A novel robot-world calibration in surgical robot system for zygomatic implant placement based on its motion characteristics and mechanical structure

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Zygomatic implant technology has been successfully applied to the repair of atrophic maxilla to avoid a large number of grafting surgery and shorten the recovery time. However, because of the long trajectories of zygomatic implant placement, the destruction of normal anatomical landmark and the narrow operating space, it is difficult to operate and ensure the accuracy. At present, the surgical robot system with real-time optical navigation system assistance is widely used in the field of zygomatic implant placement. The robot-world calibration is the crucial process of an optical-navigated surgical robot system, which is accompanied by complex mathematical calculation and a large number of time consumption. In this study, an automatic robot-world calibration method based on mechanical structure and motion characteristic of an UR (Universal Robots, Odense, Denmark) is proposed. The calibration reference frame fixed at the end-effector of the robot makes a circular and linear motion with the rotation and translation of the terminal joint. Further, the least square fitting algorithm is used to calculate the center of the circular motion and the direction of the linear motion. The terminal joint of the robot automatically carries out a set of specific motions according to the preset command, then the position and direction of the tool center point (TCP) of the robot are determined and the matrix of robot-world calibration is calculated. Through an animal experiment on the maxilla of a pig, the accuracy of the surgical robot system with this robot-world calibration has been evaluated. The deviations of the entry point, exit point and angle are respectively 1.44±1.01mm, 1.68±0.76mm and 1.01±1.06°. It demonstrates that the surgical robot system has a higher operation accuracy than that of the surgeon, and overcome the limitation of the line-of-sight problem of the optical tracking device to some extent.