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CLINICAL INNOVATIONS

The Accuracy of Surgical Automatic Robotic assisted Implants Placement in Edentulous Maxilla: An In Vitro study

Shengchi Fan[1], Zhenggang Cao[3], Chunxia Qin[3], Feng Wang[1], Wei Huang[1], Xiaojun Chen[3], Yiqun Wu[2]

[1]Department of Oral Implantology, Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University, School of Medicine, Shanghai, China 200011
[2]Second Dental Clinic, Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University, School of Medicine, Shanghai, China 200011
[3]School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China

Abstract

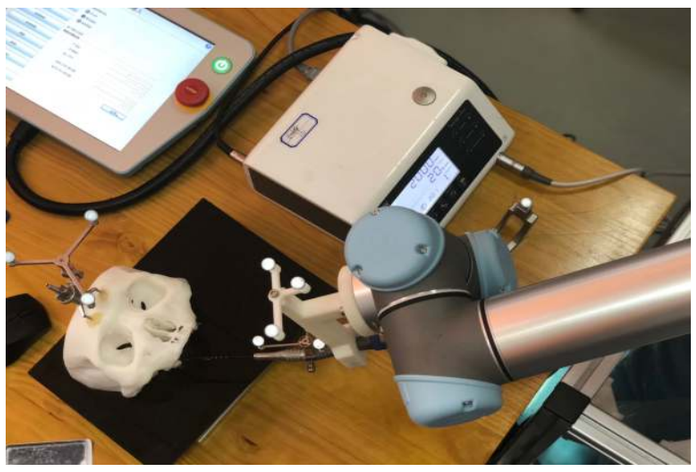
Real-time surgical navigation has been increasingly applied in implant placement. The error from the human application is hard to be quantified and eliminated. The purpose of this study is to build an automatic navigation-robotics system for the implant placement and to investigate the planed/placed accuracy and feasibility of this system by placing zygomatic implants in the severe atrophy maxillary phantom. The drilling trajectories are planned through the preoperative planning system. Through a coordinate transformation algorithm, the real-time visualization of the surgical instruments are constantly updated according to the movement of the robot arm and zygomatic implant can be placed with the control of a six degree of freedom robot. Measurements of deviation is to combine the pre/post operation CBCT, and the three-dimensional distances between the entry/apical point of the corresponding planned/placed implants were calculated. Twelve zygomatic implants were placed in the 6 phantoms, the entry, apical and angular deviations at were 2.34±0.79mm (range from 1.25 to 3.25 mm), 2.57±1.73mm (range from 0.21 to 4.23 mm), and 2.76±1.39 degrees (range from 1.10 to 5.01 degrees), respectively.
The automatic robotic system could achieve accept planned-placed accuracy in ZIs placement in the severe atrophy edentulous maxilla.

Background and Aim

The real-time surgical navigation system for improving the accuracy of implants placement has been tested and validated in various clinical cases. Most kinds of errors have been profoundly investigated to evaluate the accuracy. However, the application error associated with the surgeon is hard to eliminate and usually is negligible in the current studies. In order to avoid human error maximally, surgical automatic robot system can be introduced to eliminate it with successful outcome. The aim of this study is to evaluate the accuracy of surgical navigation-robot system in placement of dental implants in the severely atrophic edentulous maxilla. In this model study, zygomatic implant (ZI), which is with a length of 50 mm was introduced to verify the reliability of this automatic robot system.

Methods and Materials

To simulate the edentulous maxilla, six phantoms were fabricated according to rapid prototype with fused deposition modeling technology. Bone-anchored fixed titanium mini-screws (diameter 1.0 mm, length 9.0 mm, square cavity 1.0 mm) (CIBEI, Shanghai, China) were served as fiducial markers, and the phantoms then underwent CBCT scanning (i-CAT, Imaging Sciences International, Hatfield, PA; 0.39 mm/pixel; 0.5 mm slice thickness). The DICOM data were transferred to a planning software (DentalHelper, Shanghai, China). Each phantom received two ZIs.



Three main parts of this automatic robot system were included, a pre-operative planning system, a surgical navigation system and a robotic control system. With the use of application program interface (API), this robotic system is programming in Visual C++, Visualization ToolKit. Insight Segmentation and Registration Toolkit. The Image-Guided Surgery Toolkit and QT and then integrated into the software of robotic system.

Fig1: The preoperation image was fused with the postoperation image, and the planned-placed deviations of implants were measured

The intraoral coronal entry points of implants were at or near the top of the alveolar crest at the level of the second premolar/first molar region. Pre-operation planning was set up in surgical navigation system (OralImplantPlanningV1.0, Shanghai, China) and guided robot arm (Universal Robot UR6, Odense, Denmark) to perform automatically trajectory drilling procedure.

Results

The entry deviations, exit deviations and angle deviations of twelves 50 mm ZIs between preoperatively planned and postoperatively placed implants were measured in this study. The mean deviations of entry points was 2.34±0.79mm (range from 1.25 to 3.25 mm). The mean deviations of exit points was 2.57±1.73mm (range from 0.21 to 4.23 mm).The mean deviations of angle was 2.76±1.39 degrees (range from 1.10 to 5.01 degrees).

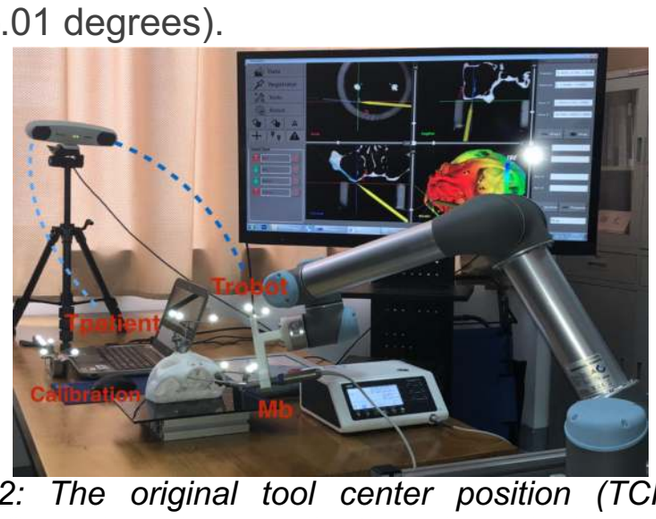


Fig2: The original tool center position (TCP) be configured as the coordination of surgical instrument to serve as the TCP of robotic. The TCP and tool configuration can be calculated by the calibration matrix transform (Mb). Registration matrix (Tt) is the transform relationship between preoperative image coordinate system and intra-operative patient coordinate system. Tpatient and Trobot respectively are the transformation matrix of the patient reference coordinate system and the robot reference robot system to the position measure coordinate system.

Conclusion

Despite the limitations of present study, the automatic robotic system could achieve accept planned-placed accuracy in zygomatic implants placement in the severe atrophy maxilla. The deviation cloud be minimized after the system upgrading the force feedback technology.

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