autonomous dental drill; multi-degree freedom robotic arm;

1. Introduction:

Robots are replacing humans in many fields ranging from simple tasks like household maintenance to complex tasks like precision welding and cutting. Robotic and intelligent systems possess a unique quality of accuracy and precision, the presence of these traits have led to their immense application in various fields especially in medical applications. Surgical robotics is an emerging field followed by medical assistive robotics and many researchers around the world are currently working in these fields. There have been numerous breakthroughs and advancements in the field of surgical robotics since its early days. The “Remote Surgical Robotic Arm”, developed by University

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of Michigan [1] and the “Autonomous Surgical Robots”, developed by InTouch Health LTD [2], stand as an epitome to the development of robotics in the field of surgical and medical assistive robotics. The recent years have seen the emergence of surgical robots in dentistry. The operational procedures have been fully researched and standardized by the dentists so that the data of critical parameters is accessible. With the accessible data, the dentists are focused on feeding this data to robots which can replicate the operational procedure with a higher accuracy and at economical costs of operation and minimal time requirements. An example of such standardized procedure is the process of dental implantation.Robotics is lacking use in dental applications even though all the adequate technologies have already been developed and with easy adaptability [2]. Some of the technologies are already 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 intra-oral scanner, after which a milling device produces the restoration, but we have not yet seen any robot able to prepare teeth for crowns, inlays or bridges.

This paper presents the development of a robotic arm which will mobilizes to reach the given location i.e the drill site on the mandible. The movement of the arm is driven by the motors to the particular location by three degree of freedom. Once the arm approaches the drill site, it drills a hole of required depth. By conducting pseudo experiments, the feasibility of this modelis demonstrated.

2. Dental implantation process

Dental Implantation process involves a dental implant, which is a small metal pin to be fixed into the jaw bone or the mandible to mimic a tooth’s root. The dental implantation process involves the following steps. The first step involves drilling a hole in the jaw bone and fixing the implant to the jaw bone to obtain firm grip to prevent any loose fitting. The second stage involves preparing a platform or a stage to fix the prosthetic tooth. The stage three involves the fixing of the prosthetic ceramic tooth to the base using abutment. The three staged process as shown in Fig.1 generally requires a completion time of 60-90 minutes and requires high amount of precision and concentration. The prosthetic tooth and implant is shown in Fig. 2.

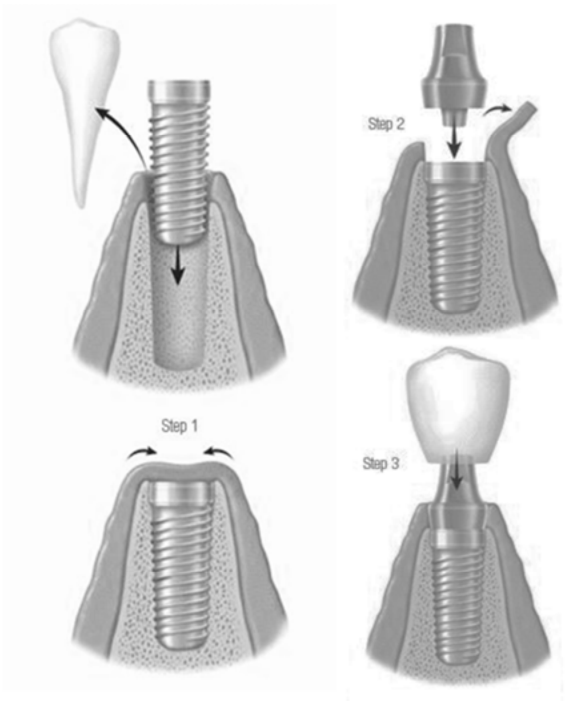

Fig. 1. Three stage dental implantation process

Fig. 2. The prosthetic tooth and implant

The implant is used to anchor replacement teeth and bridges and installing one normally involves complicated and time consuming surgery. The implant fixed to the mandible or the jaw bone is shown in Fig. 3 [4]. The robotic arm can overcome the problems that are faced when dental implants are placed by clinicians with knowledge and skills by reducing errors in angulations, site and maintaining safety of adjacent landmarks. One of the most important factors affecting the outcome of dental implantation is the accurate insertion of the implant into the patient's jaw bone, which requires a high degree of anatomical accuracy. The purpose of using a robot to aid in dental implant surgery is to automate the drilling process involved with the procedure. Benefits of using the robot are an overall safer procedure, more accurate drilling, and quicker healing times.

Fig.3. The implant fixed in the jaw bone.

3. Robotic arm

A robotic arm is developed which can accurately reaches a particular co-ordinate with good precision and can automate the drilling process during the dental implantation procedure by consuming minimum time without trading off with accuracy. Initially the location i.e the coordinates of the tooth are fed into the system by the dentist. These coordinates are fed into the program which initiates the operation of the robotic arm. The coordinates are then converted into the cylindrical coordinates. The robotic dental arm should move to the respective position. The respective position is a linear combination of three orthogonal vectors. Each vector movement will be achieved by independent motors (DC servo/DC stepper) motions. Each motor excited by a control signals to achieve the linear movement in that particular vector direction. These control signals are computed as a function of the given coordinates, mechanical aspects of Robotic arm, electrical and electronics aspects of the motor drives. Thus all these motor will coordinate to provide motion to the hand piece to reach the given location.

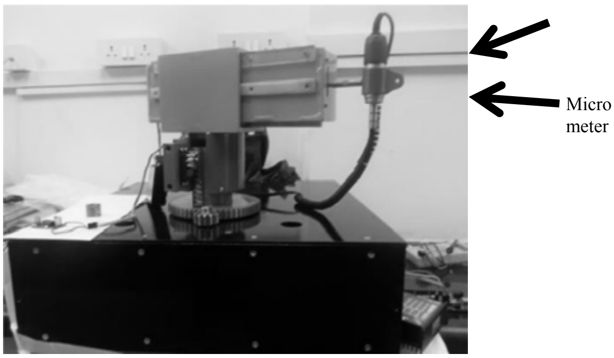

Fig.4. The robotic arm with dental drill

A miniature basic model of the dental robotic drill arm has been developed which was able to create a route for a robot to drill site. Once it reaches the destination the micro motor held by the hand piece starts the drilling in the precise location. The prototype model developed is shown in Fig. 4.

A robotic arm is developed can accurately reaches a particular co-ordinate with good precision and can automate dental implantation procedure by consuming minimum time without sacrificing accuracy (Fig. 4). The input to this arm is the coordinate that it should reach and jaw bone density on which it should drill. The Dentist provides the location of drill which will be then be converted to cylindrical coordinates by the program in host computer and fed to arm. To reach the coordinate, arm translates along three orthogonal vectors, “r”, “Φ”, and “z” of cylindrical coordinate system, as a linear combination of these three orthogonal vectors defines every point in 3D space. In the Fig. 5 the green color base represents the link for the movement in “Φ” direction and the yellow block represents the motion in “r” direction and the blue motor and the red portion represents motion in the “z” direction. This gives the three degree of freedom.

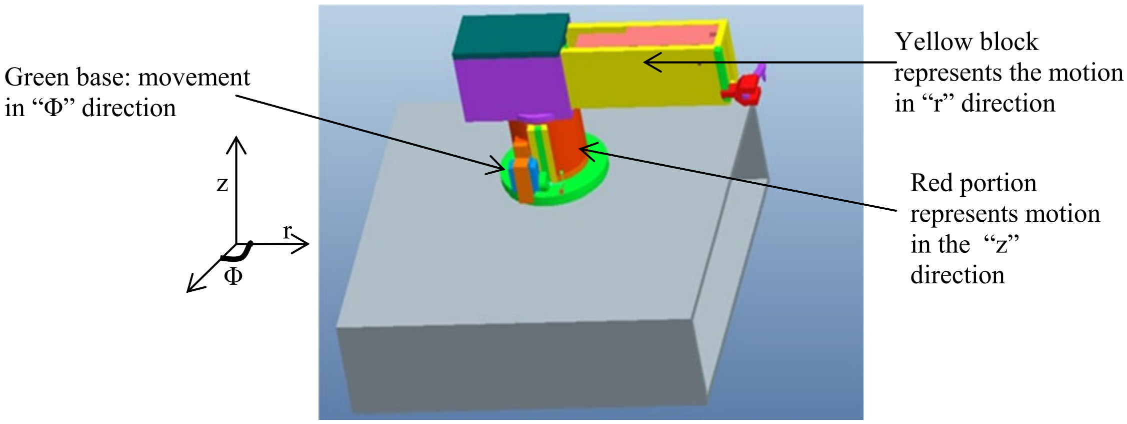

Fig.5. The robotic arm with the different links

To facilitate movement along ‘r’ axis, a 10Kg-Cm torque stepper motor rotates a pinion which is coupled with a rack that is attached to link that extends along ‘r’ axis as shown in Fig. 6. The coordinates extracted from the information obtained from the dentist is sent from the host PC. This signal is fed to the microcontroller which gives the required control signal or the actuate signal to the driver circuit which is amplified to power the stepper motor. The required number of turns is obtained from the stepper motor which is translated into the linear motion to move the part of the robotic arm (the yellow block in Fig. 5) to give the movement along ‘r’ axis. The block diagram representing this control is depicted in Fig. 6.

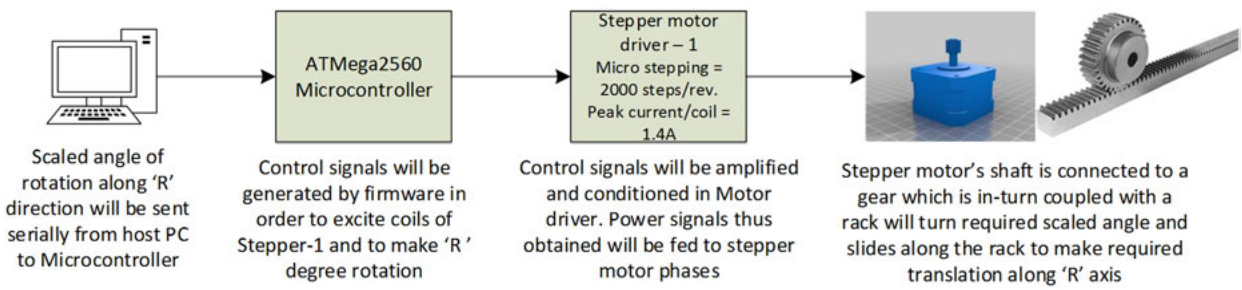

Fig.6. Block diagram showing movement in “r” direction

Similarly, another 85Kg-Cm torque stepper motor is attached to a gear couple which is responsible for rotation along ‘Φ’ of the cylinder. The control action along this direction is represented as shown in Fig. 7.

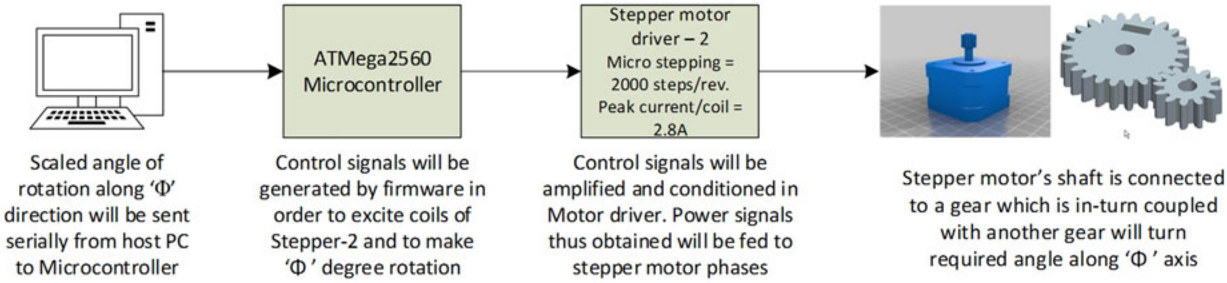

Fig.7. Block diagram showing movement in "Φ" direction

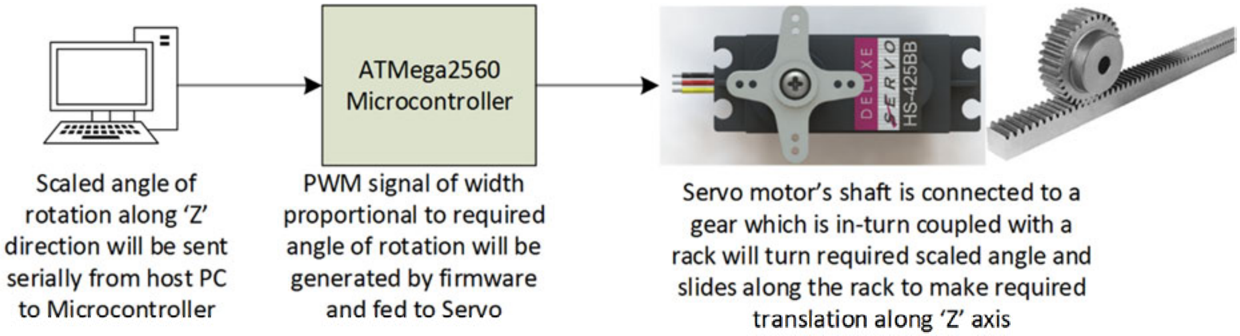

Fig.8. Block diagram showing movement in "z" direction

A 16Kg-Cm torque servo is powering the rack-pinion attachment which will lift the arm in 'z' direction as shown in Fig. 8. This servo motor is being powered by 24V, 5A SMPS via 7V, 3A buck converter, whereas the two steppers' motor drivers are being powered by a 48V, 5.2A SMPS. The control signal to the servo is a PWM signal generated by microcontroller based on angle input fed to it by Dentist whose pulse width is proportional to the angle swept by the servo. Stepper's excitation pulses are generated by microcontroller similarly but are fed to Stepper driver first to amplify the power. This provides the movement along the 'z' direction.

4. Results

A basic prototype model of the dental robotic drill arm has been developed, for assisting in dental implants. This bot was designed to operate on a mandible placed on a stable surface. The mechanical design was computed in the PROE software. Utilizing this design the prototype model was manufactured. The driver's circuits of appropriate ratings for the motors were fixed inside the base of robotic arm. The connecting wires are inset within the bot. When the location of the drill is given, this model is able to reach the drill site in its first stage. This bot was equipped with one high torque stepper motor, two low torque steppers and one high torque servo motor for reaching precise coordinates and placing/lifting hand piece (dental drill). If the three cylindrical coordinates are taken as "r", "Φ", and "z". The robotic arm moves about 15cm along "z" direction, 270^0 about its main axis and 11cm about the radial direction.

Motor-1 (high torque servo motor) serves the purpose of lifting and dropping the drill bit i.e., along the "z" axis. A stepper motor moving along the rack and pinion moves the arm in "r" axis direction. A high torque stepper motor moves the arm in "Φ" axis direction. The overall size of the model is 50cm x 50cm x 40cm.

At present the model has achieved a basic open loop control i.e, upon giving the location of the drill; it actuates the motors through the electronic drivers and reaches the location. Input angles were set to achieve a linear motion of 3cm and angular rotation of 30 degrees for motors along 'r' axis and 'Φ' respectively. When measured, we achieved a linear motion of approximately 1.2cm and angular rotation of 18 degrees. We recorded an error of 1.8cm and 12 degrees respectively in this open-loop control. Using the micrometer a drill is driven into the surface which is used to fix the implant. This model has yet to consider the closed loop control to decrease the steady state error, and improve its transient response. There are some vibrations while drilling which have to be nullified.

5. Conclusions

A basic prototype model of the dental robotic drill arm has been developed, for assisting in dental implants. This model is able to reach the drill site in its first stage. While the preliminary results look promising, there are still some areas that need to further addressing. For instance, patient movement must be tracked using some type of motion sensing device. When motion by the patient is detected, the robotic drill must be able to turn itself off. These will be incorporated while modifying the model in stages. This model will be clinically analyzed with the consented cooperation by the doctors of Army College of Dental Sciences, Secunderabad.

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References

[1] http://www.pennmedicine.org/robotics/davinci.html
[2] http://www.sages.org/publications/guidelines/consensus-document-robotic-surgery/
[3] http://uakronrobotics.com/dental-implants-using-robotics/
[4] http://oralfacialsurgerydfw.com/oral-surgery-procedures/dental-implants/