Title: Robot-Assisted Endodontic Treatment ver3.2

**Blue lines are contents**

1. Introduction (5~10 pages)
   1. Motivation
2. Introduce the procedure of RCT- Open->Clean->Fill
   1. Previous Work and Problem Definition
3. Previous work: briefly mention the existing dental robots
4. Problem definition:
5. Assist dentists to operate RCT and focus on cleaning procedure
6. Root canal cannot be visually observed and is too small to clean well
7. Risk of file breakage
   1. The Proposed Method
8. Solutions: (be consistent with problem definition)
   1. Build a robot-assisted system and enable it to drill
   2. Force-guided alignment
   3. Control the file rotation speed
9. Prospect:

Move to the infected teeth -> Root canal searching -> Repetitive drilling -> Apex Detection

* 1. Main Contributions of the Thesis (1.2-1.4 are consistent with each other)
* Integrate a 6-DoF robotic manipulator with 6-DoF F/T sensor for performing endodontic treatment.
* Develop a framework for robot alignment regarding the position and orientation of root canal.
* Protect the endodontic file from fracturing by controlling file rotation speed.
  1. Organization of the Thesis

1. State-of-the-Art (3~5 pages)
2. YOMI – commercial robot
3. HK - dental implant robot
4. Korean - dental implant robot
5. NCTU – RCT robot
6. Design and Analysis of the Dental Surgical Robot – DentiBot (15 pages)
   1. Requirement and Specification
7. Payload, resolution and workspace
8. Why not RCM mechanism
   1. Design of the DentiBot
9. Why Robot Arm - Meca500, F/T sensor - Mini40, Customized Handpiece
10. 7 DOF discussion
    1. Kinematics Analysis
11. Coordinate Definition (One figure, 0~6 robot frame, Sensor frame, and Tool frame)
12. Forward Kinematics
13. Inverse Kinematics
14. Jacobian Matrix (three parts: geometric Jacobian based on frame0, geometric Jacobian based on frame6, analytical Jacobian)
    1. Coordinate Transformation of Robot Arm
       1. Translation Analysis - Tool Center Point

four-point method

* + 1. Rotation Analysis

How to find the direction vector of the tool based on TCP method and subsequently derive its orientation.

1. Force-Guided Robot Alignment (Tutorial, only variables without numbers and data) (cite some technical papers) (30 pages)
   1. Problem Definition
2. Problem definition:

1. why not Image processing 2. How to cooperate with a dentist

1. Proposed method

1. Like Peg-in-hole method based on F/T feedback 2. Two modes - Dragging mode and Self-alignment mode

* 1. Integration of F/T sensor

1. Gravity compensation
   1. Dragging Mode
2. Admittance Control based on F/T sensor
   1. Control scheme - block diagram
   2. Admittance control (why mass-damper system and why not spring)
   3. Determination of Robot command (select Movejoints due to singularity problem, why position control rather than velocity control)
   4. Self-Alignment Mode

Utilize [Chapt. 3.4] Transformation from robot to tool + [Chapt. 4.3] adm ctrl

* + 1. Coordinate Transformation of F/T sensor

1. Transformation from sensor to tool
   * 1. Motion Planning Based on Admittance Control
   1. Discussion about Affection of Parameter Setting
2. (K, Bi, Mi) (w/o numbers)
3. Modes: Doctor Dragging and Auto navigation (w/ numbers; get reasonable and suitable parameters first)
4. Control of Endodontic File Rotation (15 pages)
   1. Problem Definition
5. Main cause of Files Fracture
6. File property
   1. The Proposed Method and Theorem
7. CACS2020 prototype1
8. Motion Planning: sections + how to move when reverse (refer to the paper of Prof. Tsao)
9. Current threshold setting
10. Experimental Results (20 pages)
    1. Experimental Setup
11. Communication protocol – EtherCAT, RTOS – NI target
12. For 6.2 experiment: (Stewart-Platform + PhaseSpace + markers)
13. For 6.3 6.4 experiments: (Acrylic root canal model + truth tooth)
    1. Accuracy of Self-Alignment During Drilling
14. Validation of admittance control
15. Metrics: position comparison between the target and the robot
    1. Efficacy of the Control of Endodontic File Rotation
16. Validation of Self-alignment Mode
17. Metrics: time, completeness and file breakage
18. Completeness definition: comparison of pixel area before and after experiment via image
    1. Preclinical Evaluation of Robot-Assisted RCT
19. Validation of Repetitive Experiment
20. Metrics: file breakage(Y/N), compare w/o reverse
21. Conclusions and Future Works(1 pages)

(Patient move tracking via cable, root canals searching)

1. Appendix