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Micro Robot - A Revolution in Endodontics.

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ABSTRACT

Robotics was successfully applied to the medical field which led to a new scope with vast areas of research; specially, robotics with dental application is relatively an untraveled area to explore. Access opening, bio mechanical preparation and obturation are the three vital steps in endodontic treatment. This procedure is time consuming and completely relies on the clinician's mastering skills which can be gained only through years of training and practice. Hence there are chances of human error in this stressful procedure. In order to improve the quality and reliability of endodontic therapy, an endodontic micro robot is built with an objective to modernize the traditional treatment, moving from a "manual act" to science-based automation. This paper will discuss the mechanical design and manufacture of endodontic micro robot and innovations involved from the traditional way endodontists root canal treatment to science and technology based system.

Keywords: Endodontic micro robot, Micro sensors, Micro actuators, CAD-CAM, NC digital controller.

INTRODUCTION

It is said that "Many great inventions are not just done by impulse or motivation but by a series of small things brought together".[1]

Robots are small entities introduced in the field of medicine and dentistry to increase precision, quality and safety of various procedures.[2] MICROROBOTICS is a field that is getting a lot of attention today. The terms micro robots or micro robotics are related to robots that are able to handle objects and carry operations at the micrometer range.[3]

Endodontics treatment is most commonly performed treatment of infected tooth. It involves three phases: (1) access preparation, (2) root canal preparation or cleaning and shaping and (3) obturation.[4]

Root canal preparation is a mechanical process that is done with hand files and reamers, along with drills or tools of different designs that are attached to rotary engines of different speeds. The principle in this procedure is similar to drilling/reaming process used in the machining industry. The machining industry has moved from manual operation to Computer Numerical Control (CNC). The quality and accuracy of a produced device is controlled by a computer program on an automatic precision machine. In the same way, the reliability of endodontic treatment could be greatly enhanced by applying advanced endodontic technology innovation with principles of advanced engineering and computer aided technology.[5]

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The Advanced Endodontic Technology Development project was proposed by Dr. Hong Seok, a professor at Columbia University in the United States. This project has been introduced with a goal of developing a computer aided treating system and an intelligent miniature robot which can perform endodontic treatment automatically.[5] It consists of five sub subjects. (1) Development of a technique to thoroughly assess the tooth's condition using 2-dimensional x-ray images to build a computer 3-D tooth model, (2) Development of an automatic prescription system from the 3-D root canal model, using computer-aided treatment procedure planning, (3) Design and built of a smart non-destructive, multi-purpose precision micro machine to perform automated root canal drilling and filling as shown in [Figure 1], (4) Development of a new ultrasonic cleaning tool with pressure assisted jetting/vacuum waste removal, (5) Development of new root canal filling materials.

The development of an endodontic micro robot is the center piece of Advanced Endodontic Technology Development project, as this micro machine gives the precision well beyond what the human hand can achieve. It is an advanced step in an evolving partnership between humans and robots, which seeks to exploit the capabilities of both to perform a better task.[6]

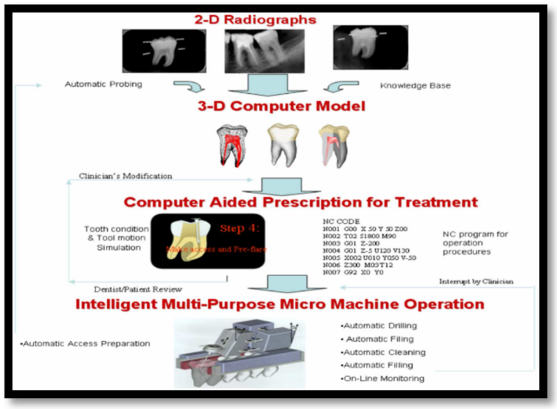

Figure 1: Summary of automated root canal treatment process.[6]

This machine will be mounted on several teeth within the patient's mouth. With online monitoring and intelligent control, the micro machine or robot will perform all the steps of root canal treatment automatically with specific objectives such as 1) Reducing the dependency on the skills of the dentist 2) Minimizing human error 3) Providing accurate diagnosis and treatment.

3-D computer modeling of root canals

In conventional endodontic treatment, a destructive access cavity preparation is done by removing much of the peri- cervical dentin which compromises the structural integrity of tooth structure. 3-D computer modelling of root canals is a non-destructive assessment of the internal anatomy of the teeth. In this, a less invasive technique and a computer program are developed to assess internal tooth geometry by building 3-D tooth models from 2-D radiographs. This model reveals the dimensions and geometry of the root canal, and displays the location of canal orifice and canal curvature in 3-D computer graphics thus avoiding the destructive access preparation.[7]

Computer-aided treatment process consists of computer-aided prescription of treatment procedures similar to functions like CAD/CAM programs in the machinery industry. In this process, computer aided design generates NC codes (G codes and M codes) or a standard numerical controlled program which determines the tool paths and cutting parameters for the automated root canal treatment. By integration of this auto-prescription program into micro robot will plan the sequence of the operations using a variety of tools and precise control parameters with intelligent drilling to complete the preparation of the root canal. The dentist can review the access preparation and canal drilling by assessing the displayed geometry of the 3-D tooth model during treatment.[7]

Micro Sensors, Actuators, and Control Systems

This machine design also incorporates sensors for intelligent monitoring of the treatment process. Because of the compact features of the sensors, they can be fabricated using a surface micro machine method to produce silicon-on-insulator (SOI) wafers, which will be embedded in the micro robot.[8]

Movement of micro robot

To provide an accurate positioning of the tool, with correct angular orientation, an ideal basic machine must have five degrees of freedom to control the following axes as illustrated in [Figure 2 & 3] : 1) X-axis, along the teeth row, with 5 mm stroke 2) Y-axis, across the teeth row, with 4 mm stroke 3) Z-axis, the tool advancement direction, perpendicular to the tooth occlusal surface, with a stroke of minimum 15 mm for a shorter tool and 28mm for a longer tool 4) Tool entrance angle of ± 12° in the X-Z plane 5) Tool entrance angle of ± 12º in the Y-Z plane.[5]

To summarize the micro robot has linear motion in the X, Y, Z directions, and rotational motion in θ x, θ y directions. The tilt angles θ x, θ y are controlled by additional linear actuators X' and Y'. There is another rotational motion provided for the spindle ω z. The five axes (five degrees of freedom) and the on/off spindle of the tool can be controlled by six micro actuators. Each actuator is independently controlled by a digital NC controller. The NC controller should react to the sensor signal quickly, typically in a few milliseconds.[8]

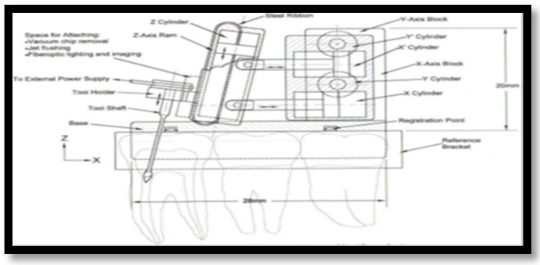

Figure 2: Micro-robot conceptual design.[6]

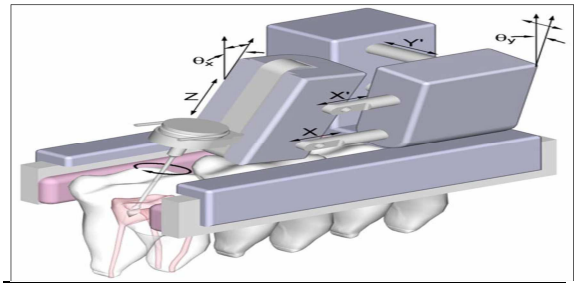

Figure 3: Multi-purpose micro-machine for automatic endodontic treatment.[6]

This machine can hold various endodontic tools and auxiliary devices. With a quick tool change approach, utilizing a cartridge design, different tools can be pre-mounted on a small modular unit, which can be inserted into a sliding adaptor on the Z axis. Auxiliary functions in the machine include an irrigation nozzle for cleaning, a vacuum suction cup for chip and waste fluid removal, and/or optical fibers for lighting, imaging and observation. Though a manual remote control is provided for the clinician, a fully automatic operation with computer-aided treatment procedure planning and control is the ultimate goal for a zero-defect operation. An interface system will be provided for the clinician to interact with the machine control.[7]

The dimensions of the equipment should be within 20x20x28 mm which is compact enough to fit into the patient's mouth and sit on the teeth between his/her two jaws as illustrated in [Figure 4]. The machine should be able to provide minimum of 500gm (4.9 Newtons) or more thrust force necessary for tool penetration into the crown and dentin.[9] It consists of machine with a saddle-shaped base. It will ride on a pair of reference brackets and the teeth. Before taking X-rays and mounting this machine, the brackets are used in assorted sizes which fit the patient's teeth. By utilizing neighboring teeth as support it must be pre-clamped firmly on the tooth to be treated. The bracket pair provides three radiopaque reference points for the machine registration, thus establishing a coordination system.

Once the machine is seated on the reference bracket, it is rigid enough that patient can bite on it and the machine base will have no motion relative to the patient's teeth, regardless of the patient's head or jaw movements.

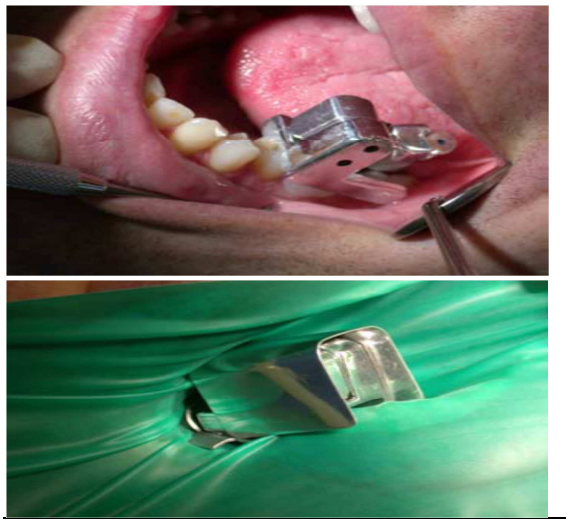

Fig 4. Machine model showing how it fits in the patient's mouth: to the right is the machine placed together with a rubber dam. The machine is protected by a stainless steel cover. To the left is the machine without cover or rubber dam, showing the relationship in size to the teeth.[6]

Endodontic micro robot provides following benefits according to IADR's press release which includes 1) It provides an efficient treatment with direct benefit to the patient, 2) It saves the dentist from having to lean over which could lead to employment opportunities for dentists with spinal disabilities, 3) Transmission of disease between the dentist and the patient can be avoided and 4) Useful in providing dental care in countries at war or with economic problem.[8]

CONCLUSION

The development of endodontic micro robot will change the traditional way of root canal treatment to a more accurate, time saving, automated computer controlled treatment procedure with numerous benefits. But it is highly expensive and further research is still needed regarding its fabrication and clinical applications.

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