

# Possibilities of Computer Application in Primary Knee Replacement

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## 1. Introduction

Frequency of knee joint osteoarthritis has been growing over the last years. Range of degeneration involvement of the knee joint varies from unicompartmental to tricompartmental. The medial part of the knee is damaged most frequently. The solution of serious knee joint degeneration is a total replacement by endoprosthesis. It is indicated not only in the case of idiopathic gonarthrosis, but also in rheumatoid arthritis, osteonecrosis, post-traumatic arthritis or in different arthropathies. The fundamental condition for long term survival of a knee joint endoprosthesis (TKR) is the right position of femoral and tibial components with mechanical axis correction of a lower limb. Endoprosthesis implanted in wrong position can lead to acceleration of polyethylene wear and component release. Abnormal varus or valgus position have already been proved as a main cause of component failure. A malposition of femoral and tibial components has also a great influence on patella tracking during knee movement and on possible patellofemoral complications. That is why single bone resections must be performed with a great emphasis on the precision and in relation to the mechanical axis of the limb. Surgeons use a scale of different targeting equipments which serve preferably to the best possible matching of the bone cuts to the patient's geometry. The results show that even in cases of surgeon's great experience in TKR up to 30 % of operated cases have a four-degree and larger deviation of tibiofemoral angle from the ideal mechanical axis after bones resections. That is why computer navigation systems have been developed to eliminate the error of surgeon (Insall et al., 1985). The computer navigation systems were integrated into a routine orthopaedic practice more than thirteen years ago. After that the navigation became quickly a common tool at many working places for primary implantations of knee endoprosthesis. Instrumentation for mechanical targeting of resections described earlier have certain restrictions which cannot be exceeded. For example, it is a certain degree of freedom such as a rotation of a femoral and tibial components or impossibility to reach their perfectly accurate position with regard to the resected bones. It may be said that standard targeting devices are constructed for the standard bone geometry.

The first study of navigation in orthopaedics reporting the use of infrared radiation was made by the group of Saragaglia (Grenoble, France) in years 1994 -1996 and in 1997 these surgeons implanted the first total endoprosthesis of a knee joint (Laskin, 1984; Bitter et al., 1994) under the assistance of the OrthoPilot navigation system (B.Braun-Aesculap,

Tuttlingen, Germany). In 1995 independently of the above mentioned group Krackow and Mihalko conducted a project of the development of a system for computer controlled TKR with the use of the Optitrack equipment (Northern Digital, Ontario, Canada). The first navigated implantation of TKR was made by this group in 1997 as well (Krackow, 1983). This project led to the creation of the Knee Track Module (Stryker Howmedica Osteonics, Allendale, NJ). Both systems - OrthoPilot and Knee Track Module represents first kinematic navigation systems.

We distinguish 4 basic types of navigation nowadays:

1. Kinematic navigation (imageless, CT-free) - is used for data registration through combination of physical palpation and kinematics. Data are transferred into a computer by means of infrared radiation. This type is the most often used way of navigation in orthopaedic surgery.
2. Fluoroscopy based navigation - it registers combined data obtained by physical palpation and kinematics but it uses C-arm at the beginning. Images are created by a computer on the basis of this information. Then surgeon operates on the radiologic replica of patient's anatomic area. The system is more frequently used in traumatology and in spine surgery.
3. CT-based navigation - it uses computer tomography for data collection. Today, it is used the mostly in a revision surgery and spine surgery.
4. MR-based navigation - it uses magnetic resonance for data collection. It is used mainly in neurosurgery.

The most simple and the most practical of these methods is the kinematic navigation. Anatomical structures are digitized by orientation palpation points with a portable "pointer". During bone resection computer shows surgeon the ideal position of instruments and optimal bone cuts. Computer equipped systems, which consist of standard resection patterns on the one hand and highly accurate navigation system on the other hand, are a natural consequence of current computer technology integration into surgery. Computer software reduces the risk of surgeon's error and enables fast and accurate placement of resection blocks (Hart & Janeček, 2003). It eliminates the use of intramedullary and extramedullary targeting devices and so reduces the risk of pulmonary embolism.

The aim of this chapter is to present the experience of authors with using of kinematic navigation systems and computer generally in the implantation of total and unicompartmental knee joint replacements. It points out to advantages and disadvantages of a navigation application during surgeries and to the importance of pre-operative planning by the help of digital images in connection with a surgical planning station. It also refers to special circumstances when the computer navigation technology can be the only one possibility of the implantation of the knee endoprosthesis.

## **2. Computer navigation in standard or minimally invasive total knee replacement**

Authors of the article have been working with kinematic navigation systems routinely since the beginning of the year 2000. The study, which was published in the 2003 by the senior surgeon (Hart et al., 2003), was the third randomized study evaluating the use of navigation in a standard TKR surgery in world literature. Higher accuracy in case of the use of navigation in comparison with a standard instrumentarium in TKR has already been confirmed. Navigation system usually consists of five basic parts: 3D-camera with a control

unit, infrared diodes, computer system, foot switch and mobile case with transformer (Fig. 1). A camera placed on a tracing bar localizes the position of diodes in an operative field. The camera is connected with the control unit and it enables to distinguish diode deviation already from the distance of tenths of one millimeter. Three diodes are needed at least during surgery. These are placed on nondeformable basis and they can be anchored by fastening mechanism on relevant bicortical screws, palpator or resection blocks. The computer system is formed by a computer itself and a keyboard with mouse. The computer gets information about diodes movement, it evaluates information and transfers it into a graphic form on a monitor. The foot switch has two pedals and it enables surgeon to control individual steps of the navigation system.

Before an operation we take standing weight bearing X-rays of the whole lower limb of a frontal plane and a standard X-rays of a sagittal plane. We evaluate relevant axis and angles, measure size of deformity and plan the size of endoprosthesis components in both planes in a way mentioned in the following subchapter by the help of PACS system with its application module. The patient's preparation before surgery does not differ from a standard procedure. The navigation system (camera) is being placed into the opposite side with regard to the surgeon into the distance of approximately 2 m.

Minimally invasive (MIS) or less invasive approach is an alternative to a common approach to the knee joint in TKR. Its use in connection with the navigation was published by the team of authors in 2006 (Hart et al., 2006). The procedure itself with the use of navigation does not differ from a standard parapatellar approach (Hart et al., 2005). In this case the navigation system serves as "the third eye" of the surgeon working in reducing operative field. The skin incision length is usually up to 12 cm. Subvastus approach does not disturb the extensor apparatus. M.vastus medialis is lifted and arthrotomy is made. It is followed by percutaneous insertion of original bicortical self drilling screw into the distal femur approximately 7 cm above the articular surface. We insert the second screw similarly into the proximal tibia about 10-12 cm below the articular surface. Then diodes are fastened on both screws. We fasten the third diode as a mobile one on a palpator (pointer).

Further step is to determine the real anatomy of a lower limb. A mechanical axis is determined by three points - by the center of hip, knee and ankle joints. First, we enter the information about the center of knee joint into the computer by a palpator with the fixed diode. Next, we determine the center of a hip joint. Movement of the femur in all planes has one fixed point which is the center of the femoral head. We determine the center of a hip joint by circular movements in a slight flexion. As the third, we localize the center of the ankle joint. We fasten an elastic tape on the area of tarsus during the surgery and the mobile diode on it. Then we enter data into the soft-ware by the movement in the ankle joint to the maximum extent of flexion and extension. Last we precisely determine the center of a knee joint. One of the possibilities how to determine the center of the knee is palpation of one anatomic point on each side of a joint. The second possibility is to use the same kinematic procedure as in the ankle joint: first is done of the determination rotation axis by tibial rotation round its longitudinal axis in flexion of 90° and second is to get the second transverse axis by movements of flexion - extension.

Then follows is the collection and saving of information relating to orientation points in the knee area which is necessary to do for an accurate placement of resection blocks and for the accurate size of the femoral component. A palpator with a fixed mobile diode is used for it.

The size of a femoral component is given by the distance of a dorsal condylar line and anterior femoral corticalis. We palpate medial and lateral epicondyles as well to determine the exact rotation of the femoral component. Next, we check orientation points in the area of the ankle joint. A malleolar line serves to an additional confirmation of the ankle joint center.



Fig. 1. Kinematic navigation system

After setting of all orientation points, an axis reconstruction of a lower limb appears on the monitor, both in a sagittal and frontal plane. Numeric data appear on the monitor as well besides the graphic illustration. In the frontal plane we get the information about the deformity in the sense of varus - valgus. The program will illustrate the degree of flexion contracture too. In this moment, it is necessary to compare computer specified values with preoperative measured values on X-ray photographs. If we find out (exceptionally) a difference greater than  $5^\circ$  in both planes, it is necessary to recheck fixation quality of both diodes and to repeat the whole procedure. First of all the proximal tibia is resected. A mobile diode is fasten to a resection block and we follow on the monitor the accuracy of its placement on proximal tibia. Both, the block orientation in a sagittal plane and frontal plane

and the height of resection, are illustrated. We fix the block to the bone first by one pin to secure the zero deviation from the ideal position in a sagittal plane and the requested level of resection. Then, the resection block position in a frontal plane is corrected and after reaching the zero deviation in the frontal plane, the resection block is fixated by the second pin.

After the proximal tibia resection the balancement of collateral ligaments is being found out. After balancing of the collateral ligaments, it is being approached to balancing of extension and flexion gaps. After that the femoral resection follows. First, we reach zero position ( $90^\circ$  to the femoral mechanical axis) in a sagittal and then in a frontal plane. The block is fixed to the femur by two pins and articular surface is resected.

After the application of a relevant trying components including an polyethylene insert of suitable height, the collateral ligaments balance is checked again. Graphic and numeric expression of the real limb mechanical axis is being watched on a monitor and values shown are compared with actual clinical findings. If the result is satisfactory, original components are implanted. The mechanical axis of the limb is being checked again during hardening of the bone cement.

A prospective study has been accomplished in author's institution (Hart et al., 2006) in which results of knee joint replacements in 40 patients implanted by MIS approach were compared with 40 endoprosthesis implanted through a standard approach. Arthritis of 3<sup>rd</sup> and 4<sup>th</sup> degree was indication for all these surgeries. Less pain and faster rehabilitation was found early after surgery in MIS group. This difference was only found until 10<sup>th</sup> day after surgery. This difference was not obvious after 6 and 12 weeks after the surgery. TKR implantation accuracy was preserved with the use of the computer navigation system in cases with MIS approach in comparison with the standard approach.

### **3. Comparison of preoperative digital planning with computer navigation in TKR**

The knowledge of mechanical and anatomical axis construction of lower limb and basic angles is necessary for a correct planning and also for a post-operative evaluation of obtained component position. The connecting line between the centre of the femoral head and the centre of the knee joint is called the mechanical axis of the femur, the connecting line between the centre of the knee and the ankle joint is called the mechanical axis of the tibia. The line between the femoral head centre and the ankle joint centre (the Mikulicz's line) constitutes the mechanical axis of the lower limb. If it runs through the centre of the knee joint, femoral and tibial mechanical axes are parallel. In case of a varus knee deformity the mechanical axis of lower limb runs medially from its centre and the medial angle between femoral and tibial mechanical axes is smaller than  $180^\circ$ . In case of a valgus deformity the mechanical axis of a lower limb runs laterally from the knee joint centre and the medial angle between femoral and tibial mechanical axes is greater than  $180^\circ$ .

The right position of a lower limb during X-ray examination is important for an accurate preoperative planning. The AP X-ray is performed under the load in standing patient in such a position so that the patella aims forward. The rotation of the lower limb within  $10^\circ$  does not influence the result of axis measurement significantly (Whietside & Arima, 1995). Greater external rotation of the limb simulates a varus deformity, the internal rotation

simulates a valgus deviation. Severe gonarthrosis is usually connected with a flexional contracture which causes a possible mistake of measurement during the preoperative planning. The lateral X-ray of the knee is also taken in the standing patient with his knee in extension. Weight-bearing radiographs of the whole lower limb are necessary for an accurate determination of axial relations.

PACS (Picture Archiving and Communication System) system serves to the X-ray photographs storing. It is a storing and communication system of image data which supports both photos distribution and their description and arrangement. It serves to acceptance, storing, distribution and picture display. It is becoming an essential part of orthopaedic surgeon's everyday practice in connection with an orthopaedic planning station. Orthopaedic planning tools enable more accurate preoperative templating of TKRs than former standard templating (Fig. 2.).

It is possible to measure angles on the femoral and the tibial and the relation of femoral and tibial axis by means of a planning station on digitalized X-rays. It is possible to plan height of needed proximal tibial and distal femoral resection and to template femoral and tibial component sizes and polyethylene inlay height and their positions. Accuracy of TKR can be checked postoperatively in the same way. There was compared a lower limb axis deviation measured by PACS before and after a surgery with values gained by kinematic computer navigation preoperatively in the authors' institution (Hart et al., 2010). There was also compared the size of components measured during the pre-operative planning by PACS, with sizes measured by the navigation during the surgery. There were 311 total knee endoprosthesis evaluated from January 2009 till September 2010 (21 months). All surgeries were done by experienced surgeons. Primary gonarthrosis was an indication for knee replacement in 278 cases. After proximal tibial osteotomy or fractures of the knee 33 TKR were done. Surgical technique was the same in all patients. In 253 cases was used the replacement with preservation of posterior cruciate ligament, in 58 cases with its resection. In all cases both components were fixated by bone cement.

Before and after surgery X-ray weight-bearing images of the whole lower limb were taken. By the help of PACS with the application of the orthopaedic planning station there was measured a lower limb axis before surgery (the angle between the mechanical femoral axis and the mechanical tibial axis) and components sizes and these values were compared with values measured by computer navigation during the surgery. The value of the deformity of lower limb axis measured by computer navigation before and after implantation was recorded during the surgery. The load during the surgery was imitated by axial pressure on a heel in the axis of operated lower limb. Postoperative radiological control was carried out on the seventh postoperative day with the full weight bearing. Agreement between components sizes planned by the orthopaedic planning station in PACS and really implanted components with the use of computer navigation was 73 % (in 227 endoprostheses) in the femoral component, 91 % (in 283 endoprostheses) in a tibial component and 48 % (in 149 endoprostheses) in polyethylene inserts.

In the majority of cases of disagreements smaller femoral (92 %) or tibial (90 %) component was implanted than which had been planned preoperatively, in case of polyethylene inlay it was mostly necessary to use higher sizes (86 %). The cause of disagreement on the femoral component size in 84 total endoprostheses (27 %) was greater difference between a flexion and extension gap than 3 mm according to navigation. This is not possible to be found out

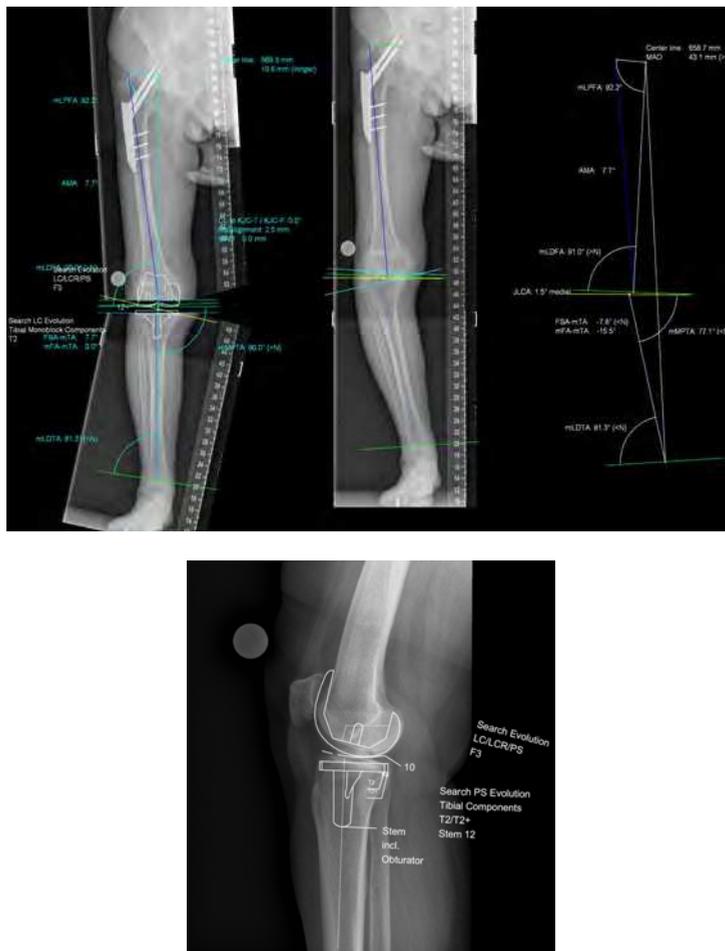


Fig. 2. The X-rays with preoperative templating by the orthopaedic planning station in PACS.

by the preoperative planning on X-ray photographs. Also a tibial component implantation of another size planned by PACS (9 %) had its cause in the size change of an implanted femoral component (the difference between both components would be larger than two sizes). In cases of 77 total replacements (92 %) there was the necessity to implant smaller femoral component by one size to balance tighter flexion gap. It was less frequent that the flexion gap was larger than extension one. This imbalance was solved by larger femoral component (8 %). Preoperative planning of the tibial component size by the help of PACS is relatively accurate because its size is determined only by AP and mediolateral dimensions of the tibial plate are and it is not influenced by flexional or extension gaps. The greatest disagreement was registered in polyethylene inlay planning - in 162 total endoprostheses (52 %). In 116 cases (72 %) there was implanted higher polyethylene insert by 2 mm than what had been planned preoperatively by PACS system. In 23 replacements (14 %) there

was implanted higher polyethylene insert by 4 mm and in 23 cases (14 %) lower insert by 2 mm. The cause of this disagreement is usually knee joint balancing done by releasing of soft tissues on medial side in cases of varus deformity or on lateral side in cases of a valgus deformity.

These results show that the preoperative planning by digital templating estimates femoral component and polyethylene insert sizes only approximately, while tibial component sizes quite precisely. The computer navigation has its main significance in determination of the femoral component size depending on collected data accuracy and on flexional and extension gap balancing. The height of polyethylene inlay is determined by resection sizes of a proximal tibia and distal femur, by balancing of gaps and by knee joint stability during testing of trial inserts after cementing of original components.

The average mechanical axis measured preoperatively by PACS was 5.3° of varus (range 20.5° valgus to 16.9° varus). The mechanical axis measured by the navigation before endoprosthesis implantation was on the average 1.8° of varus (the range 13° valgus to 11° varus). Agreement in both measurements (with the difference less than 3°) was achieved only in 171 total replacements (55 %). The Table 1 shows an absolute value distribution of a lower limb mechanical axis deviation measured by PACS before surgery and by navigation at the beginning of the surgery.

In 190 patients (61 %), where the mechanical axis deviation measured by PACS was smaller than 10°, was an agreement with values measured by the navigation in 87 % of cases (165 endoprostheses). In 121 patients with the deviation of the mechanical axis preoperatively more than 10° (39 %) the agreement with values measured by the navigation was only in 5 % of cases (6 replacements). The reason for this difference is the relation between the force acting on the knee joint and the amount of lower limb deformity. In X-ray examination of the whole lower limb under the load the axial deformity of knee joint gets worse due to body weight. This deformity in ligaments is emphasized with a bigger axial deviation. The measurement of the mechanical axis deviation preoperatively by the navigation takes place only in a lying position with exclusion of the weight of the body. That is why the value is always smaller than the value measured during the preoperative planning. The bigger is the axis deviation measured by PACS, the bigger is the difference between values. Pressure on the heel in the axis of a lower limb during the navigation simulates the limb load insufficiently.

deviation (mFA - mTA)	number and % of the patients (MediCAD@2.06)	number and % of the patients (OrthoPilot)
0° - 5.0°	34 (11 %)	47 (15 %)
5.1° - 10.0°	156 (50 %)	255 (82 %)
> 10.0°	121 (39 %)	9 (3 %)

Table 1. The deviation of the axis of lower limb measured by orthopaedic planning system in PACS and by kinematic navigation system preoperatively.

The average mechanical axis measured by the navigation after the total endoprosthesis implantation was 0.4° varus (range, 3.0° valgus to 2.0° varus). The mechanical axis measured by PACS after the surgery was on average 0.5° varus (range, 3.5° valgus to 4.2° varus).

Agreement in both measurements (with the difference less than  $3^\circ$ ) was achieved in 90 % of cases (280 endoprostheses). These results show the importance of navigation in total endoprosthesis implantations - the axis deviation within the range of  $0^\circ - 2.0^\circ$  was measured post-operatively in 280 patients (90 %) by to the navigation and in 274 patients (88 %) by PACS. The axial deviation over  $4^\circ$  was not recorded by the navigation and only in 3 patients (1 %) by PACS. The Table 2 shows an absolute value distribution of the lower limb axis after endoprosthesis implantation measured by the navigation and PACS.

deviation (mFA - mTA)	number and % of the patients (MediCAD@2.06)	number and % of the patients (OrthoPilot)
$0^\circ - 2.0^\circ$	274 (88 %)	280 (90 %)
$2.1^\circ - 4.0^\circ$	34 (11 %)	31 (10 %)
$> 4.0^\circ$	3 (1 %)	0

Table 2. The deviation of the axis of lower limb measured by orthopaedic planning system in PACS and by kinematic navigation system postoperatively

#### 4. Computer navigation of valgus knee kinematics before TKR

Computer navigation technique can be used for a surgical approach choice in TKR implantation. Valgus deformity was analysed in the author's institutions in 50 patients. At the beginning of a surgery there were fixated navigation markers to the tibia and femur in these valgus limbs and data were collected for the navigation just before surgical approach was chosen. After data registration (software for correcting osteotomy) changes in values of a lower limb axis deformity in various of knee joint flexion ( $0^\circ$ ,  $30^\circ$ ,  $60^\circ$ ,  $90^\circ$ ,  $120^\circ$ ) were observed. In case of persistence of axis valgus deformity throughout the whole range of a knee movement it is called "right" valgus, in case of gradual transition of valgus deformity into varus during flexion it is called "false" valgus. In a „right“ valgus knee there is a mismatch between both condyles in both the vertical and anteroposterior dimensions, the lateral condyle is generally smaller. (Šváb et al., 2010). In a „false“ valgus knee there is no mismatch between anteroposterior dimensions of both condyles, the knee axis changes from valgus into varus with increased degree of flexion and lateral soft tissue structures are that's why not so contracted as in „true“ valgus knee deformity, where the knee stays in valgus deviation during the whole range of motion.

In case of the "right" valgus deformity the lateral parapatellar approach according to Keblish is preferred because of an easier release of tight lateral structures. In case of the false deformities a standard medial parapatellar approach can be used. Valgus deformity of a lower limb was measured preoperatively by the navigation within the range from  $4^\circ$  to  $13^\circ$  (on average  $7.8^\circ$ ). The right valgus deformity was observed during the knee joint passive flexion in 34 patients (68 %). The average value of the valgus knee joint deformity in extension in the group with the right valgus was  $7.9^\circ$  (range,  $4^\circ$  to  $13^\circ$ ). Deviation value in this group decreased gradually during flexion in all cases. The difference in the degree of axis deviation between  $0^\circ$  and  $120^\circ$  of flexion in this group was on average  $5.5^\circ$  (range,  $1^\circ$  to  $10^\circ$ ). Changes of the axial deviation depending on the degree of the knee joint flexion are illustrated in figure 3.

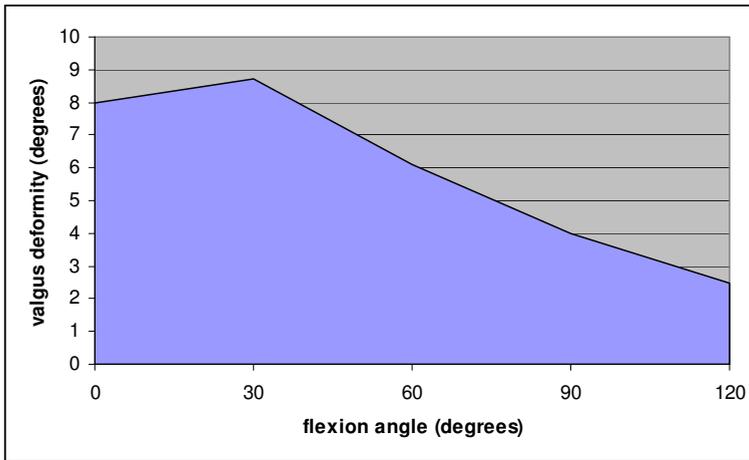


Fig. 3. The progress of the „true“ valgosity during the flexion of the knee joint

The false valgus deformity of a knee joint was registered in 16 patients (32 %). In this group the average value of the valgus deformity was 7.5° (range, 6° to 9°). The varus deviation of the mechanical axis was already observed in 60° or 90° of flexion. The difference in the degree of the axis deviation of the limb between 0° and 120° of flexion in this group was on average 12.0° (range, 10° to 14°). Changes of the axial deviation depending on the degree of knee joint flexion with pseudovalgus are illustrated in figure 4.

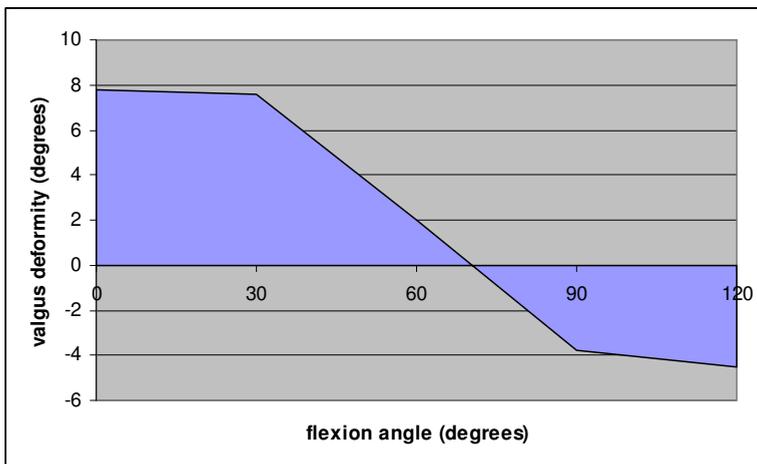


Fig. 4. The progress of the „false“ valgosity during the flexion of the knee joint.

Because of the analysis of the knee joint valgus deformity by the computer navigation at the beginning of the surgery the operative time extended on average by 6 minutes (range, 4 to 11 minutes). The navigation was used consequently after the switch on the TKR a module for total endoprosthesis implantation.

## 5. Kinematic navigation in TKR with distal femoral disturbances

Kinematic navigation system is usually used to precise the knee endoprosthesis implantation. In cases of distal femoral deformity or in the presence of metal material in the distal femur is the navigation the best way how to solve this problem (Fig. 5).



Fig. 5. The X-rays show the deformity of the femur, before and after implantation of TKR

The deformity can be caused by an injury or chronic osteopathy. Some metal material can be present after fracture osteosynthesis or after a revision implantation of hip joint total endoprosthesis. In these cases it is not possible to use standard intramedullary targeting devices and the kinematic navigation system is the best possibility how to implant the femoral component of the knee joint replacement correctly. 13 patients with the femoral deformity or presence of some metal material in the area of the distal femur have been operated in the authors' institution. It was the condition after the distal femoral metaphyseal fracture with left plate in 4 patients. In 5 patients it was the condition after femoral diaphyseal fracture treated by an intramedullary nail (in one case the nail was broken). In 1 patient the femoral fracture was healed with an extended fragment malposition ad latus. In 3 patients the long stem femoral component of a hip replacement was present. In all these patients a standard implantation of a knee joint replacement was done with use of the computer navigation technique. The record lower limb axis has been restored in all these patients.

## 6. Kinematic navigation system for prevention of the hypocorrection or hypercorrection of the mechanical axis in UKA

The importance of kinematic navigation during the implantation of unicompartamental replacements is high. It can be used for knee surfaces resection but first of all for a simple

control of the axial limb deviation during the implantation of the UKA. At the beginning of the surgery it is necessary to fix navigation markers percutaneously at the femur and tibia, to collect data (software for correction osteotomy) and to display the measured lower limb axis (Fig. 6).

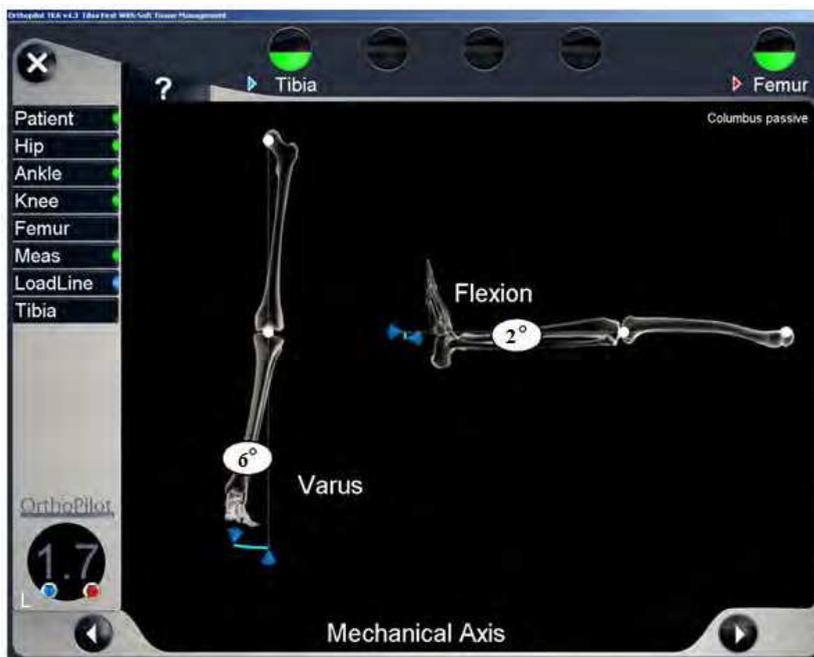


Fig. 6. The axis of the lower limb shown on the display of kinematic navigation system before UCA implantation

Then we implant the knee joint unicompartmental replacement through a standard medial parapatellar approach and standard surgical technique. After the fixation of tibial and femoral components by bone cement the navigation is used for the right choice of polyethylene insert height with regard to its stability and especially the limb axis. The right size of the polyethylene insert is chosen so that the lower limb mechanical axis would be straight. There were implanted 67 unicompartmental replacements in the authors' institution from April 2008 till September 2010 (30 months) (Fig. 7).

In 32 patients the replacement was made in a standard way without navigation, in 35 patients with the kinematic navigation. There were 20 men of average age 69.5 years (range, 54 to 82 years) and 47 women of average age 69.2 years (range, 49 to 85 years). In 29 cases a right knee was operated and in 38 cases a left knee. The medial compartmental replacement was done in all patients. All surgeries were made by experienced surgeons. In the group of patients operated without the use of navigation the average lower limb axial deviation was measured before the surgery was 5.1° varus (range, 1.0° to 12.6°). The average axial deviation measured radiologically in the long weight bearing X-rays after surgery was 2.1° of valgus (range, 8.5° valgus to 5.2° varus). The overcorrection of the lower limb mechanical axis into

valgus without the use of navigation happened in 20 patients (63 %). The hypercorrection of axis into valgus  $> 2.0^\circ$  happened in 12 patients (38 %). Varus deformity  $> 2.0^\circ$  after surgery was recorded in 6 patients (18 %). The Table 3 shows the distribution of an absolute value of a lower limb mechanical axis after the unicompartmental endoprosthesis implantation measured by the planning station PACS.

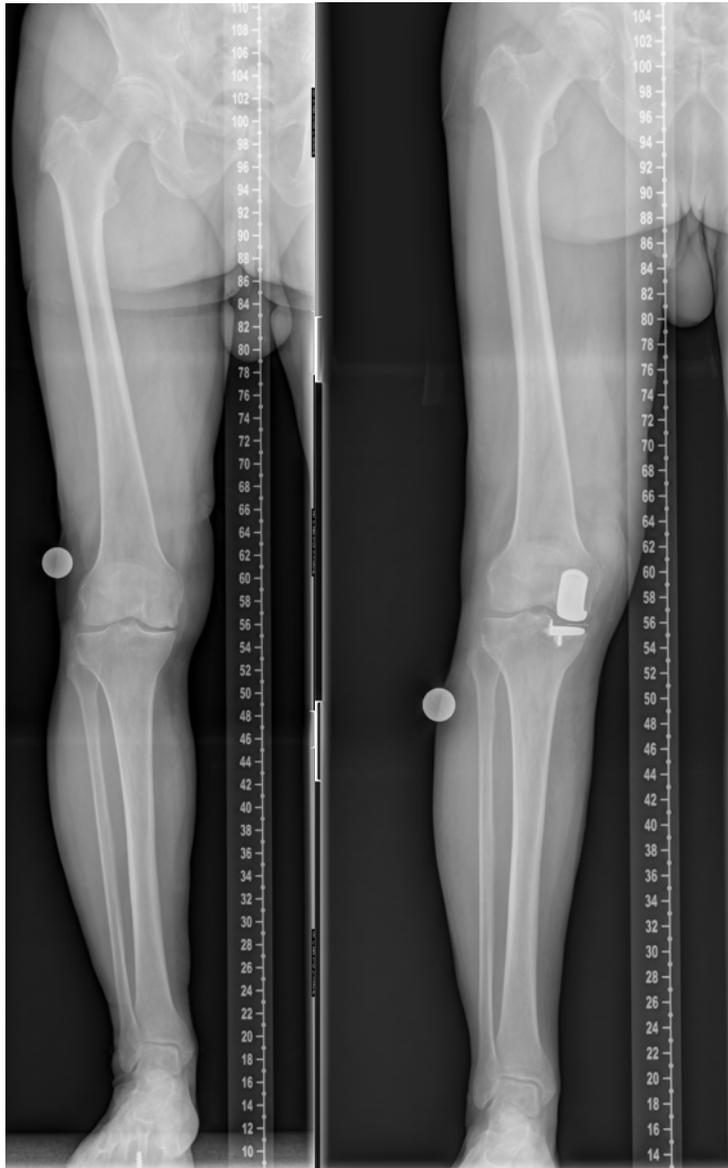


Fig. 7. The X-rays show the correction of the axis of lower limb before and after the surgery

valgus deformity	number of patients	varus deformity	number of patients
0.1° - 2.0°	8 (25 %)	0° - 2.0°	6 (19 %)
2.1° - 4.0°	8 (25 %)	2.1° - 4.0°	3 (9 %)
> 4.0°	4 (13 %)	> 4.0°	3 (9 %)

Table 3. This table shows the distribution of deformity of a lower limb mechanical axis after UCA implantation without navigation system

The average axis deviation of the lower limb was 4.1° varus (range, 1.0° to 9.0°) in the group of patients operated with the use of navigation (35 replacements). Axial deviations measured by navigation after the endoprosthesis implantation and by PACS 7 day after the surgery were the same (with the difference  $\leq 2^\circ$ ) in 92 % of cases. The average axial deviation measured after the surgery was 0.5° varus (range, 5.1° valgus to 6.5°). The overcorrection of the lower limb mechanical axis into valgus happened only in 6 patients (17 %) with the use of the navigation. In these cases the hypercorrection was due to the prevention of mobile polyethylene core dislocation. The axis hypercorrection into valgus  $\geq 2.0^\circ$  happened in one patient (3 %). Varus deformity  $> 2.0^\circ$  after the surgery was found in 4 patients (12 %). The Table 4 shows absolute value distribution of the lower limb mechanical axis after the unicompartmental endoprosthesis implantation measured by planning station PACS.

valgus deformity	number of patients	varus deformity	number of patients
0.1° - 2.0°	5 (14 %)	0° - 2.0°	25 (71 %)
2.1° - 4.0°	1 (3 %)	2.1° - 4.0°	3 (9 %)
4.0° <	0	4.0° <	1 (3 %)

Table 4. The table shows the distribution of deformity of a lower limb mechanical axis after UCA implantation with navigation system

The kinematic computer navigation represents significant help for the right choice of mobile polyethylene inlay height. An implant failure is threatening in cases of varus deformity reversing. In cases of more frequently observed hypercorrection into valgus lateral gonarthrosis usually develops. Both situations must be later solved by a conversion on TKR.

## 7. Conclusion

The importance of the kinematic computer navigation of knee endoprosthesis lies above all in the reduction of out-layers. This fact is important especially for beginning orthopaedic surgeons. The kinematic navigation should prevent from wrong resection of distal femur or proximal tibia. Navigation succeeds in 88 % cases (Hart et al, 2003) to reach the deviation from an ideal axial position of a lower limb less than 2°. Without the navigation it is observed in 70 % cases. However, it is not possible to rely on the kinematic navigation absolutely (as it is only auxiliary method). The key factor of the navigation system

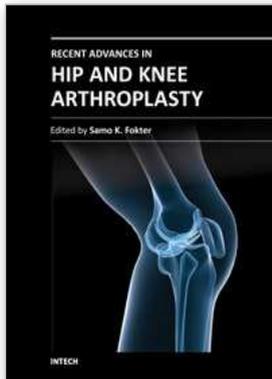
successful use during the whole surgical procedure is to keep an unchanged position of femoral and tibial diodes. Change of their position can influence dramatically the result of the whole navigation process. It is possible to avoid this complication in osteoporotic skeleton by an accessory Kirschner wire which prevents from the screw rotation. The time waste during the surgery, which represents time less than 10 minutes in hands of experienced surgeons, is not significant with regard to the above mentioned navigation system advantages.

Another substantial benefit of the computer navigation in a total knee joint endoprosthesis implantation is in cases after fractures of the femur, where osteosynthesis material is left or after bone healing in a malposition which makes impossible to carry out the distal femoral resection with the use of an intramedullary targeting device. The navigation helps routinely also at the beginning of the surgery to distinguish the right valgus deformity from the false one. According to it we choose the suitable surgical approach. In unicompartmental knee joint replacements it is possible to choose the right polyethylene inlay height by the help of the navigation so that the lower limb mechanical axis is restored as accurately as possible. In this way we avoid axis overcorrection into valgus in most cases and subsequent decompensation of the lateral compartment and later necessity of conversion on TKR.

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## **Recent Advances in Hip and Knee Arthroplasty**

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The purpose of this book is to offer an exhaustive overview of the recent insights into the state-of-the-art in most performed arthroplasties of large joints of lower extremities. The treatment options in degenerative joint disease have evolved very quickly. Many surgical procedures are quite different today than they were only five years ago. In an effort to be comprehensive, this book addresses hip arthroplasty with special emphasis on evolving minimally invasive surgical techniques. Some challenging topics in hip arthroplasty are covered in an additional section. Particular attention is given to different designs of knee endoprostheses and soft tissue balance. Special situations in knee arthroplasty are covered in a special section. Recent advances in computer technology created the possibility for the routine use of navigation in knee arthroplasty and this remarkable success is covered in depth as well. Each chapter includes current philosophies, techniques, and an extensive review of the literature.

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