CT EVALUATION OF FEMORAL COMPONENT ROTATION IN TKA: COMPARISON OF TIBIAL AXIS METHOD TO TRANSEPICONDYLAR LINE.

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Purpose:
Accepted landmarks for determining femoral component rotation in total knee arthroplasty (TKA) include the posterior condyles, Whiteside’s line, arbitrary three to four degrees of external rotation, and transepicondylar axis (TEA). All methods require anatomical identification, which may be variable. The purpose of this study was to radiologically evaluate femoral component rotation (CT analysis) based on a method that references to the tibial shaft axis and balanced flexion tension without identification of femoral anatomical landmarks.

Methods:
Out of a cohort of 3058 mobile bearing low contact stress TKA, CT scans of 38 randomly selected well functioning TKA were evaluated to determine femoral component positioning. Spiral CT scans of the femoral epicondylar region with four mm cuts were performed to accurately identify medial and lateral femoral epicondyles. Rotational alignment was measured in relation to the transepicondylar axis using CT-implemented software by two independent radiologists.

Results:
Mean femoral rotational alignment was parallel to the TEA (average 0.3 degrees internal rotation) ranging from six degrees internal to four degrees external rotation. All thirty-eight cases had satisfactory clinical results, range of motion of over 90°, and showed perfect patello-femoral tracking and patellar congruency on axial views.

Conclusions:
Femoral rotation position based on tibial shaft axis and balanced flexion tension gap is patient specific, reproducible and results in predictable femoral rotational positioning and patella tracking. CT analysis in this study confirms that the tibial shaft axis method produces a consistent femoral component positioning that relates accurately to the TEA. Tibial shaft axis method avoids the need for arbitrary landmark identification, placing the femoral component predictably in an optimum position in relation to the tibia and patella.

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A Modular and Universal Planning System for Navigation- and Robotic-Based Interventions in Alloarthroplasty and Large Bone Surgery

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In the framework of the modiCAS (Modular Interactive Computer Assisted Surgery) Project, which emerged from a collaboration of the University of Siegen and the University of Frankfurt in the fields of mechatronics and medicine, the development of a modular system to assist the surgeon during the whole planning and operation procedure has been started. A completely new realization of a planning system for bone surgery and alloarthroplasty is presented. Characteristics of the new system are generic interfaces for navigation, robotics and real-time data acquisition, graphic interactivity, documentation of each planning-step, a flexible wizard-guided concept and adaptable teaching modes. The system can be configured to any data source such as X-ray, CT, MRI, US with individual calibration. For planning, the data sources can be merged in any user defined way. In contrast to all existing planning systems the presented system can optionally be linked to navigation and robotic systems.

The software was realized to run platform-independent on any personal computer surrounding. We used commercially available software libraries for computer graphics and graphical user interface programming. The whole system consists of several modules which are closely linked together and support all major pre- and intraoperative steps of surgery. The user interface remains the same during the planning and the intervention. Preoperative planning is carried out on a totally new planning station comprising an interactive and intuitive graphic interface, while intraoperative features include interactive matching procedures, true real-time-capability and incorporation of navigation and robotics.

Initially we realized modules to support total hip alloarthroplasty. The first application of the system is for a clinical trial on total hip alloarthroplasty. Planning is performed on the basis of radiographs and CT-datasets. Intraoperatively a navigation system and a robotic surgery system are used. Preliminary results show very precise and reproducible preparations that could be achieved in short time without special training of the clinician. Furthermore the unlimited intraoperative access to the whole planning dataset appeared to be very convenient to the surgeon because it allowed immediate response to unforeseen patient specific situations.

Future adaptations of the universal planning system will be total knee alloarthroplasty, spine surgery and trauma surgery. The existing system can easily be configured to any surgical procedure because the same basic functionality is used for all applications and only special configurative datasets have to be generated for each application.

The open architecture of the system enables easy integration of further input or output devices, an easy adaptation to different interventions, planning styles and operative techniques is possible.

Keywords:
planning system, navigation, robotics, orthopedic surgery

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Navigation in Knee Arthroplasty

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INTRODUCTION

Nowadays, longevity of total knee arthroplasties is very acceptable. Survivorship analyses demonstrate a success in a range of 80% to more than 95% over a period of more than ten years (1-4). However, long-term results largely depend, amongst other factors, on restoration of physiological alignment of the lower limb (5-11). Jeffery et al. (12) reported a three percent loosening rate over eight years when knees were correctly aligned whereas insufficient alignment lead to prosthetic loosening in 24 percent. Rand and Coventry (13) found a 90 percent survivorship rate at ten years when the mechanical axis was aligned in a range from nought to four degrees of valgus. Valgus position of more than four degrees or varus alignment resulted in only 71 percent and 73 percent of survivorship respectively.

Recently, computer aided instrumentation systems (14,15) became available and preliminary results of small series were reported (16-17).

The purpose of this study was to assess the accuracy of computer integrated instrumentation for knee alignment.

MATERIAL AND METHOD

The OrthoPilot® represents a computer controlled image supported alignment system. A 3-D Optottrak™ camera localizes infra-red diodes fixed to rigid bodies within the surgical field. Thereby a spatial coordinate reference system is provided. The localizer is linked to a UNIX work station which performs the operative protocol using a graphical interface and a foot pedal. The rigid bodies are fixed to the bones by bi-cortical screws. An intraoperative kinematic analysis and various additional landmarks lead to definition of the centres of hip, ankle and knee joint and sizing of endoprosthetic components. With the use of LED-equipped alignment instruments the femoral and tibial resection planes are determined.

The OrthoPilot® navigation system is not dependant on CT data and no additional preoperative planning is therefore necessary.

A prospective comparative multicentre study in five institutions, four in Germany and one in France, was carried out. 821 patients with primary tricompartmental knee arthroplasty using the SEARCH LC knee (B Braun AESCULAP) were included in the study. The OrthoPilot® Navigation system was used in 555 cases and 266 knees were implanted with the use of conventional instrumentation. At the three months follow-up alignment was assessed using standardized one leg stance radiographs with regard to the mechanical axis and the femoral and tibial angels in the coronal plane. For the lateral femoral and tibial angels standard lateral x-rays were used. Prosthetic alignment was verified by an independent observer.

RESULTS

The radiographically assessed results were subdivided into three groups. An error of ± one degree in the radiographical measurements and small deviations caused by the play of surgical instruments have to be considered. With respect to the femoral and tibial angels in the ap and lateral view the group of very good clinical results was, therefore, defined in the range between ninety degrees and ± two degrees. Deviations of three and four degrees from the optimum were classified as being clinically acceptable. Aberrations of more than four degrees were classified as outliers. When measuring the mechanical axis deviations from fully precise femoral and tibial angels may add up. For this reason zero degrees ± three degrees were rated as a very good result, deviations of four to five degrees were considered to be acceptable and alignment beyond five degrees from the optimum was classified as an unsatisfactory result.

Mechanical axis:
35.2% of the navigated cases were aligned at exactly zero degrees. This was achieved in only 24.4% of the manual cases. 88.6% of cases using navigation and 72.2% in the manual group showed zero degrees and varus or valgus angles of up to three degrees. 8.9% and 18.1% of cases respectively showed deviations of four or five degrees of valgus or varus alignment representing an acceptable clinical result. In only 2.5% of the navigation group aberrations of more than five degrees occurred. The rate of dissatisfying results was 9.8% in the manual group.
Femoral axis (coronal plane): In the navigation group 48.1% of cases showed an alignment at exactly 90 degrees which was the case in only 33.5% of the control group. Altogether, in 89.4% of the navigated cases a very good result was observed. In the conventionally instrumented cases only 77.1% very good results were found. There were 1.6% outliers beyond the limits of four degrees in the navigation group in comparison to 4.9% amongst the control cases.

Femoral axis (sagittal plane): Very good results with up to two degrees of deviation from a ninety degree position were obtained in 75.5% of navigated cases and 70.7% of manual cases. 37.3% and 34.6% respectively showed an ideal alignment of exactly ninety degrees. Unsatisfactory results were observed in 9.5% of the navigated cases and 9.4% of the manual cases.

Tibial axis (coronal plane): 58.7% of the computer assisted and 40.6% of the reference cases were exactly aligned at rectangles. All in all, in 91.9% navigated and only 83.5% manual cases a very good result was obtained. Only 1.1% outliers had to be observed in the navigation group whereas 3.4% unsatisfactory results were registered with manual technique.

Tibial axis (sagittal plane): 44.3% of the navigated cases and only 26.7% of cases in the control group were aligned perpendicular to the dorsal tibial cortex, thus showing no posterior slope. Altogether, 81.3% could be classified as very good clinical results in the computer assisted group. The corresponding rate of the manual group was 69.9%. Equivalent values of 8.6% in the navigation group and 8.3% in the reference group were registered beyond the limits of four degrees deviation. The additional operation time for the use of the navigation system is calculated between eight and ten minutes after having passed through the learning curve.

CONCLUSIONS Knee navigation facilitates proper alignment of endoprosthetic components and with the use of the OrthoPilot® system results are clearly more favourable in comparison to conventional instrument technique. In addition, the data obtained from literature demonstrate that the use of this navigation system contributes to reducing outliers in number. With the learning curve the OrthoPilot® alignment system proved to gain in reliability.

Deviations from perfect alignment are still difficult to be classified into surgical or technical deficiencies.

Many technical and software improvements which were introduced in the meantime will, in addition, contribute to reliability and time saving.

Comparative studies with different navigation systems are not yet available. They might allow an even more profound insight into the possibilities and advantages or disadvantages of computer assisted knee alignment.

LITERATURE

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Revisionschirurgie mit dem Navigationssystem beim Prothesenversagen

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In allen Fällen klagten die Patienten über Schwellungen des Gelenkes, Ergüsse oder Schmerzen. 11 Patienten hatten Giving way Phänomene. 33 bicondylen Oberflächenersatzprothesen und 8 Hemisplitter wurden revidiert.


Mit dem Stryker Navigationssystem können intraoperativ Positionsfehler der Prothese, Achsenfehler und Instabilitäten genau analysiert werden. Damit ist die Voraussetzung für eine Korrektur der Fehler gegeben.
Fluoroscopic-assisted navigation of the TKR with the Medtronic “Viking – System“ and with the Genesis II

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The C-arm is routinely used intraoperatively to control the anatomic structures during osteotomies and during reposition and nailing of the femoral neck fractures. Fluoroscopic navigation has been introduced in spinal surgery and it is a widely accepted tool for pedicle screws. It has been proven that fluoroscopic imaging in two planes shows an adequate reproduction of the 3-dimensional anatomy and enables a realistic acquisition for computer-assisted navigation.

This experience with the Medtronic system is now adapted for application as the „Viking System“ for total knee replacement using the Genesis II knee arthroplasty.

After experimental cadaver studies and critical evaluation the system was tested the first time in our clinic during live surgery. In the first series of 40 Genesis II TKR we could establish a high degree of accuracy and reproducibility with the fluoroscopic navigation.

Several advantages using the fluoroscopic navigation can be shown:
1. The navigation offers an online documentation at each step during surgery
2. These data give a good background for further studies
3. Fluoroscopic assisted navigation needs only very short radiation exposure
4. Fluoroscopic imaging is superior to virtual pixels in other systems
5. There is no limitation to use fluoroscopic navigation in case of severe destruction of the knee or in case of severe contracture of the ipsilateral hip or ankle joint
6. The intraoperative and postoperative controls show a deviation of the alignment of less than 2 degrees.

During the study we could find a reduction of the time of surgery. The examination of additional laxity tests at various degrees of flexion with the trial implants in situ give an assessment of the ligament stability.

Fluoroscopic assisted navigation may be used during the routine TKR to be prepared for the difficult case and to avoid malalignment in the routine TKR.

Further investigation i.e. in a prospective study may reveal the advantage of navigation in correlation to the clinical outcome and the survival rates of the TKR.