35 Navigated Implantation of the *Columbus* Total Knee Arthroplasty with the *OrthoPilot* System: Version 4.0

F. Lampe, E. Hille

Authors' Experience with the OrthoPilot Navigation System in Total Knee Arthroplasty

We started the OrthoPilot-assisted implantation of the Search Evolution knee endoprosthesis (Aesculap, Tuttlingen, Germany), which was the implant available for use with navigation at the time, in our hospital in June 1999 [1]. Stulberg, Saragaglia and Miehlke have already described the OrthoPilot navigation system in detail in various chapters in this volume, and reported on the good prosthesis alignment they were able to achieve. In our own patients we have compared the radiological results in 110 cases. 55 patients were treated with **navigated** Search Evolution knee replacements and 55 with **conventionally** implanted Press Fit Condylar (PFC) knee endoprostheses (DePuy, a Johnson&Johnson Company). It should be borne in mind that the navigated cases constituted our first patient series, and were therefore affected by the learning curve, whereas for conventional implantation of the PFC system we already had years of experience in our hospital to draw on. In spite of this, looking at the so-called alignment index, which makes it possible to consider as a whole the five relevant parameters for evaluating prosthesis alignment – the mechanical leg axis and the four femoral and tibial component angles in the anterior and the sagittal plane – we could already record significantly better results in the navigated group, even though the differences compared with the conventionally treated patients in our series were not quite so pronounced as in other comparable studies (Table 35-1) [2, 3].

Table 35-1. Radiological alignment index[a] – authors' own results

Deviation from optimum	Navigated [% of cases]	Conventional [% of cases]
0–10° (very good – good)	72	50
11–20° (satisfactory)	25	45
21–30° (poor)	3	5
>30° (unacceptable)	0	0
Average deviation [°]	8.5 ± 4.4[b]	10.8 ±5.3[b]

[a]Sum of the 5 individual angle deviations. [b]Significance $p<0.05$

Based on our positive experiences with the OrthoPilot system, we started navigated implantation of the new Columbus knee endoprosthesis (Aesculap, Tuttlingen, Germany) in December 2002. This implant has a convincing concept and design and in our opinion satisfies all the criteria of a modern surface replacement. Furthermore, the new Version 4.0 of the OrthoPilot system promises adequate support in balancing the soft tissues in order to achieve congruent and symmetrical gaps, so that the combination of the Columbus knee with the OrthoPilot navigation system appears very promising.

Concept and Design of the Columbus Knee Endoprosthesis

The foundations for the design of surface knee replacements were laid in the 1970s. The experiences gathered in the subsequent decades led to growing convergence in the requirements concerning implant design. Today, new developments have to be orientated towards and assessed according to these requirements. For this reason we should first give a short summary explaining some particular aspects of the Columbus design concept which have persuaded us to introduce this implant as first users in our hospital (Fig 35-1).

- The implant geometry guarantees the greatest possible femorotibial congruence in the frontal and sagittal plane to maximize the contact surfaces and minimize contact stresses. This reduces polyethylene wear and improves the intrinsic stability of the implant.

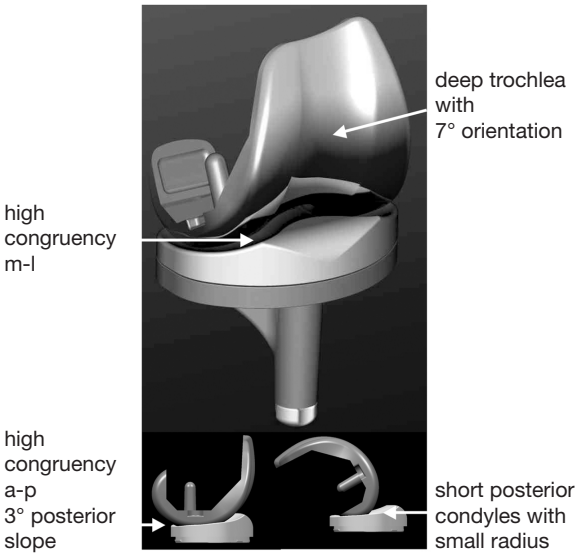


Fig. 35-1. Columbus Knee Replacement (Aesculap, Tuttlingen, Germany)

- The anteroposterior and mediolateral geometry of the femoral components has been optimized. There are 7 femoral sizes and 5 tibial sizes (of which sizes 1–4 each have an additional plus variation with a larger sagittal diameter) available. Femoral and tibial components of all dimensions can be combined with each other freely. This means that optimum consideration can be taken of the individual anatomical and biomechanical conditions.
- The femoral geometry has a deepened and retropositioned trochlea in the kinematically favorable 7° position. This improves femoropatellar congruence and kinematics, which has a positive influence on flexion ability and polyethylene wear after patellar resurfacing.
- The radius and length of the posterior condyles in the sagittal plane have been reduced, improving the intrinsic flexion ability of the implant.
- Polyethylene components with a 3° posterior slope are available in posterior cruciate ligament retaining (PR) versions. Furthermore cruciate ligament substituting (PS), »rotating platform« (RP) and »deep dish« versions are provided. The components have modular heights up to 20 mm.
- The conventional instrumentation is highly advanced. The possibility of navigation with the new OrthoPilot Version 4.0 exists as an alternative.

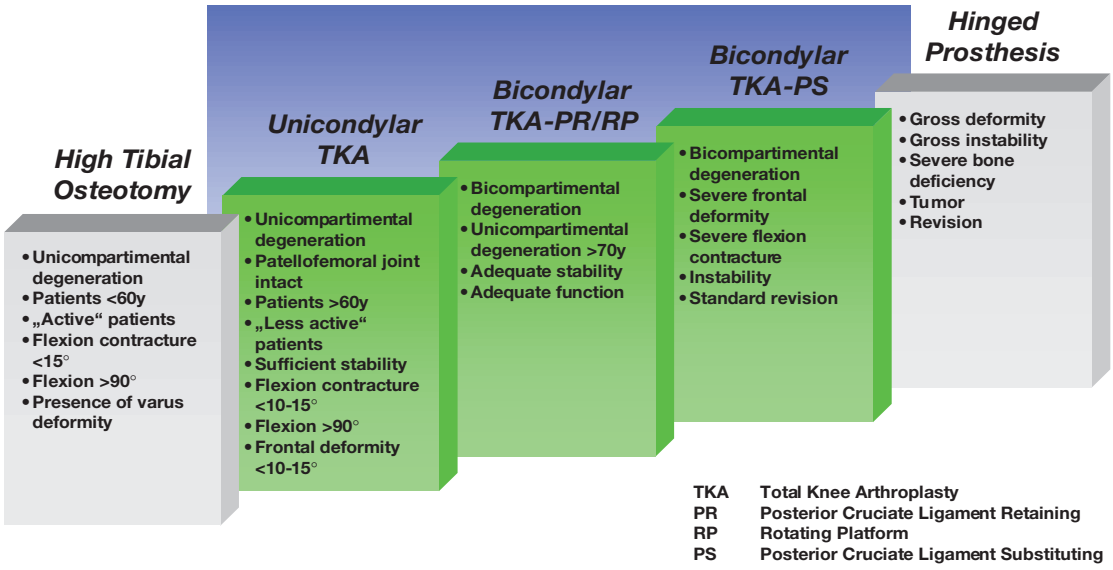


Fig. 35-2. Histogram of differential indications in the treatment of degenerative knee joints in our hospital. The three central columns (green) correspond to the indication spectrum for the Columbus system with OrthoPilot navigation.

- The system will shortly be enlarged with stem extensions and augmentations. A unicondylar and revision system will also be available.

The Columbus System can cover most indications in the treatment of degenerative knee joints or revision surgery thanks to its modular structure and the possibility of using PR, PS and RP components. The surgeon is able to choose between conventional instrumentation and the OrthoPilot navigation system, which has proved itself in routine use in many hospitals (Fig. 35-2).

In our hospital, OrthoPilot-navigated implantation of the Columbus knee prosthesis is now a standard treatment. To date, we have performed around 40 implantations using this system. We will now focus on the special aspects of navigated implantation and report on our first clinical experiences.

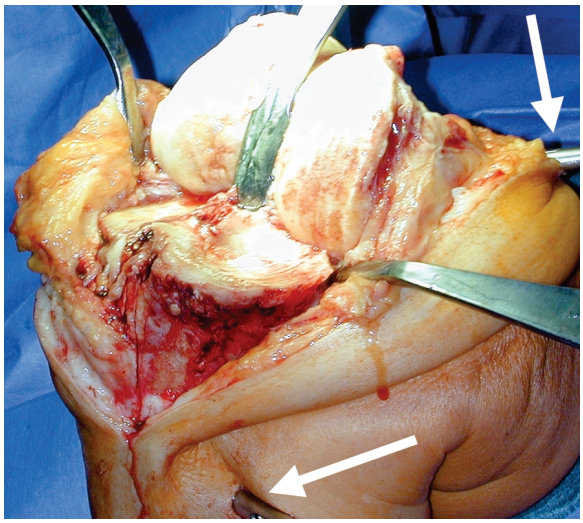


Fig. 35-3. Exposure of the joint for navigated implantation of a knee endoprosthesis. The arrows indicate the position of the fixation screws for the transmitters on the tibia and femur

OrthoPilot Navigation of the Columbus Knee Replacement

Following a median longitudinal skin incision, approach to the knee joint is via medial parapatellar arthrotomy. After subperiostal exposure of the anteromedial tibia and lateral eversion of the extensor mechanism the tibia can be subluxated in front of the femoral condyles (Fig 35-3). In this way the joint is exposed so that all the steps required for navigation (including acquisition of the anatomical landmarks, alignment of the navigated templates and resection blocks) can be carried out safely and reproducibly. The screw for the femoral transmitter is fixed into place within the arthrotomy, the tibial screw is fixed somewhat more distally via a small additional skin incision (see Fig 35-3).

After recording the anatomical and kinematical data by navigation, the OrthoPilot system provides the surgeon on screen with a graphic and numerical display of the individual leg axis of the patient in the frontal and sagittal plane, enabling an objective, dynamic assessment of the deformity, function and stability to be made. We then perform the tibial resection in the frontal and sagittal plane perpendicular to the mechanical tibial axis. Here it must be remembered that a 3° posterior slope has already been integrated into the polyethylene components. A larger slope can of course also be chosen in the bone resection, but this must then be added on to the pre-set slope of the polyethylene components. A special universal alignment device is available for three dimensional alignment of the tibial resection block. This guide is fixed onto the bone (femur or tibia) and permits the spatial positioning of the cutting blocks via thumb screws. However, we prefer free-hand navigation for both tibia and femur, which with some practice is reliable and in particular quick to perform. After the bone resection the actual resection plane achieved is checked by navigation with the help of a template and any resection errors (e.g. through saw-blade drift in subchondral sclerosis) are corrected.

In our opinion, one crucial innovation in the OrthoPilot Version 4.0 is the navigated measurement of the flexion and extension gap using a spreader that now follows. This means that, at an early stage in the operation, the surgeon has information available about the mediolateral soft tissue balance and the congruence of the flexion and extension gaps, which can be used in later planning calculations. Here is a typical example:

The extension gap measures 11 mm laterally and 9 mm medially. Thus it corresponds to around the thickness of the thinnest tibia component (10 mm). In this case the extension gap can be expected to present an adequate width after the distal femoral resection has been per-

formed and, if necessary, it will be perfectly possible to balance it with a medial release. The measurement of the flexion gap in this example is 12 mm laterally and 9 mm medially. Here it can be expected that, through the later external rotation of the femoral component, a symmetrical flexion gap will be formed which will be wide enough to accommodate the tibial component. If the flexion gap is clearly too narrow in relation to the extension gap, it can already be assumed that this will have to be widened through an appropriate release (e.g. posterior cruciate ligament release), a corrective tibial resection with increased posterior slope or the selection of a smaller femoral component. If the opposite is the case, and the flexion gap is too wide, a larger component would be appropriate in order to reduce the flexion gap in relation to the extension gap.

As this example shows, the surgeon has quantitative data available for flexible intraoperative planning, which can be made more concrete and implemented by navigation as the operation proceeds.

The following step serves to navigate and record the posterior condyle tangent (relevant for femoral rotational alignment and establishing size) and the distal femoral joint line (relevant for defining the distal femoral resection plane) with the help of a corresponding template. Subsequently the distal femoral resection block is navigated, taking the resection height into consideration, orientated into frontal and sagittal alignment and fixed into place (either using the universal alignment aid or freehand). The surgeon can again follow the effect of the positioning of the cutting block on the size and symmetry of the extension gap graphically and numerically on screen, and for example decide in narrow conditions (as long as the flexion gap has already been measured as wide enough) whether to resect 11 mm from the distal femur (with slight proximalization of the joint line) instead of the required 9 mm (distal component thickness). Alternatively, the surgeon can increase the extension gap later through a posterior capsule release to match it to the flexion gap. After resection, the result is again checked by navigation and the resection plane is corrected if necessary.

In the step that now follows, a navigation template is used to determine the position of the resection block for the remaining femoral resections, thus establishing the rotational and translational alignment of the femoral component. During this process, the system informs the surgeon on screen about the anteroposterior position of the component to prevent notching of the anterior femoral cortex (we position the component so that it finishes 1 mm in front of the anterior cortex). The rotation of the component in relation to the posterior condyle line is also displayed. As a rule we turn the component externally until the system shows a symmetrical flexion gap. Additional soft tissue release might have to be performed if an unrealistic rotation of the femoral component would otherwise have to be made to balance the flexion gap. In addition, the system shows for orientation purposes the deviation of the posterior condyle tangent from the transepicondylar axis established by palpation. Here the limited reliability and objectivity of epicondyle palpation should be borne in mind. The navigation template has after all been designed to allow visual assessment of its alignment in relation to the Whiteside line. The important thing is to keep looking at the symmetry and width of the gaps during this procedure. If the flexion gap is too narrow, the surgeon can reduce the size of the femoral component suggested by the system. After re-aligning the navigation template, the effect on the width of the flexion gap can be seen on the screen. In the opposite case, if the flexion gap is too wide, a larger femoral component is suggested to the system. Thus, the final size of the femoral component is established at this point, as part of balancing the flexion gap. The seven very close component sizes represent a clear advantage here. A further example:

The system suggests a femoral size 4. The template is moved anteriorly until the value –1 for the femoral notching is shown on the screen. The template is now rotated externally until the flexion gap measures 2 mm medially and laterally (corresponding to the distance between the components), and is thus symmetrical and congruent to the extension gap. In this example, this occurs at 4° external rotation in relation to the posterior condyle line. At 6°, the transepicondylar axis deviates only by 2° from the orientation of the components. Visually, the template is optimally aligned in relation to the Whiteside line. The system proposes a 10 mm thick tibial component. In this case optimum conditions exist for all navigated parameters, so that the position of the size 4 resection block is now established. If in this example the flexion gap would be too large at 6 mm, the surgeon calls up the size 5 in the system instead of the size 4. The system now virtually defines the decreased flexion gap with a correctly positioned navi-

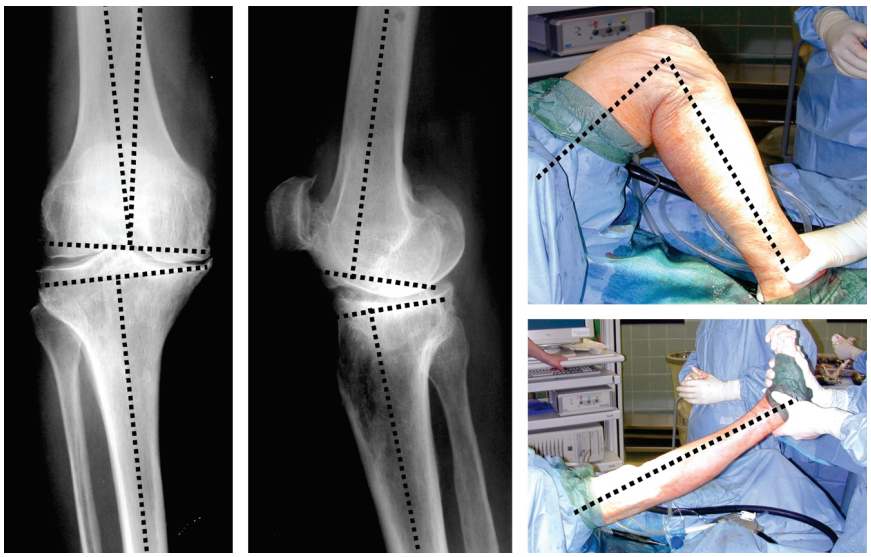
gation template as only 1–2 mm. In this case the size 5 resection block is selected.

In general, the surgeon will tolerate a gap asymmetry of maximum 2–3 mm. Above this the situation has to be corrected, for example through further soft tissue balancing. After final positioning and fixing of the femoral resection block, the remaining resections are performed. Trial components of the appropriate dimensions are fitted and then function, stability, gap symmetry (ligament balancing), gap congruence (gap balancing) and patella tracking are checked both by navigation and clinically (plausibility check). After obligatory jet lavage the definitive components are implanted; we cement both the femoral and the tibial components. Apart from a few exceptions we leave the surface of the patella native, merely removing osteophytes and performing denervation to the margin by electro-cauterisation. After placement of intra-articular and subcutaneous drainage connected to an autotransfusion system, the wound is closed in the usual way.

The patients who have been treated in this manner are mobilized on the first day postoperatively. Additionally, continuous passive motion is prescribed from the first day postoperatively. If possible, in order to increase the efficiency of the physiotherapy, pain is treated for 5–7 days via a peridural catheter placed during surgery. When the patients have attained free extension and at least 90° of flexion they are discharged into the rehabilitation clinic.

First Clinical Experiences with the Columbus Knee Endoprosthesis

We have now been using the Columbus knee for about 3 months. As we had already gained sufficient experience using the previous OrthoPilot versions in combination with the Search Evolution prosthesis since 1999, the changeover to the new implant system and the OrthoPilot software version 4.0 did not cause any problems. The operation is already being routinely performed by two surgeons experienced in navigation. The experiences to date with the implant and the new software can be described as thoroughly positive, especially with regard to the new aspects of gap and soft tissue balancing. It has been confirmed once again that the OrthoPilot system can be reliably used in everyday clinical practice. Because of the as yet short period of use of the first Columbus series, we cannot present any follow-up data on this at the current time. Instead, two case reports are used to illustrate the possibilities of navigated treatment with Columbus. One case concerned a 75 year old man with osteoarthritis and pronounced varus deformity. Function was limited significantly to 0/25/60° (extension/flexion; ◘ Fig. 35-4). The X-rays show the preoperative status and the resection planning. Despite the high grade function limitation, after adequate exposure of the joint (see Fig 35-3) it was possible to treat the patient with an OrthoPilot-navigated Columbus knee. The intraoperative



◘ **Fig. 35-4.** Case 1

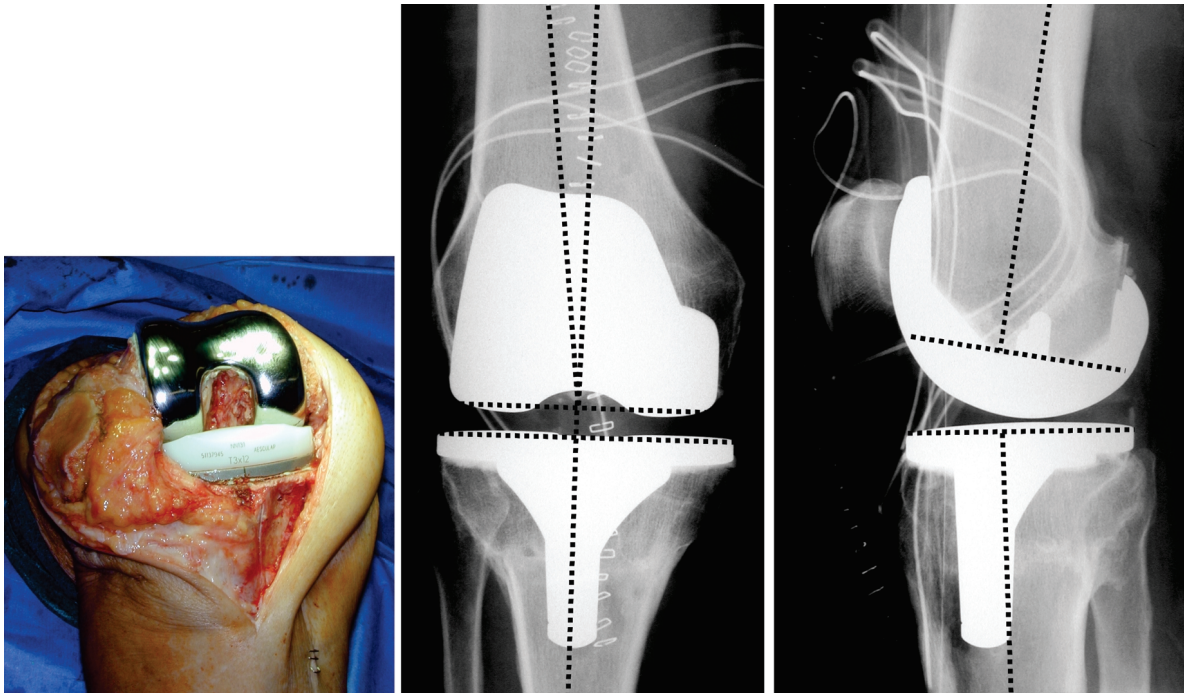


Fig. 35-5. Case 2

images show a restoration of function with stable ligaments after implantation of the prosthesis. The second case concerned a 76 year old man with osteoarthritis of the knee after high tibial osteotomy with a function of 0/10/100° (extension/flexion; Fig 35-5). Displayed is the operating site after implantation of the prosthesis and the postoperative X-ray status showing correctly aligned components.

This year will see the beginning of an international prospective multicenter study with regard to the OrthoPilot-navigated implantation of the Columbus knee replacement.

References

1. Hille E, Lampe F (2000) Erste praktische Erfahrungen mit einem Navigationssystem. In: Eulert J, Hassenpflug J (Hrsg) Praxis der Knieendoprothetik. Springer, Berlin Heidelberg New York Tokyo, S 91–96
2. Konermann W, Saur MA (2003) Postoperatives Alignment von konventionell und navigiert implantierten Knietotalendoprothesen. In: Konermann W, Haaker R (Hrsg) Navigation und Robotik in der Gelenk- und Wirbelsäulenchirurgie. Springer, Berlin Heidelberg New York Tokyo, S 189–199
3. Miehlke RK, Clemens U, Jens JH, Kershally S (2001) Navigation in der Knieendoprothetik – vorläufige klinische Erfahrungen und prospektive vergleichende Studie gegenüber konventioneller Implantationstechnik. Z Orthop 139: 109–116