OrthoPilot® Navigation System
OrthoPilot KneeSuite™ – TKR
Columbus® Knee Surgical Technique

OrthoPilot
The OrthoPilot System assists in the precise implantation of knee and hip endoprostheses. Integration in the surgical workflow as well as minimal prolongation of operation time were essential criteria in the development of the OrthoPilot system. At the same time, we focused on a navigation system that is non-traumatic for the patient. From the beginning, a method was developed that eliminates use of CTs and MRIs and the X-ray exposure or the expenses that these entail and extends surgery time as minimally as possible.

Indications for Use:
The OrthoPilot Next Generation Navigation Platform is a system for computer-aided navigation of surgical instruments. Its purpose is to position endoprosthesis in arthroplasty in the patient. It aids the surgeon in accurately positioning the cutting guides, drills and reamers for total endoprosthesis replacement surgery and provides intraoperative measurements of bone alignment. It indicates angles and positions for implant placement.

For more information about indications and contraindications, please refer to the Instructions for Use posted on www.aesculapimplantsystems.com.

Benefits:
- CT Scan not required
- Ergonomic instruments precisely aligned to the surgery
- User-friendly navigational flow integrates itself easily into the operating room and procedure
- Proven precision of implant alignment
- Intraoperative documentation with OrthoPilot
- Numerous studies confirm significantly better alignment
- Routinely used in over 600 hospitals
- Over 300 OrthoPilot publications worldwide
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Table of Contents
1. Instrument Overview .......................................................... 6
2. Preoperative X-Ray Image-Based Planning .......................... 8
3. Preoperative Planning ...................................................... 9
4. Patient Preparation ........................................................ 11
5. OrthoPilot Set-Up and Transmitter Position .......................... 12
   5.1 OrthoPilot Positioning .................................................. 12
   5.2 Femoral Transmitters .................................................. 12
   5.3 Tibial Transmitters .................................................... 12
6. Entering Patient-Related Information ................................... 13
7. Determination of the Joint Centers .................................... 14
   7.1 Registration of the Knee Center .................................... 14
   7.2 Registration of the Hip Joint Center ................................. 15
   7.3 Optional Determination of the Hip Joint Center with Pelvic Reference ............. 16
   7.4 Feasibility Check of the Mechanical Lateral Distal Femoral Angle (mLDFA) ....... 16
   7.5 Determination of the Ankle Joint Center ................................ 17
   7.6 Determination of the Knee Joint Center ........................... 18
   7.7 Determination of the Proximal Tibial Center ........................ 18
8. Joint Line Planning .......................................................... 19
   8.1 Planning the Tibial Joint Line ........................................ 19
   8.2 Planning the Femoral Joint Line ..................................... 19
9. Posterior Condylar Line and Anterior Cortical Point ................. 20
   9.1 Registering the Medial and Lateral Posterior Condyle .................... 20
   9.2 Registering the Anterior Cortical Point ............................ 20
10. Registering the Epicondylar Line ........................................ 21
11. Ankle Joint Palpations .................................................... 22
   11.1 Medial and Lateral Malleolus ....................................... 22
   11.2 Anterior Ankle Joint Point .......................................... 22
12. Leg Axis, Condyle Registration and Rotation Determination .......... 23
   12.1 Representation of the Mechanical Leg Axis ......................... 23
   12.2 Condyle Registration .................................................. 23
   12.3 Setting Femoral Rotation ............................................ 24
13. Registering the Tibial Bone Situation .................................. 25
   13.1 Registering the Medial and Lateral Tibial Bone Situation .............. 25
   13.2 Registering the Tibial Medullary Channel ........................... 25
14. Tibial Plateau Resection .................................................. 26
15. Determining the Size and Reassessing the Tibial Resection .......... 27
   15.1 Implant Size Determination ........................................ 27
   15.2 Reassessing the Tibial Resection ................................... 27
16. Registering the Femoral Bone Situation ................................ 28
17. Measuring the Joint Gap in Extension and Flexion ........................................ 29
   17.1 Measuring the Joint Gap in Extension and Flexion .................................. 29
   17.2 Measurement of the Joint Gap in Flexion ............................................. 29
18. Registering the Femoral Diaphysis ......................................................... 30
19. Femoral Planning ......................................................................................... 31
   19.1 In Extension ......................................................................................... 31
   19.2 In Flexion ............................................................................................ 32
   19.3 Display and Control Elements (Center) ............................................. 32
20. Augmentation Planning and Distal Femur Cut ........................................... 33
   20.1 Control ............................................................................................... 33
   20.2 In Extension ......................................................................................... 33
   20.3 In Flexion ............................................................................................ 34
   20.4 Display and Control Elements (Center) ............................................. 34
21. Distal Femur Resection, Control and Rotational Alignment ....................... 35
   21.1 Distal Femur Resection ....................................................................... 35
   21.2 Reassessing the Distal Resection ..................................................... 36
   21.3 Setting the Rotational Alignment ..................................................... 37
22. Mechanical Axis ......................................................................................... 38
23. Femur First Technique ................................................................................. 39
   23.1 Registering the Femoral Diaphysis .................................................... 39
   23.2 Registering the Femoral Bone Situation ......................................... 40
   23.3 Distal Femur Resection ................................................................... 41
   23.4 Reassessing the Distal Resection ................................................... 42
   23.5 Setting the Rotational Alignment ................................................... 43
24. Mechanical Axis ......................................................................................... 44
25. Instrument Set Overview – OrthoPilot® TKR ............................................. 45
26. Software – OrthoPilot TKR Columbus® .................................................... 45
27. Schematic Program Flow TKR 1.2 ............................................................. 46
   27.1 Schematic Program Flow – Tibia First ............................................ 46
   27.2 Schematic Program Flow – Femur First ........................................... 48
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### 1. Instrument Overview

<table>
<thead>
<tr>
<th>Femur-RB Revision, C-Hook</th>
<th>Femoral Orientation Guide</th>
<th>T-Handle for Revision and Navigation Adapter</th>
<th>Tibial Revision Cutting Guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large NE191R</td>
<td>Columbus Knee System NE324T</td>
<td>T-handle for Revision NE198R Navigation Adapter NE199R</td>
<td>Columbus Knee System, Right NQ651R</td>
</tr>
<tr>
<td>Small NE163R</td>
<td></td>
<td></td>
<td>Columbus Knee System, Left NQ650R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibia-RB Revision NP192R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight Pointer FS604</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>Code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibial Cut Control Plate</td>
<td>NP617R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbus Knee System</td>
<td>NP617R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbus Revision</td>
<td>NP617RM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revision Spreader with Spreader Forceps</td>
<td>NE750R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revision Spreader</td>
<td>NE750R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spreader Forceps</td>
<td>NP609R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal Femoral Revision Cutting Guide</td>
<td>NQ701R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 in 1 Revision Cutting Guide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbus Knee System F2 – F8</td>
<td>NQ721R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NQ721R-NQ728R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive Transmitters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>FS633</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>FS634</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>FS635</td>
<td></td>
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</tr>
</tbody>
</table>

*Note: Images of each product are included in the document.*
The OrthoPilot system and the revision software can be used in all cases of bicondylar implant failure (non-septic and firmly in position) where an implant replacement with a revision prosthesis is indicated. Bone quality and hip joint flexibility should be adequate.

**Note:** For more information about indications and contraindications, please refer to the instructions for use posted on www.aesculapimplantsystems.com.
Aesculap considers it necessary to carry out adequate preoperative planning on the basis of the following X-Ray images:

- Whole leg image in standing position
- Knee joint in AP projection
- Knee joint in lateral projection
- Tangential image of the patella

Optional:
- X-Ray images before primary implantation
- X-Ray images of the opposite side
- CT image of the primary implant

Selected information which can be obtained on the basis of the X-Ray images:

- Axis deviation
- Implant alignment, joint gap, ML implant size
- Slope, joint gap in flexion, AP implant size
- Rotational position, patella position

Optional:
- Joint line planning (fibula tip, epicondyles, etc).
- Joint line planning (fibula tip, epicondyles, etc).
- Rotational position (epicondyles)
Analysis to determine the reason for revision is essential when carrying out preoperative planning, as a repetition of the errors which possibly led to primary implant failure should by all means be avoided. In addition to the standard radiological examinations, the surgeon should take the following points into consideration before performing revision surgery:

- Soft tissue situation
- Functionality of the extensor mechanism
- Removal of the primary prosthesis
- Bone preservation
- Restoration of good axis orientation
- Functional stability
- Restoration of the joint line

Anatomic landmarks such as the fibula head or the trans-epicondylar line serve as orientation marks when determining the height of the joint line.

The surgeon can obtain the following information when analyzing the X-Ray images with the help of the Aesculap prosthesis systems Columbus Revision X-Ray templates:

- Angle between anatomic and mechanical femur axis
- Resection heights
- Implant sizes
- Tibial and femoral entry points for intramedullary alignment
- Tibial augments and/or femur wedges required
4. Patient Preparation

Positioning and sterile draping of the patient is carried out according to the standard procedures which are also applied in the conventional technique. Aesculap recommends using a leg holder, which facilitates leg control during the various phases of the surgery.

In order to record the register points and carry out all the necessary bone cuts, it is necessary to change the leg position several times. The leg holder enables the knee position to be changed between full extension and full flexion.

**TIP**

To facilitate mobilization of the quadriceps, bring the knee to 100° flexion prior to activating the tourniquet. If a pad is used, make sure that it does not hinder full circulation of the hip joint which is required for registering the femoral head center.
5. OrthoPilot Set-Up and Transmitter Position

5.1 OrthoPilot Positioning

When positioning the OrthoPilot System, ensure that the physician has an unobstructed view of the screen at all times. Unit or camera can be positioned on the opposite side of the leg to be operated on or on the same side and is ideally at a distance of approximately 2 m (1.8 – 2.2 m) from the transmitters. In many cases, it has proven beneficial to position the camera at shoulder height on the opposite side of the patient and align at approximately 45° to the operating field.

TIP

Aim the laser pointer inside the handle of the camera at the knee joint to be operated on while the leg is in approximately 90° flexion. The camera alignment can be adjusted at any stage of the operation except during determination of the hip center.

5.2 Femoral Transmitters

Position the transmitters so that they are visible to the camera during the entire surgery. After opening the knee joint, attach the C-hook (NE191R or NE163R) in the femoral incision approximately 10 cm proximal from the joint line. For this purpose, tighten the screw of the femoral C-hook with a manual screwdriver. The C-hook should be at a right angle to the femur axis. One of the two transmitter adapters should point towards the femoral head. On the anterior side, it has proven beneficial to place the C-hook on the lateral edge of the cortex.

TIP

The tip of the pointer with a length of approximately 10 cm can be used as a guide for the distance to the joint.

5.3 Tibial Transmitters

Place the tibial TKR Rigid Body (NE192R) on the front edge of the tibia from the medial side either in the incision or through a separate approximately 2 cm long incision further distal on the tibia. After pre-drilling using the 3.2 mm drill (NP615R) from the navigation instrument set (NQ594 tray #ST1002), and after preliminary preparation using the thread cutter (NE292R), fix the rigid body with the special monocortical screw. This screw is also tightened with a manual screwdriver. The first few turns, in particular, should be carried out under pressure. The transmitter adapter should point in a medial direction at right angles to the tibia axis.

Attach the passive transmitter (FS635) marked red to the femoral rigid body (C-hook) adapter. Attach the passive transmitter (FS634) marked blue to the tibial TKR rigid body adapter. Attach the yellow passive transmitter (FS633) to the respective instruments required at each stage.
6. Entering Patient-Related Information

Entering Hospital-Related Data
- Name of the Surgeon
- Name of the Hospital/Department

Entering Patient Data
- First Name
- Last Name
- Date of Birth
- Gender
- Side
  - Left
  - Right
- Instrument Type
  - Columbus_Revision_Passive
  - Columbus_Revision_Active

Planning of the Desired Postoperative Joint Line Using X-Ray Images

The joint line can be planned starting either from the femur or from the tibia.

The following options can be selected for planning from the femoral side:
- Femur-related joint line
- Non femur-related joint line

The following options can be selected for planning from the tibial side:
- Tibia-related joint line
- Non tibia-related joint line

The distances in millimeters between reference points which can be freely selected and the planned post-operative joint line of the femur or tibia are entered directly from the X-Ray image, while taking into account the respective magnification factor.

In every case, it should be indicated whether the joint line is to be distalized or proximalized by selecting "=>Distal" or "=>Proximal".

Joint line planning either from the femoral or the tibial side is mandatory.
7. Determination of the Joint Centers

7.1 Registration of the Knee Center

An approximate knee center point is palpated with the tip of the pointer distally in the center of the trochlea with the implant in position. Here, the pointer (FS604) is connected to the yellow transmitter (FS633 - passive) or (FS601 - active, yellow port), depending on the transmitter technology used.

**TIP**
To facilitate palpation, it is recommended to hold the leg in a flexed position. The point at which the medullary channel is opened can be registered.
7. Determination of the Joint Centers (continued)

7.2 Registration of the Hip Joint Center

The start screen for recording the hip joint center is displayed.

Only when the leg is not moving, an arrow pointing upward is displayed, and data entry can begin with movement of the femur in the 12 o'clock direction.

**TIP**

The circular movement which is described can be performed clockwise or counter-clockwise.

The femur is moved so that the white circle, like the hands on a clock, is moving over the fields arranged in a large circle. As soon as sufficient measurement data for precise determination of the femoral head center has been registered, the program automatically moves to the next step.

Irregular or excessively broad movement can trigger messages “incorrect data” or “too wide movement”, and the movement must then be repeated.

**TIP**

- Ensure the femur transmitter is visible during the entire cycle of the movement.
- Ensure unrestricted freedom of circular movement (no obstruction by holding and fixing equipment).
- Avoid transmitting force from the femur to the pelvis.
- Avoid any pelvic movement (responsibility of the surgeon; if this cannot be avoided, alternative determination of hip center, achieved via long press of right footswitch, can be performed. This would require an additional RB fixed to the iliac crest).
- Avoid a hip flexion angle > 45°.
7.3 Optional Determination of the Hip Joint Center with Pelvic Reference

Registration of the femoral head center, which requires a reference transmitter to be attached firmly to the iliac crest, can be started by prolonged activation of the right pedal. This mode is displayed by a separate representation on the screen with the subtitle “Hip joint center (pelvic ref)”. Large movements of the hip joint must be carried out until the information displayed indicates that sufficient data has been registered. As soon as sufficient data has been registered, the program automatically moves to the next step.

7.4 Feasibility Check of the Mechanical Lateral Distal Femoral Angle (mLDFA)

By applying the orientation block (NE324T - Columbus) at the distal femoral condyles in 0° slope to the mechanical femoral axis, the abnormal varus/valgus position and the mLDFA for the feasibility check are displayed. If this angle seems implausible to the surgeon based on his or her preoperative X-Ray planning, determination of the hip joint center must be repeated (if necessary with the pelvic pin, see Chapter 7.3).
7. Determination of the Joint Centers (continued)

7.5 Determination of the Ankle Joint Center

In this program step, the movement of the transmitter at the foot is tracked in relation to the transmitter at the tibia, and the center of the ankle joint is determined.

Fix the transmitter to the metatarsal area via the footplate (NM769R) intended for that purpose and using the elastic strap (NM743). The sterile fixing is effected supracutaneously on the sterile draping. After attaching the footplate, attach the transmitter, which should point toward the camera.

By pressing the right pedal, data collection is started. As soon as sufficient measurement data has been registered, the software automatically moves to the next program step.

**TIP**

In order to coordinate the actual movement with the display on the screen, it is best to start the movement in the middle of the flexion/extension range of the ankle joint. If the maximum physiological and anatomical range of movement was repeatedly covered, the user can also advance to the next step by pressing the right pedal.

In cases of an arthrodesis, this step can also be skipped. In this case, the ankle joint center is determined exclusively on the basis of palpation of the malleoli and the anterior ankle joint point.
7.6 Determination of the Knee Joint Center

In this program step, the movement of the transmitter at the femur is tracked in relation to the transmitter at the tibia, and the center of the knee joint is determined. The message “knee center” is displayed on the screen. By pressing the right pedal, determination of the knee joint center is started. Flexion and extension movements are next carried out with the leg. For this, the leg should be grasped with one hand under the heel.

In order to coordinate the actual movement with the display on the screen, it is recommended to start the movement with the knee in approximately 90° flexion position.

Rotation of the tibia is not mandatory. Nevertheless, rotation at 90° flexion may be carried out to increase accuracy as soon as two arrows are displayed on the screen. Solid arrows indicate that the data was registered. As soon as sufficient measurement data has been registered, the software automatically moves to the next program step. If the maximum range of movement was repeatedly covered (even without inward or outward rotation), the next step can optionally be advanced by the user by pressing the right pedal.

7.7 Determination of the Proximal Tibial Center

In this step, the center of the proximal tibia is recorded at the polyethylene surface of the implant which is in position using the pointer (FS604). For this procedure, the entry point of the intramedullary channel is:

- At the center of the medial-lateral diametral line of the tibial head,
- At the transition from the first to the second third of the anterior/posterior diametral line of the tibial head, as measured from the anterior edge.
8. Joint Line Planning

8.1 Planning the Tibial Joint Line

In this step, the reference point for planning the joint line which was selected in preoperative X-Ray planning is recorded from the tibial perspective.

Examples of possible reference points:
- Fibula head
- PE inlay
- Implant/bone interface

If no tibia-related joint line planning was performed, the message "not required" appears on the screen, and the step can be skipped by pressing the right pedal.

8.2 Planning the Femoral Joint Line

In this step, a reference point for planning the joint line is recorded from the femoral perspective. Examples of reference points that can also be easily located on the X-Ray image prior to surgery include:
- Epicondyles
- Implant/bone interface
- Distal condyles of the implant which is in position

If no femur-related joint line planning was performed, the message "not required" appears on the screen, and the step can be skipped by pressing the right pedal.
9. Posterior Condylar Line and Anterior Cortical Point

9.1 Registering the Medial and Lateral Posterior Condyle

Place the tip of the pointer at the middle of the posterior medial condyle of the primary prosthesis. The point selected is the one lying furthest posterior, (i.e. the one with the greatest distance from the anterior femoral cortex).

The registration on the lateral side is made in the same manner.

9.2 Registering the Anterior Cortical Point

This point is required for determining the size of the femoral component ("continuous" display). It is located at the place where the anterior shield of the implant in position ends proximally. In cases of “notching” of the implant in position, a point located somewhat higher on the bone should be selected in order to avoid renewed “notching”. In the medio-lateral direction, the most anterior point should be palpated.

The proposal for the size of the femoral component is calculated on the basis of the distance between this point and the posterior condyle. This point is used later to determine whether there is a danger of cutting into the anterior cortex.
10. Registering the Epicondylar Line

Next, the epicondylar line is registered via registration of the medial and lateral epicondyle. In a later program step, the user can decide whether to use the epicondylar line or the connecting line between the posterior condyles palpated on the primary implant as reference line for rotational alignment or correction of the femoral component of the revision implant.

The tip of the pointer is placed first on the medial, then on the lateral epicondyle. The recording is made in each instance by pressing the right pedal.
11. Ankle Joint Palpations

11.1 Medial and Lateral Malleolus

The pointer is placed at the center of the medial malleolus, and the respective point is registered using the right pedal. The registration on the lateral side is made in the same manner.

11.2 Anterior Ankle Joint Point

For the registration, place the pointer at the anterior edge of the distal tibia as closely as possible to the ankle joint gap. The following step is displayed: "Anterior ankle joint point". This palpation point should lie on the central tibial axis immediately adjoining the ankle joint center. It should be palpated there (as indicated by the red point) and not in the middle of the two malleoli.

TIP

The second metatarsus/second ray or the extensor hallucis longis tendon can be used as a reference during this step.
12. Leg Axis, Condyle Registration and Rotation Determination

12.1 Representation of the Mechanical Leg Axis

In the following step, the registered axis location/position is displayed in coronal and in sagittal view. The axis location/position is displayed dynamically while the relationship between the mechanical tibial axis and the mechanical femoral axis is calculated on a step by step basis. The system thus enables dynamic goniometry of the knee joint, including specification of the current axis deviation or flexion position within the scope of movement.

**TIP**

This step can be used as a feasibility check of the abnormal axis position in various flexion positions of the leg and also permits preliminary conclusions to be drawn regarding the ligament situation by applying varus and valgus stress.

12.2 Condyle Registration

The distal and posterior condyles of the primary implant are registered with the help of the femoral orientation guide (NE324T – Columbus®) with footplates (NE441RM/NE442RM), which must be in contact with both the distal and the posterior condyle surfaces. The alignment in the sagittal plane is displayed on the right half of the screen. Data should be registered when the guide is in approximately 0° slope in relation to the mechanical femur axis in the sagittal plane. For additional information, the alignment angle in degrees of the epicondylar line registered with the pointer in relation to the posterior condyles of the primary implant is indicated.

**TIP**

If inward rotation of the primary implant was detected by means of a preoperative CT image, the epicondylar line consequently appears to be rotated outward in the display in relation to the implant which is rotated inward. If this value is not feasible, renewed palpation of the epicondyles is recommended. Before registering the condyles, the tibial implant or at least the polyethylene inlay should be removed.
12.3 Setting Femoral Rotation

The new rotational position of the femoral revision prosthesis is adjusted using the orientation guide (NE324T - Columbus) without footplates. This rotational value is decisive for calculation and display of anterior notching, since the femoral prosthesis cannot be freely positioned in AP direction, its position being determined by the stem position +/- 4 mm. This value is adopted in the femoral planning screen, but can also be readjusted there later.

**TIP**

Ideally, rotational correction, if required when changing from the primary to the revision prosthesis, is determined beforehand with the help of the epicondyles using a CT image.

**Note:** For the femur first technique, see Chapter 23.
13. Registering the Tibial Bone Situation

13.1 Registering the Medial and Lateral Tibial Bone Situation

Place the tip of the pointer on the medial tibial plateau. The lateral tibial plateau is then registered. For palpation, it is recommended to use significant landmarks, such as one of the lowest points of the more severely damaged side and one of the highest points of the less severely damaged side. In a later step, the position or incision height of the tibial incision guide is shown as determined by these two palpations.

13.2 Registering the Tibial Medullary Channel

The deviation of the tibial medullary channel in relation to the mechanical axis in terms of varus/valgus angle and tibial slope can be both recorded and also modified/corrected to a minor extent via the navigation adapter (NE199R) equipped with the yellow transmitter (FS633 - passive) and attached to the revision T-handle (NE198R).

This step can be skipped by prolonged pressing of the right foot pedal, and resection of the tibia can be navigated directly without reference to intramedullary alignment.
14. Tibial Plateau Resection

After gradual introduction of intramedullary reamers from the Columbus instrument set, remove the revision T-handle (NE198R) with navigation adapter (NE199R). Continue until the desired length and diameter is reached under continuous navigation control with respect to varus/valgus angle and slope. The 0° tibial connection sleeve (NE190R) can then be attached to the stem.

Depending on which leg, left or right, is being operated on, the yellow transmitter is either attached directly to the tibial cutting guide or to the adapter (NE162R) which is attached to either of the cutting guides right leg (NQ651R) or left leg (NQ650R). The connecting element (NE171R) is used to establish connection through the respective cutting slot with the 0° tibial sleeve attached to the reamer.

Because of the connection to the intramedullary reamer which is fixed in position, the varus/valgus angle and the tibial slope can no longer be modified. The precise resection height in relation to the bony reference points palpated on the tibia medially and laterally can be determined by moving the cutting guide in a proximal or distal direction.

The tibial cutting guide is initially fixed from the anterior side using two headless screw pins, after which the connecting element to the reamer and the reamer itself are removed. The cutting guide can now still be relocated via the available pin holes, e.g. for a staggered cut, if required.

If the tibial medullary channel registration step was skipped by prolonged pressing of the pedal, the tibial cutting guide with the yellow transmitter attached can be freely navigated to the desired varus/valgus and slope value in relation to the mechanical axis, irrespective of the alignment of the tibial diaphysis or the medullary channel. The height of the tibial resection can be navigated to the points previously registered.

At the center of the upper border of the screen, the PE inlay best suited is indicated. This is selected on the basis of given resection planning for achieving the planned joint line possible from the tibial side. In addition, the deviation from the planned joint line on the basis of given cutting template alignment and the PE inlay indicated appears centrally in the middle of the screen.

When the desired resection height has been set, the cutting guide is additionally fixed medially and laterally via oblique headed pins, and the resection can then be performed.

TIP

In order to avoid contamination of the marker spheres on the transmitters, it is advisable to either remove the transmitters or to cover them appropriately until resection has been completed.
15. Determining the Size and Reassessing the Tibial Resection

15.1 Implant Size Determination
At this stage, after tibial resection, it is advisable to determine the size of the femur and of the tibial plateau using appropriate instruments (trial plateaus for the tibia and femoral orientation block for the femur). If necessary, the femur size must be corrected via the plus and minus symbols with the help of prolonged pressing of the pedal on the right or left as appropriate.

15.2 Reassessing the Tibial Resection
The tibial control plate (NP617R or NP617RM) with attached yellow transmitter serves to reassess and record the tibial resection.

The screen displays the actual alignment and position of the resection surface in relation to the mechanical axis in terms of varus/valgus angle and tibial slope.

The data registered here using the right pedal is used for further calculations, and it is therefore imperative to record this value afresh if resection of the tibia is repeated.

If augmentation of the tibia is intended either medially or laterally or even bilaterally, it is mandatory during this step to place the appropriate trial augmentations from the Columbus® instrument set underneath the control plate before performing the measurement.

If joint line planning from the tibial side was performed, the PE inlay accordingly best suited for achieving the planned joint line is indicated at the center of the upper part of the screen. As central information, the deviation from the planned joint line appears in the center of the screen.
The objective of the following steps is to use the pointer to register the distal and posterior condylar defects for augmentation planning later. The data is recorded in the following sequence:

- Posterior condyle, medial
- Posterior condyle, lateral
- Distal condyle, medial
- Distal condyle, lateral

The values displayed for the two distal palpations are the distances in millimeters from the respective bone palpations to the planned femoral joint line. This distance must be filled out by the implant (distal implant thickness) together with appropriate augments.
17. Measuring the Joint Gap in Extension and Flexion

17.1 Measuring the Joint Gap in Extension

Before measuring the flexion/extension gap, osteophytes which could influence ligament tension and capsular tension must be removed. With the leg extended as far as possible (0°–10°), introduce the distractor (NE750R) between the tibial resection and the distal femur condyles and force apart with identical force medially and laterally using the spreader forceps (NP609R). The plates of the distractor must lie flat on the tibial resection surface in order to ensure precise measurement.

The OrthoPilot® screen indicates the medial and lateral gap distances in millimeters and the mechanical leg axis in degrees, revealing possible ligament release, as well as the flexion position of the leg.

After recording the data by pressing the right pedal, release the distractor and move the leg into a 90° flexion position.

Since the gap distances represent the distance from the recorded tibial resection surface to the respective bone points recorded distally on the medial and lateral distal condyle, a preparation plateau can be placed underneath on the tibial side. This prevents possible sinking of the distractor plates into the cancellous bone. If application of the distractor on the femoral side proves difficult, a femoral trial prosthesis could be attached and distraction could be carried out against the femoral trial prosthesis.

The gap distances indicated on the OrthoPilot screen remain unaffected, regardless of whether the distraction procedure is carried out with or without tibial preparation plateau and/or trial femur.

17.2 Measurement of the Joint Gap in Flexion

With the leg in 90° +/- 5° flexion, force apart the distractor medially and laterally with identical force using the spreader forceps, and register the gap situation.
At this stage of the surgical procedure, determine the alignment of the femoral medullary channel, just as for the tibia, by means of reamers of different diameters, (i.e. the angle between mechanical axis and femoral diaphysis is indicated). This value in turn indicates which angled stem should ideally be selected in order to avoid ending up with a femoral distal varus or valgus cut.

Corrections can also, to a minor extent, be achieved here in the course of femoral shaft preparation of the diaphysis via the different reamers which are always introduced under navigation control.

The target value is either 5°, 6° or 7°, since angled stems are available in the Columbus implant system (5° and 7° for pressfit, 6° for cemented).
19. Femoral Planning

TIP

Yellow values in the cutting height display signify that cutting is performed above the respective reference points recorded at the distal and posterior condyles, (i.e. no bone tissue is actually resected). The yellow value can also be taken to signify the distance from the palpated bony reference point of the respective condyle to the rear surface of the femoral implant which must be filled with cement or augments.

19.1 In Extension

1. Measured extension gap, in this example 20 mm laterally and 20 mm medially, is indicated by the blue columns and the blue numbers.

2. Distal femoral cutting height, in this example 1 and −1 mm respectively from the lateral and medial sides, is indicated by white columns and white numbers or yellow columns and yellow numbers respectively. Yellow signifies a negative cut in relation to the palpated bony defects. Genuine bone cuts are represented by white numbers and white columns.

3. In this example, the remaining extension gap of 2 mm laterally and 1 mm medially after planned installation of implant components are indicated by the green columns and the green numbers. As soon as the remaining gap distances become negative, they are represented by yellow columns and yellow numbers. A negative yellow gap distance in clinical terms signifies distension of the soft tissue (e.g. ligaments).

4. Varus/valgus display, in this example 1°, is indicated by the arc inside the femur and the number in the elliptic field.

5. The value displayed in the rectangle with rounded corners indicates the deviation in mm from the planned joint line. If the number is not zero, the information is supplemented by the term proximal for proximalization of the planned joint line and distal for distalization of the planned joint line.

6. Valgus/value of 1° in the gray ellipse is a reminder of the stem position from the reamer navigation, in this example.
19.2 In Flexion

1. Measured flexion gap, in this example 18 mm laterally and 18 mm medially, is indicated by the blue columns and the blue numbers.

2. Posterior femoral cutting height, in this example 2 mm laterally and 3 mm medially, is indicated by the white columns and the white figures.

3. In this example, the remaining flexion gaps of 2 mm laterally and 2 mm medially after planned installation of implant components, are indicated by the green columns and the green numbers, or by yellow columns and yellow numbers if the remaining extension gap becomes negative. A negative gap distance in clinical terms signifies distention of the soft tissue (e.g. ligaments).

4. Rotation, in this example 0°, is indicated by the arc in the femur and the number in the elliptic field. Indicated as number of degrees in relation to the recorded posterior condyles of the primary implant.

5. Anterior cutting height (notching), in this example 0 mm, is in relation to the point palpated anterior (position of the anterior femoral shield in relation to this measured point). This value turns red as soon as the femoral shield is below this palpated point.

19.3 Display and Control Elements (Center)

1. Stem reminder from the reamer navigation step in the gray ellipse, in this example 7°.

2. Femoral implant of size 5 with distal implant thickness of 8.5 mm for e.motion® (not sold in the USA).

3. Total height of the tibial component (metal plate with PE inlay), in this example 10 mm.

4. Orange crosshairs line. The crosshairs represent a virtual pointer (virtual mouse).

5. White arrow tip: If the white arrow tip is selected, the system can be switched to the next step by briefly pressing the right foot pedal. This can also be achieved once planning has been completed by prolonged pressing of the foot pedal.

6. Recycle bin: If the recycle bin is selected, all modified values are reset to the values originally calculated by the software by briefly pressing the right foot pedal. This step should be carried out if completely new planning is desired.

7. Switching to femoral augmentation planning and back again.
20. Augmentation Planning and Distal Femur Cut

20.1 Control

Augmentation planning is accessed via the “Augmentation” button. Yellow columns and numbers represent negative bone cuts, (i.e. resection is carried out distal to the defect point, which can indicate that an augment needs to be used).

20.2 In Extension

1. Lateral and medial resection height at the distal femur, in this example 1 mm laterally and -1 mm medially.
2. Selected augments for the medial and lateral condyle distally.
3. Change with respect to the planned joint line, in this example 0 mm, is displayed in the white rectangle.
20.3 In Flexion

1. Lateral and medial resection height at the posterior femoral condyles, in this example 3 mm laterally and 4 mm medially.

2. Selected augments for the medial and lateral condyle posterior.

3. Rotational position of the femoral prosthesis, in this example 0° external rotation, is displayed in the white ellipse in relation to the recorded posterior condyles of the primary implant.

4. Anterior cutting height (notching), in this example 0 mm, in relation to the point palpated anterior (position of the anterior femoral shield in relation to this measured point). This value turns red as soon as the femoral shield is below this palpated point.

20.4 Display and Control Elements (Center)

1. Stem reminder from the reamer navigation step in the gray ellipse, for this example is 7°.

2. Size 5 femoral implant.

3. Total height of the tibial component (metal tibia plate with PE inlay), in this example is 10 mm.

4. Orange crosshairs line. The crosshairs represent a virtual pointer (virtual mouse).

5. White arrow tip: If the white arrow tip is selected, the system can be switched to the next step by briefly pressing the right foot pedal. This can also be achieved once planning has been completed by prolonged pressing of the foot pedal.

6. Recycle bin: If the recycle bin is selected, all modified values are reset to the values originally calculated by the software by briefly pressing the right foot pedal. This step should be carried out if completely new planning is desired.

7. Switching to femoral planning and back again.
21. Distal Femur Resection, Control and Rotational Alignment

21.1 Distal Femur Resection

Attach the 5°, 6° or 7° femoral angled sleeve most appropriate for the situation to the reamer from the step “Registering the femoral diaphysis”, which was last selected and is still inserted in the femur. The distal femur resection guide (NQ704R - Columbus®) is fitted with the yellow transmitter (FS633 - passive or FS601 - active). With the help of the connecting element (NE171R), the cutting guide is connected via the cutting slot to the 5°, 6° or 7° femoral sleeve attached to the reamer.

Because of the connection to the intramedullary reamer which is fixed in position, the varus/valgus angle and the slope can no longer be modified. The precise resection height in relation to the bony reference points palpated on the distal femoral condyles medially and laterally is determined by moving the cutting guide in a proximal or distal direction.

The target values are those which were selected during femoral planning. If these values are reached in terms of varus/valgus angle, resection height, joint line and slope, the color of the ellipses in which the values are displayed changes to green.

If the step “Registering the femoral diaphysis” was skipped by prolonged pressing of the pedal, the distal femoral cutting guide with the yellow-marked transmitter attached can be freely navigated to the desired varus/valgus and slope value in relation to the mechanical axis. The alignment of the femoral diaphysis and the medullary channel are not taken into account in this procedure. The height of the femoral resection can be navigated to the points previously recorded. Possible deviations from the joint line planned in the femoral planning screen on the basis of given cutting guide alignment appear in the center of the screen. These appear green when the planned values are reached.

TIP

In order to avoid contamination of the marker spheres on the transmitters, it is advisable to either remove the transmitters or to cover them appropriately until resection has been completed.
The femoral cutting guide is initially fixed from the anterior side using two headless screw pins, after which the connecting element to the reamer and the reamer itself are removed. The cutting guide can now still be relocated via the available pin holes. When the desired resection height has been set, the cutting guide is additionally fixed medially and laterally via oblique headed pins, and the resection can then be carried out.

**TIP**

The cutting guide slot labeled “0” is decisive for regular resection, and the 5, 10 or 15 mm cutting slot (Columbus) must be selected in cases where augments are needed.

21.2 Reassessing the Distal Resection

After reassessing the distal femur resection using the 4-in-1 cutting guide (NQ721R-NQ728R Columbus), rotational adjustment and AP positioning is carried out in accordance with prior planning. In order to record accurate values, the respective trial augment must be placed underneath the 4-in-1 cutting guide for measurement in cases where distal augments have been prepared.
21.3 Setting the Rotational Alignment

In addition to showing the rotation in relation to the recorded distal condyles of the implant in position, the screen also displays the rotational position in relation to the registered epicondyles. The AP position in relation to the anterior cortical point as well as the posterior cutting height with indication of the planned augments and the resultant remaining gap distances in flexion are also displayed.

After the desired position has been reached, the 4-in-1 cutting guide is fixed distally in the bone with two pins. The reamer can be removed via the 4-in-1 guide, provided its diameter does not exceed 16 mm. For larger diameters, the cutting guide must be removed for removal of the reamer and must subsequently be refitted onto the two pins. The cutting guide is additionally fixed from the medial and lateral sides using oblique pins. After removal of the distal pins, the cuts can be performed in the sequence anterior, posterior, followed by the oblique cuts. The cutting display for the posterior cut refers to the cutting slot marked "0". Only if posterior augmentation is planned should the cutting slot marked 5, 10 or 15 mm (Columbus®) be selected.

After completing resection, implantation can now be performed, at first with trial implants and then with the final implants. Instrumentation and implant assembly is implemented as described in the surgical technique for Columbus Revision DOC1022.
The mechanical axis achieved postoperatively (varus/valgus angle) as well as the maximum possible extension of the leg can now be checked using trial implants and at the end using the final implant. A documented result of the surgery is provided, which can be attached to the patient file, if desired.
23. Femur First Technique

23.1 Registering the Femoral Diaphysis

At this stage of the surgical procedure, the alignment of the femoral diaphysis is determined, just as for the tibia, by means of reamers of different diameters, (i.e. the angle between mechanical axis and femoral diaphysis as indicated). This value in turn indicates which angled stem should ideally be selected in order to avoid ending up with a femoral distal varus or valgus cut.

Corrections can, to a minor extent, be achieved here as well in the course of femoral shaft preparation of the diaphysis via the different reamers which are always introduced under navigation control.

**TIP**

The target value is either 5°, 6° or 7°, since angled stems are available for these angles in the Columbus® implant system (5° and 7° for pressfit, 6° for cemented).

*Note: Please follow all steps up to and including Chapter 12.3.*
23.2 Registering the Femoral Bone Situation
The objective of the following steps is to use the pointer to register the distal and posterior condylar defects for augmentation planning later. The data is recorded in the following sequence:
- Posterior condyle, medial
- Posterior condyle, lateral
- Distal condyle, medial
- Distal condyle, lateral

The values displayed for the two distal palpations are the distances in millimeters from the respective bone palpations to the planned femoral joint line. This distance must be filled out by the implant (distal implant thickness) together with appropriate augments.
23. Femur First Technique (continued)

23.3 Distal Femur Resection

Attach the 5°, 6° or 7° femoral angled sleeve most appropriate for the situation to the reamer from the step "Registering the femoral diaphysis", which was last selected and is still inserted in the femur. The distal femur resection guide (NQ704R - Columbus®) is fitted with the yellow transmitter (FS633 - passive or FS601 - active). With the help of the connecting element (NE171R), the cutting guide is connected via the cutting slot to the 5°, 6° or 7° femoral sleeve attached to the reamer.

Because of the connection to the intramedullary reamer which is fixed in position, the varus/valgus angle and the slope can no longer be modified. The precise resection height in relation to the bony reference points palpated on the distal femoral condyles medially and laterally is determined by moving the cutting guide in a proximal or distal direction.

The target values are those which were selected during femoral planning. If these values are reached in terms of varus/valgus angle, resection height, joint line and slope, the color of the ellipses in which the values are displayed changes to green.

If the step “Registering the femoral diaphysis” was skipped by prolonged pressing of the pedal, the distal femoral cutting guide with the yellow-marked transmitter attached can be freely navigated to the desired varus/valgus and slope value in relation to the mechanical axis. The alignment of the femoral diaphysis and the medullary channel are not taken into account in this procedure. The height of the femoral resection can be navigated to the points previously recorded. Possible deviations from the joint line planned in the femoral planning screen on the basis of given cutting guide alignment appear in the center of the screen. These appear green when the planned values are reached.

**TIP**

In order to avoid contamination of the marker spheres on the transmitters, it is advisable to either remove the transmitters or to cover them appropriately until resection has been completed.
The femoral cutting guide is initially fixed from the anterior side using two headless screw pins, after which the connecting element to the reamer and the reamer itself are removed. The cutting guide can now still be relocated via the available pin holes. When the desired resection height has been set, the cutting guide is additionally fixed medially and laterally via oblique headed pins, and the resection can then be carried out.

**TIP**

The cutting slot labeled "0" is decisive for regular resection, and the 5, 10 or 15 mm cutting slot (Columbus) must be selected in cases where augments are needed.

**23.4 Reassessing the Distal Resection**

After reassessing the distal femur resection using the 4-in-1 cutting guide (NQ721R - NQ728R Columbus), rotational adjustment and AP positioning is carried out in accordance with prior planning. In order to record accurate values, the respective trial augment must be placed underneath the 4-in-1 cutting guide for measurement in cases where distal augmentations have been prepared.
23.5 Setting the Rotational Alignment

In addition to showing the rotation in relation to the recorded distal condyles of the implant in position, the screen also displays the rotational position in relation to the registered epicondyles. The AP position in relation to the anterior cortical point as well as the posterior cutting height with indication of the planned augments and the resultant remaining gap distances in flexion are also displayed.

After the desired position has been reached, the 4-in-1 cutting guide is fixed distally in the bone with two pins. The reamer can be removed via the 4-in-1 guide, provided its diameter does not exceed 16 mm. For larger diameters, the cutting guide must be removed for removal of the reamer and must subsequently be refitted onto the two pins. The cutting guide is additionally fixed from the medial and lateral sides using oblique pins. After removal of the distal pins, the cuts can be performed in the sequence anterior, posterior, followed by the oblique cuts. The cutting display for the posterior cut refers to the cutting slot marked "0". Only if posterior augmentation is planned should the cutting slot marked 5, 10 or 15 mm (Columbus®) be selected.

After completing resection, implantation can now be performed, at first with trial implants and then with the final implants. Instrumentation and implant assembly is implemented as described in the surgical technique for Columbus Revision DOC1022.

**Note:** After preparation of the femur, the procedure is continued by following the steps described in Chapters 13–15. The subsection 15.1 does not apply to the femur first technique, as the size of the femoral component was already determined beforehand.

The final display and reassessment of the postoperative mechanical axis is analogous to Chapter 22 of the tibia first technique.
The mechanical axis achieved postoperatively (varus/valgus angle) as well as the maximum possible extension of the leg can now be checked using trial implants and at the end using the final implant. A documented result of the surgery is provided, which can be attached to the patient file, if desired.
### 25. Instrument Set Overview – OrthoPilot® TKR

**ST1002 – OrthoPilot Navigation Instrument Set**

<table>
<thead>
<tr>
<th>Index</th>
<th>Qty.</th>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>NE191R</td>
<td>Rigid Body C-Hook</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>NE163R</td>
<td>Rigid Body C-Hook, Small</td>
</tr>
<tr>
<td>C</td>
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<td>NE191801</td>
<td>Rigid Body Adapter</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>NE192R</td>
<td>Revision Tibia Rigid Body Adapter, Offset</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>NE199R</td>
<td>Revision Navigation Adapter for T-Handle</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>NE190R</td>
<td>Sliding Link Block 0° for Tibia Cutting Guide</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td>NE171R</td>
<td>Revision Adapter for Distal Cutting Guide</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>NE445R</td>
<td>Sliding Link Block 5° Femoral Alignment Guide</td>
</tr>
<tr>
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<td>1</td>
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<td>Sliding Link Block 6° Femoral Alignment Guide</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>NE447R</td>
<td>Sliding Link Block 7° Femoral Alignment Guide</td>
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<td>NE324T</td>
<td>Columbus Femoral Orientation Guide</td>
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<td>Post. Footplate L</td>
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<tr>
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<td>Post. Footplate R</td>
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<table>
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</thead>
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<td>OrthoPilot Passive Transmitter (Red)</td>
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<td>1</td>
<td>FS604</td>
<td>OrthoPilot Straight Pointer</td>
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<td>1</td>
<td>NP617R</td>
<td>OrthoPilot Cut Check Plate</td>
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<td>1</td>
<td>NM476R</td>
<td>OrthoPilot Transmitter Base Plate</td>
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<td>2</td>
<td>NM743</td>
<td>OrthoPilot Elastic Foot Strap</td>
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<td>NQ595R</td>
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</table>

### 26. Software – OrthoPilot TKR Columbus®

**Software Module**

OrthoPilot TKR Columbus | FS222
27. Schematic Program Flow TKR 1.2

27.1 Schematic Program Flow – Tibia First

- Input patient data
- Operating field, instrument selection
- Preoperative joint line planning
- Knee center registration
- Hip center registration
- Feasibility check of mL DFA

Regular

- Knee center registration
- Reference point tibial joint line
- Reference point femoral joint line
- Registration medial posterior condyle
- Registration lateral posterior condyle
- Registration anterior cortical point
- Registration medial malleolus
- Registration lateral malleolus
- Registration anterior ankle joint point
Mechanical axis pre-OP

Registration distal and posterior condyles

New rotational position

Registration bony situation tibial

Registration tibial diaphysis

Planning of tibia cut

Check tibia size

Registration tibia cut

Registration medial posterior condyle

Registration lateral posterior condyle

Registration medial distal condyle

Registration lateral distal condyle

Registration joint gap in extension

Registration joint gap in flexion

Registration femoral diaphysis

Femoral planning

Planning distal femur cut

Registration femoral cut

Setting 4-in-1 femoral cutting guide

Mechanical axis post-OP
27. Schematic Program Flow TKR 1.2

27.2 Schematic Program Flow – Femur First

- Input patient data
- Operating field, instrument selection
- Preoperative joint line planning
- Knee center registration
- Hip center registration
- Feasibility check of mLDFA
- Ankle center registration
- Knee center registration
- Knee center registration
- Reference point tibial joint line
- Reference point femoral joint line
- Registration medial posterior condyle
- Registration lateral posterior condyle
- Registration anterior cortical point
- Registration medial malleolus
- Registration lateral malleolus
- Registration anterior ankle joint point
Registration femoral cut

New rotational position

Registration distal and posterior condyles

Registration femoral diaphysis

Registration medial posterior condyle

Registration lateral posterior condyle

Registration medial distal condyle

Registration lateral distal condyle

Planning distal femur cut

Registration femoral cut

Setting 4-in-1 femoral cutting guide

Registration tibial diaphysis

Planning of tibia cut

Registration tibia cut

Mechanical axis post-OP