Single-step robot guided bone resection and individual reconstruction of the skull

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Abstract

The TICC (Tomography Image processing CAD-CAM) processing chain allows the supply of existing craniofacial defects with individually prefabricated implants based on helical CT data [1, 2]. In combination with individual templates single-step bone resection and reconstruction is available [3, 4, 5, 6]. New developments in navigation and robotics allowed a robot guided bone resection according to the preoperative planning with the CAD system [7, 8, 9, 10]. This study shows results of resection experiments on ovine cadaver heads.

Keywords: CAS, Resection, robotics

1. Introduction

The TICC-processing chain developed by an interdisciplinary research group at the Ruhr-University Bochum in Germany allows the supply of existing craniofacial defects with individually prefabricated implants based on helical CT data. Until now more than 250 implants made of pure titanium have been inserted successfully with great benefit for the patients (Fig. 1).

Fig. 1: Individual skull reconstruction by implants made of titanium.
Special indications as tumour or osteomyelitis require a single-step bone resection and reconstruction with the preoperatively fabricated implant. So far a resection template was necessary to perform the bone resection corresponding to the prefabricated implant.

New developments in intraoperative navigation and robotics allow a robot guided bone resection of the cranial and facial bone according to the preoperative planning with the CAD system. In consequence a single-step operative approach becomes possible without a resection template (Fig. 2).

Fig. 2: Robot resection at the Inst. of Process Control & Robotics, University of Karlsruhe, Germany.

2. Materials and Methods

To investigate and evaluate the clinical practicability and the precision of the robot guided bone resection an animal model was evolved: Three ovine cadaver heads were prepared with miniscrews (Medicon, Tuttingen, Germany) as markers and the data acquisition was carried out with helical CT (Somatom Plus 4, Siemens, Erlangen, Germany). The data were transmitted to the CAD system (STRIM 100 Matra-Datavison, Paris, France) and three complex bony defects were planned in relation to the markers (Fig. 3,4,5).

<table>
<thead>
<tr>
<th>n°</th>
<th>figure</th>
<th>defect description</th>
<th>extension</th>
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<tbody>
<tr>
<td>#1</td>
<td>3</td>
<td>parietotemporal, right side</td>
<td>6.5 by 4.5 cm</td>
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<tr>
<td>#2</td>
<td>4</td>
<td>parietal, bilateral</td>
<td>5.0 by 4.5 cm</td>
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<tr>
<td>#3</td>
<td>5</td>
<td>orbitotemporal, left side</td>
<td>5.0 by 3.0 cm</td>
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Table 1. Defects of the ovine heads.

For the defects #2 and #3 an individual implant and the trajectories for the robot resection were planned with the CAD system. Afterwards the trajectories were transmitted to the control unit of the robot by an ASCI-interface. After referencing the markers with an infrared navigation system and with the manually guided robot’s arm the bone resections were performed with the robot system CASPAR (Stäubli RX90CR, Orthomaquet/URS, Schwerin, Germany). During the bone resection of defect #1 the operation table and the holding fixation of the ovine head were not connected to the robot and the infrared navigation system was not integrated in the robot’s arm.