

Human-Robot Collaboration System Using Virtual Fixture Method and Image-Guided for Dental Implant Surgery

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INTRODUCTION

The main purpose of this work is to develop a methodology and propose an approach to improve the control of human-robot collaboration for robotic dental implant placement. In this study, a human-robotic implant system (HRIS) is designed according to the hand-guiding control in a human-robot collaboration that can increase efficiently the accurate and stable osteotomy drilling based on the surgeon's decision and robotic manipulators motion during the implant placement. The proposed method is able to modify the surgeon's position and orientation hand according to the posture of the desired placement. The implant placement is always tracked by the camera and the data of the desired position are sent to the controller of the robot. The proposed HRIS system can also be enabled or disabled during the drilling according to the decision of the surgeon for increasing the safety performance of the system.

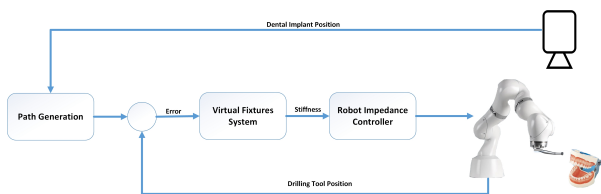


Fig. 1: The proposed structure for the hand-robot collaboration system

MATERIALS AND METHODS

To control and modify the surgeon's hand, the virtual fixture method is used as the main control approach. In fact, the virtual fixture is a software constraint method and it provides a balance between direct human control and autonomy. In this method, the stiffness of the both position and orientation of the robot is adapted according to the dental implant placement. The main idea of the presented approach is that whenever the surgeon deviates from the desired path, the robot will try to revise the motion of the surgeon's hand by increasing stiffness and making a constraint in order to return the surgeon's hand to its desired path. Additionally, using a camera and different defined tags the position and orientation of the implant placed always be available and sent to the controller of the system. The calibration of the position and orientation

of the desired implant placement is another challenge that should be considered. The calibration should be performed in the best mode in such a way that if the patient is moving during the surgical operation, the new and correct posture of the patient should be updated. In order to interact properly between robot and surgeon, the software of the robot controller is developed in a way that the surgeon can observe the position and orientation of the drilling tool during the surgical operation. In addition, the surgeon is able to choose different views from the drilling tool. To improve the safety performance of the system, there are some different gauges and alarm systems that are considered to warn the user as soon as the surgeon's hand has deviated from the desired path.

The structure of the find desired placement for the dental implant can be observed in the Fig.2. Accordingly, using a prob the points on the tooth's surface are collected, and then these points are registered with CT image shown in Fig. 3. To have real-time navigation, in this study a Micron Tracker camera is used.

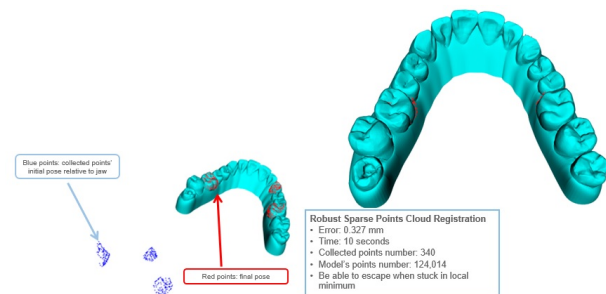


Fig. 2: Structure of identifying the best placement for dental implant

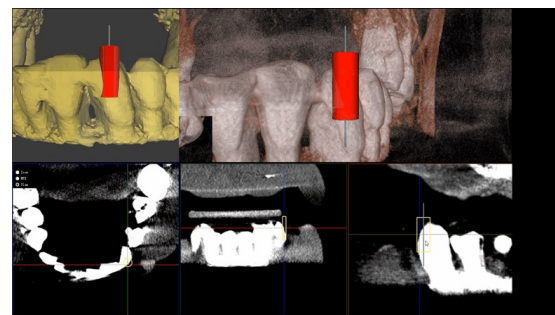


Fig. 3: CT Image of the Dental Implant Placement

CONCLUSIONS AND DISCUSSION

To verify the performance of the introduced method, the KUKA MED robot is used to perform the dental implant placement using the presented approach on a phantom head with a 3D jaw bone model. Additionally, the results between free-hand drilling and HRIS controlled drilling according to the apical center and head center of the implant placement are compared to evaluate the performance of the introduced method. Additionally, all of the required data can be logged during the surgical operation, and using this way the performance of the surgeon can be evaluated by the system and shown with the different graphs. The main structure of the introduced HRIS is presented in Fig.1. According to this structure, the camera tracks the dental placement as the desired point and provided this information for the robot, and then the robot controller is responsible to adapt the stiffness of the robot according to the virtual fixture method. The position of the drilling tool is measured by the robot using the kinematic model of the robot manipulator.

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