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Erweiterungen eines Robotersystems für die Craniofaciale Chirurgie

Improving a Robot System for Craniofacial Surgery

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Introduction

The robot system "RobaCKa" has proven to be capable of bone surgery on humans. In a successful first clinical application it cuts out a bone segment very precisely from a patient's skull along a preoperatively planned complex trajectory.
Based on the experience of this operation and other trials, some changes appear expedient in order to improve the system.

Materials & Methods

Preoperatively, four small titanium screws are inplanted into the patient's skull as artificial landmarks. Then the intervention can be planned on 3D reconstructed CT data. The "RobaCKa" system itself consists generally of a Stäubli RX90 robot, its control and an industrial PC running processing data acquired from sensors attached to the robot and a graphical user interface. A small autoclavable tool with five buttons works as input device for the surgeon. Two of the buttons work as dead man switches and must be held down whenever the robot is supposed to move.
The robot's end effector is a tool about 400 mm in length, including a mechanical overload protection, a force / torque sensor, reference frames for a tracking system and a milling tool. It is attached in axis with the robots sixth joint.
After the robot has gone through an initialisation process, the patient can be registered using the preoperatively implanted landmarks. Robot and patient have to be brought into a position, where the planned trajectory lies completely within the robot´s working envelope. Now the surgeon can lead the robot's tool to the four landmarks, using force-control. This results in an improved patient registration.

Finally the robot can mill the skull bone autonomously, supervised by a number of sensors and the surgeon.

Results

The robot system mills trajectories into a skull with a precision of about 1mm. This was proven in the first surgery of its kind on a patient. The cut bone segments must not exceed some centimeters in diameter, though. This is due to the end effector's length and fixation. Further, the mechanical overload protection causes a little bit of slackness in the tool. Since the milling tool's feed applies forces on the patients skull, the head has to be fixed very toughly so it can not shift.
Due to some irreliability of the CT data and the patient model generated from it, the cut was only performed to a safety margin of 2 mm off the patient's dura mater.

Discussion

Although the system has proven to be capable of performing surgery, there are some issues to be optimized. For example, the current system's working envelope is limited and the mechanical overload protection, preventing the patient from beeing exposed to extreme forces, causes some slackness in the tool.
In order to overcome these issues a new end effector was designed and tested in a laboratory environment. It is more compact with the tool tip close to the robot's wrist. The mechanical overload protection could be dropped and replaced by an active linear axis, allowing for a fast tool retraction in case forces exceeded certain limits. Such an additional axis could also add to dexterity when operating close to the patient´s brain.
A completely new approach to cut segments out of a skull is the use of laser technology. Tests have already shown that this technology is applicable to human bone.