Clinical Experiences with ROBODOC and the Duracon Total Knee

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Objectives

A surgical robot (ROBODOC) is used for total knee replacement (Fig. 51-1). The system has been used as clinical routine for total hip replacement at the Trauma Clinic of Trade Associations (BGU) Frankfurt, Germany since 1994. Since March 2000 it has also been used for total knee arthroplasty.

This article is intended to give an overview of the system and the first clinical experiences.

Background

The results in conventional TKA have so far been very dependent on the surgeon's experience and routine. The most common mistakes are varus and valgus mal-positions as well as mal-rotations of the implant causing mal-alignment of the anatomical axis postoperatively. These mistakes often lead to untimely loosening of the implant.

Materials and Methods

The system enables to do a 3D preoperative planning of the correct axes and rotation as well as the correct implant size. The intraoperative execution is performed by the robot according to the preoperative planning.

The ROBODOC system consists of the three components:

- the preoperative planning workstation (Orthocore),
- the surgical robot,
- the control unit which receives all the preoperative planning data and controls the robot's actions.

Presently four titanium pins need to be implanted preoperatively, two in the distal femur and two in the proximal tibia. These pins serve as «landmarks» for the following steps. After pin implantation a CT scan of the femoral head, the distal femur, the proximal tibia and the ankle including all four pins is obtained (Fig. 51-2). An aluminium
Moving the bone in one view automatically moves the other views as well.

The first step is to find the four pins on the CT-scan and to check their position. Then the femoral (FMA) and tibial (TMA) mechanical axes are created using four markers: The femoral head, the center of the femoral condyles, the center of the tibial plateau and the center of the ankle. The femoral and tibial component are planned independently, then the FMA and the TMA are put together. To plan the femoral component, the axis and rotation of the bone are aligned, the right implant size is selected and the implant is positioned. The rotation is found by using the epicondylar line. For the tibial component the rotation is set using the tibial tuberosity and the notch. The implant is selected and positioned according to those landmarks. Finally the tibial line is selected (Fig. 51-4).

When the planning is finished a synthetic X-ray can be generated to virtually see the postoperative result. The X-ray shows the post-operative anatomic axis of the lower extremity. This way possible mistakes in planning can be corrected. The data is stored on a CD-ROM. Those data are loaded into the control unit of ROBODOC.

The patient's leg is positioned in a specially designed leg holder (Fig. 51-5). The knee should be flexed to about 70° to 80°. Draping is done in the conventional manner.
and the normal approach is used for surgery. The knee is exposed and the 4 pins are identified. A Steinmann pin is implanted in the femur and the tibia. The two pins are connected with the Hoffmann II fixator system and the joint is distracted.

The robot is moved to the OR-table and femur and tibia are connected to the robot. The registration algorithm is started, the robot registers the four pins and their angles. The data is matched with the CT-data. After successful registration the cutter and the irrigation system are installed (Fig. 51-6). First the femoral part is cut by the robot (Fig. 51-7), then the tibial part and the tibial eminencia (Fig. 51-8).

Should bone motion occur during the cutting process this is registered by two bone motion monitors (femur and tibia) and the robot is stopped immediately. The pins then need to be re-registered.

After the cutting is finished the robot is moved away from the OR-table, the four pins are removed and the planned components are implanted by the surgeon manually (Figs. 51-9 to 51-11).

Soft-tissue-balancing so far is done the conventional way. The exposure is closed by the surgeon.

Results

In the first 100 patients 76 cases were done cementless, in 16 cases the tibial component was cemented and in 8 cases both components had to be cemented due to poor bone quality.

The preoperative axis was neutral in 2 cases, 28 patients had a valgus deviation and 70 patients had a varus deviation. The postoperative axes are shown in Tables 51-1 and 51-2.
Table 51-1. TKA using ROBODOC (n=100)

<table>
<thead>
<tr>
<th>Post-operative anatomical axis</th>
<th>Optimal</th>
<th>Sub-optimal</th>
<th>Inefficient</th>
<th>Varus:None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>99</td>
<td>47</td>
<td>(2°)</td>
<td>(3°)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>38</td>
<td>(1°)</td>
<td>(3°)</td>
</tr>
</tbody>
</table>

Table 51-2. Knee Society Score (KSS); ROBODOC KTEP (n = 100)

<table>
<thead>
<tr>
<th></th>
<th>KSS day 0</th>
<th>KSS 3 months</th>
<th>KSS 6 months</th>
<th>KSS 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>111 (49-156)</td>
<td>147 (83-174)</td>
<td>161 (74-185)</td>
<td>176 (111-200)</td>
</tr>
</tbody>
</table>

Fig. 51-7. Cutting of the femur

Fig. 51-8. Cutting of the tibia

Fig. 51-9. Insertion of the tibial component

Fig. 51-10. Insertion of the femoral component

Fig. 51-11. Final placement of the inlay
positioning. The optimal implant size was planned and implanted in all cases. Within the first 100 surgeries the robot could not be used in 5 cases (1 pin problem, 1 positioning problem and 3 hardware problems). Those patients received conventional TKA and are not included in the above patients.

We found an obvious learning curve. The first surgery that was performed March 27th, 2000, took 130 min, meanwhile the average OR-time is 90–100 min. By January 2002 500 patients had been operated on successfully using the ROBODOC system.

**Conclusion**

The system permits an optimal 3D preoperative planning of the correct axis, rotation and implant size. The intraoperative cutting is entirely executed by the surgical robot according to the preoperative planning. Due to the exact cut surfaces the cementless technique can be used in the majority of cases. The patients are permitted full weight bearing immediately postoperatively.

No conventional instruments are necessary for the procedure. The OR-time is slightly increased compared to the conventional method. The surgeon has immediate control of the system and the surgery can always be finished manually. Correct alignment and rotation are the known preconditions for durability in TKA. Our preliminary results show that this goal can be achieved using the system and that the outcome is very consistent.

The present disadvantages of the system are soft-tissue management including ligament balancing, the rigid fixation and the use of pins (markers). These disadvantages will be resolved in the near future by integrating a special navigation system (ROBONAV) into the ROBODOC-system.

By January 2002 500 patients had been operated on successfully using the ROBODOC system at BGU Frankfurt. The pinless system is in a very advanced stage and clinical trials are presently performed at BGU Frankfurt.

**References**