Supplement 2 - Surgical Technique

General Surgical Principles

1. **Anaesthesia** – Spinal anaesthesia, epidural anaesthesia, GA, or combined permissible.

2. **Tourniquet Use** – Surgeon preference (not used / partial use / full use).

3. **Surgical approach**
   - Medial parapatellar arthrotomy
   - Minimal medial elevation of capsule to mid sagittal plane
   - Resection of ACL prior to pre-resection knee gap balancing

4. **Prosthesis**
   - Stryker Triathlon cruciate-retaining (CR) system
   - Fully cemented femoral, tibial and patellar fixation in all cases
   - Routine patellar resurfacing with oval, onlay cemented implant in all cases unless maximal pre-resection bone thickness ≤ 15mm
   - Stability
     - CR articular insert in all cases
     - Conversion to cruciate-substituting (CS) or posterior-stabilised (PS) permitted only if PCL found to be incompetent

5. **Alignment Systems**
   - Computer-Assisted Surgery (CAS) system – Precision-3 full optical
   - Robotic-Arm Assisted Surgery (RAS) system - MAKO

6. **Alignment Definitions and Landmarks**
Mechanical Alignment (MA): standardised positioning of implants relative to fixed, non-articular, anatomic landmarks to recreate a neutral hip-knee-ankle (HKA) angle, neutral joint line obliquity (JLO) with compensatory femoral component external rotation.

Kinematic Alignment (KA): individualised positioning of implants based off articular landmarks within a restricted boundary alignment protocol. As the RAS+KA group also includes pre-resection gap balancing, and both CAS+KA and RAS+KA have restricted alignment boundaries, the final implant positioning may more closely approximate a “functional position” (Oussedik et al BJJ March, 2020) in some participants. The term, KA however will be used for these two study groups, however it is recognised adjustments towards a non-anatomically resurfaced, functional position from gap balancing and restricted alignment boundaries may result.

Femoral mechanical axis: The line connecting the hip centre to the centre of the femur at the knee.

Surgical Transepicondylar Axis (TEA): line connecting lateral epicondylar eminence and the medial epicondylar sulcus.

Tibia Mechanical Axis: line connecting the ‘tibia knee centre’ to the ‘ankle centre’. ‘Ankle Centre’ is computed from the collection of the medial and lateral malleoli landmarks. The malleoli landmarks are located on the outermost bony protuberances.

Tibia Anteroposterior (AP) Axis: a line connecting the PCL centre to the medial border of the patellar tendon.

Tibia Mediolateral (ML) Axis: The ‘Tibia ML Axis’ is perpendicular to the ‘Tibia AP Axis’.

Arithmetic hip-knee-ankle angle (aHKA): an estimation of constitutional (pre-
arthritic) knee alignment derived from subtracting the lateral distal femoral angle (LDFA) from the medial proximal tibial angle (MPTA) (Bone Joint Open July, 2020.)

7. Sizing of implants

- The femoral implant is to be within 1 size of the tibial implant.
- Sizing of the femur is determined by:
  - restoring AP dimensions with anterior cut run out to exit at tip of implant
  - maximising ML coverage without overhang
  - matching constitutional medial femoral condylar radius of curvature to implant femoral component (RAS arms)
  - restoring trochlear depth (RAS arms)
- The tibial implant, once aligned to the tibial AP axis, is to be sized for maximal ML coverage without overhang in any region. Downsizing may be required, whilst ensuring femoral-tibial implant matching.
- The patellar implant size is to be determined with the largest implant that reaches either the proximal-distal or ML cortical rim without overhang.

8. Computed Tomographic (CT) Imaging and Intraoperative CAS Resection Landmarks

- Distal femoral resection landmarks:
  - The distal resection landmarks are located on the most distal point of the medial and lateral distal condyles, avoiding osteophytes.
- Posterior resection landmarks:
  - The posterior resection landmarks are located on the most posterior aspect of the medial and lateral distal condyles, avoiding osteophytes.
• Tibia resection landmarks:
  o Location approximately 2/3 posterior AP distance of the medial and lateral plateau, such that the landmarks are near the insert low point.
  o Points to lie in the same approximate sagittal plane and are centered in the medial and lateral compartments in the coronal plane.

9. Initial resection angles

• CAS+MA and RAS+MA cohorts
  o All resection angles to be based off fixed angular resections as per group Summary Tables.
  o Femoral sagittal resection angle is variable (0-6°) with start point of 5° for females and 3° for males.

• CAS+KA and RAS+KA cohorts
  o Initial resection angles determined by:
    ▪ **CAS+KA:** *Preoperative* bilateral long-leg weight bearing radiographs used for matched bone resections utilising the measured lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA). Femoral rotation is set intraoperatively parallel to the posterior condylar axis.
    ▪ **RAS+KA:** *Intraoperative* CT-based planning using matched distal femoral, posterior femoral and proximal tibial resections in MAKO planning screen.
  o CAS+KA measurements determined by blinded orthopaedic surgeon investigator who is not part of the RASKAL Surgeon Group.
    ▪ Operative plan provided will include LDFA, MPTA, mechanical HKA (angle subtended by mechanical axes of femur and tibia on
long-leg radiographs), aHKA, Femoral Coronal Resection Angle (FCRA), Tibial Coronal Resection Angle (TCRA), Tibial Sagittal Resection Angle (TSRA), Femoral Rotation Resection Angle (FRRA)

- Femoral Sagittal Resection Angle (FSRA) is variable (0-6°) with start point of 5° for females and 3° for males.
- Tibial Rotation Angle (TRA) is centred on AP axis from centre of PCL footprint to medial border patellar tendon.

10. Final alignment targets

- **Validated implant position:** aim to be within +/- 1° of alignment targets for MA groups and adjusted (pre-resection) targets for KA groups.
- **Final HKA:** aim to be within +/- 1° boundary, then:
  - accept and record if within +/- 2° for target HKA.
  - if outside this then aim to correct to bring within +/- 2°.
- **Final knee flexion angle:** To be within +/- 3° of full extension.

11. Initial and definitive alignment measurements

- In all four groups, the following alignments will be recorded:
  1) validated resection angles (FCRA, TCRA, FSRA, TSRA, FRRA)
  2) final HKA and final knee flexion angle with definitive polyethylene insert in situ

12. Sensor compartmental load measurements

- After cementation of definitive femoral and tibial prostheses, and prior to insertion of definitive articular insert, the Verasense pressure sensor instrument
(Orthosensor, FL, USA) of the same final size and articular thickness will be inserted.

- Two towel clips will approximate the extensor mechanism.
- Surgeon is to be blinded to measurements with screened turned away from surgical field.
- Measurements will be recorded at 10°, 45° and 90°.
- The insert will be removed after the first measurements, the insert recalibrated, and measurements will be repeated.
- The mean of the 2 measures will be used.
- If the research officer believes that the sensor has an “overload” error, the surgeon will be asked to recalibrate the sensor.

1. Computer-Assisted Surgery and Mechanical Alignment (CAS+MA) Cohort

**Rationale:** CAS+MA serves as the control for both factorial groups. Coronal bone resections are performed perpendicularly to the MA of the femur and tibia. Rotation of the femoral component is parallel to the surgical TEA with secondary referencing to the femoral AP axis.

**Balancing Methodology:**

- Soft tissue releases only. No bone alignment adjustments are allowed.
- Use of gap balance data provided by CAS is allowed to undertake knee balancing.

**CAS+MA Summary Table:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alignment Targets</th>
</tr>
</thead>
</table>

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<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>HKA Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Femoral Coronal Resection Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Femoral Sagittal Resection Angle</td>
<td>0°-6°</td>
</tr>
<tr>
<td>Femoral Rotational Resection Angle</td>
<td>Primary - Parallel to surgical TEA</td>
</tr>
<tr>
<td></td>
<td>Secondary - perpendicular to femoral AP axis, 3° ER to posterior condylar axis (PCA)</td>
</tr>
<tr>
<td>Tibial Coronal Resection Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Tibial Sagittal Resection Angle</td>
<td>0°-6° posterior slope</td>
</tr>
<tr>
<td>Tibial Rotational Angle</td>
<td>Tibial AP Axis - Centre of PCL footprint to medial border patellar tendon</td>
</tr>
<tr>
<td>Combined Sagittal Resection Angle (FSRA + TSRA)</td>
<td>If tibial size &lt; femoral size, 8° combined flexion</td>
</tr>
<tr>
<td></td>
<td>If tibial size ≥ femoral size, 10° combined flexion</td>
</tr>
<tr>
<td>Resection Depths (In CAS arms, resections depths based off cartilage)</td>
<td>Medial distal femoral resection – 8mm if no significant chondral wear, 6mm if worn to subchondral bone. (Note 6mm for RAS+MA group). The lateral distal femoral resection depth is resultant.</td>
</tr>
<tr>
<td></td>
<td>Posterior medial femoral resection – 8mm if no significant chondral wear, 6mm if worn to</td>
</tr>
<tr>
<td>Knee Balancing at 10° and 90°</td>
<td>Soft tissue releases only</td>
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<tr>
<td>------------------------------</td>
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<tr>
<td>Aim to achieve:</td>
<td></td>
</tr>
<tr>
<td>10°: Lateral gap 0-2mm ≥ medial gap</td>
<td></td>
</tr>
<tr>
<td>90°: Lateral gap 0-6mm ≥ medial gap</td>
<td></td>
</tr>
<tr>
<td>Balancing Method</td>
<td>Soft tissue release algorithm</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Medial tightness in extension → pie-crust posterior fibres MCL at 10° then semimembranosus and posteromedial capsule release</td>
</tr>
<tr>
<td></td>
<td>• Medial tightness in flexion → pie-crust anterior fibres MCL at 90°</td>
</tr>
<tr>
<td></td>
<td>• Lateral tightness in extension → release arcuate ligament followed by ITB</td>
</tr>
<tr>
<td></td>
<td>• Lateral tightness in flexion → release popliteus off femur followed by LCL</td>
</tr>
</tbody>
</table>
Final Extension Range of Motion

+/- 3° of full extension

Operative Technique:

1. Remove osteophytes, resect ACL.

2. Perform CAS Registration of bony landmarks.

3. Record the following alignments with extensor mechanism clipped
   
   1. Resting HKA
   
   2. Knee flexion angle
   
   3. Corrected (stressed) alignment with knee 10° (+/- 5°)
   
   4. Record flexion stress curve

4. Set Femoral Positions at “Modify Implant Position Screen”
   
   - Input 0° femoral coronal angle (Var./Val.)
5. Perform and validate distal femoral resection

6. Perform and validate tibial resection

7. Insert 17-18mm spacer block into extension space and check

   - HKA target of 0° achieved
   - Knee extension adequate
     - Aim ≤5° flexion at this stage
     - *Only consider* 2mm distal femoral resection if navigated FFD > 10°
○ *Only consider* 2mm proximal tibial resection if all of the following present:
  
  i.  navigated FFD 6-10°
  
  ii.  femoral resection thicknesses at least 8mm on high side
  
  iii.  flexion space also tight with use of 9mm space block
  
  iv.  volume of posterior osteophytes not significant (ie FFD would likely improve with removal of large osteophytes)

8. Complete and validate 4-in-1 femoral resections and validate from posterior condylar resection

![Image of femoral resection software interface]

9. Trial implants

- Maximum size articular insert to achieve extension (0°+/- 3°)

- Perform gap balance assessment in extension
- Perform gap balance in flexion

9. Soft tissue balancing as per CAS-MA Summary Table if required

10. Insert definitive femoral, tibial and patellar implants

  - Measure sensor pressures twice with screen turned away from surgeon to maintain blinding
  - Insert definitive articular insert and record final HKA and knee extension angle
2. Computer-Assisted Surgery and Kinematic Alignment (CAS+KA) Group

Rationale: The CAS+KA cohort represents a restricted boundary KA technique. The surgeon will be provided with a plain radiographic preoperative KA plan, as CAS is considered an imageless (non-CT derived) technique.

Balancing Methodology:

- Initial balance assessment once osteophytes removed and navigation planning undertaken.
- Adjustments permitted to initial KA start plan and will be recorded.

CAS-KA Summary Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alignment Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKA Angle</td>
<td>6° varus to 3° valgus</td>
</tr>
<tr>
<td>Femoral Coronal Resection Angle</td>
<td>6° valgus to 3° varus</td>
</tr>
<tr>
<td>Femoral Sagittal Resection Angle</td>
<td>0° to 6° flexion</td>
</tr>
<tr>
<td>Femoral Rotational Resection Angle</td>
<td>Boundaries: -6° IR to + 6° ER to surgical TEA</td>
</tr>
<tr>
<td></td>
<td>Set parallel to posterior condylar axis (0° to PCA assuming cartilage intact, with matched posterior condylar resections). Adjusted if needed according to balancing protocol</td>
</tr>
<tr>
<td><strong>Tibial Coronal Resection Angle</strong></td>
<td>6° varus to 3° valgus</td>
</tr>
<tr>
<td>----------------------------------</td>
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</tr>
<tr>
<td><strong>Tibial Sagittal Resection Angle</strong></td>
<td>0° to 6° flexion</td>
</tr>
<tr>
<td><strong>Tibial Rotational Angle</strong></td>
<td>Tibial AP Axis - Centre of PCL footprint to medial border patellar tendon</td>
</tr>
<tr>
<td><strong>Combined Sagittal Resection Angle</strong> (FSRA + TSRA)</td>
<td>If tibial size &lt; femoral size, 8° combined flexion</td>
</tr>
<tr>
<td></td>
<td>If tibial size ≥ femoral size, 10° combined flexion</td>
</tr>
<tr>
<td><strong>Resection Depths</strong></td>
<td>Maximal distal femoral resection – 8mm (note 6.5mm for RAS-KA) off highest side depending on osteochondral wear pattern. Resections will be equal if similar depth of cartilage loss on both condyles.</td>
</tr>
<tr>
<td></td>
<td>Maximal posterior femoral resection – 8mm (note 6.5mm for RAS-KA). Resections will be equal if similar depth of cartilage loss on both condyles.</td>
</tr>
<tr>
<td></td>
<td>Proximal lateral tibial resection - 9mm resection set off chondral surface of highest plateau (usually lateral) in varus knee to create a resection plane parallel to the patient’s tibial joint line (7mm for RAS-KA due to bone surface reference). For valgus knees, 7mm thickness off medial plateau (note 5mm for RAS-KA).</td>
</tr>
<tr>
<td><strong>Acceptable stressed gap differences</strong> (minimum non-stressed 20mm gaps)</td>
<td>10°: Lateral gap 0-2mm ≥ medial gap</td>
</tr>
<tr>
<td></td>
<td>90°: Lateral gap 0-6mm ≥ medial gap</td>
</tr>
</tbody>
</table>
**Knee Balancing**

1. **bony recut for >2mm gap asymmetry in extension**
   - Consider 1-2° tibial angular correction for unicompartmental tightness if gap asymmetry > 2mm at 10°, and >6mm at 90°
   - Consider 1-2° femoral angular correction if not balanced at 10° only

2. **Consider soft tissue release**
   - if reached restricted alignment boundaries reached for HKA, implant or both
   - unicompartmental tightness in flexion only (to avoid change in 4-1 cuts)

3. **Soft tissue release algorithm**
   - Medial tightness in extension $\rightarrow$ pie-crust posterior fibres MCL at 10° then semimembranosus and posteromedial capsule release
   - Medial tightness in flexion $\rightarrow$ pie-crust anterior fibres MCL at 90°
   - Lateral tightness in extension $\rightarrow$ release arcuate ligament followed by ITB
   - Lateral tightness in flexion $\rightarrow$ release popliteus off femur followed by LCL
Final Extension Range of Motion | +/- 3 degrees of full extension

Operative Technique:

1. Remove osteophytes, resect ACL

2. Perform CAS Registration of all bony landmarks

3. Record the following alignments with extensor mechanism clipped
   - Knee flexion angle
   - Resting HKA
   - Corrected (stressed) alignment with knee 10° (± 5°)
     - Check if corrected (stressed gap) in extension approximates aHKA and final target HKA. Usually the corrected alignment is 1-2 degrees greater than aHKA.
     - This indicates that combined distal femoral and proximal tibial resections should restore extension gap balance (MPTA minus LDFA).
   - Record flexion stress curve
4. Adjust femoral and tibial coronal resection angles based on stressed HKA:
   - Stressed HKA (over aHKA) is the final determinant of target alignment
   - If stressed HKA = aHKA within +/- 2°, then use FCRA and TCRA as per preop plan.
   - If stressed HKA < aHKA (more varus), then increase TCRA into more varus.
     - Eg if stressed HKA = -5 degrees varus, aHKA = -2 degrees varus, then increase planned tibial resection by a further 3 degrees of varus without exceeding TCRA boundaries.
   - If stressed HKA > aHKA (more valgus), then increase FCRA into more valgus.
     - Eg if Stressed HKA = 2° valgus, aHKA = -1° varus, then increase planned femoral resection by a further 3 degrees of valgus without exceeding FCRA boundaries.

5. Set Femoral Positions at “Modify Implant Position Sreen”
   - Input femoral coronal angle (Var./Val.) as per adjusted CAS+KA plan.
- Alter femoral rotational angle (Flex.Var./Val) to obtain symmetrical 8mm posterior resections. This aligns the implant to PCA (as PCA not provided).
  Ignore the rotation angle as this stage as it is the mean of the TEA and AP axis.
- Adjust implant size.
- Adjust femoral flexion angle for sizing (0-6°) and fit.
- Adjust femoral AP and PD shift to achieve resection depth targets.

6. Perform and validate distal femoral resection
7. Complete and validate proximal tibial resection

8. Insert 17-18mm spacer block into extension space and check:
   - HKA target achieved
   - Knee extension adequate
     - Aim minimum 5° flexion at this stage, depending on volume of posterior osteophytes
- Only consider symmetric 2mm distal femoral resection if navigated FFD > 10°
- Only consider symmetric 2mm proximal tibial resection if all of the following are present: 1. navigated FFD 6-10°, 2. femoral resection thicknesses at least 8mm, and 3. volume of posterior osteophytes not significant.

- Varus-valgus stressed gaps relative to ideal gaps

9. Complete 4-in-1 femoral resections

- Use of femoral sizing guide set to 0° to PCA (can also navigate position aiming for 8mm matched posterior resections) if cartilage intact on both posterior condyles. Adjust rotation to match discrepancies in asymmetric cartilage loss.
- Insert validation tracker in to sizing slot of guide to validate cut run off and size
- Pin cutting block
- Check 4-in-1 cutting guide alignment prior to resections being performed
- Validate resection angles (FSRA, FRRA) using posterior condyles
12. Trial implants

Maximum size insert to achieve extension (0° +/- 3°)

Perform gap balance assessment in extension

Perform gap balance in flexion
12. Balance knee as per CAS+KA Summary Table if required.

13. Insert definitive femoral, tibial and patellar implants

- Measure sensor pressures twice with screen turned away from surgeon to maintain blinding
- Insert definitive articular insert and record final HKA and knee flexion angle
3. Robotic-Assisted Surgery and Mechanical Alignment (RAS+MA) Group

**Rationale:** RAS+MA is the second control group for comparison against KA. In addition, this factorial group will test whether RAS haptic boundaries reduce postoperative analgesia consumption and improves early patient outcomes due to a reduction in soft tissue trauma compared to CAS+MA. Preoperative planning software will be set to the MA alignment targets below.

**Knee Balancing:**

- Balancing will be performed with soft tissue releases only. No bone alignment readjustments allowed.
- Use of gap balance data provided by RAS is allowed to achieve knee balance.

**RAS+MA Summary Table:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alignment Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKA Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Femoral Coronal Resection Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Femoral Sagittal Resection Angle</td>
<td>0°-6°</td>
</tr>
<tr>
<td>Femoral Rotational Resection Angle</td>
<td>Primary - Parallel to surgical TEA</td>
</tr>
<tr>
<td>Tibial Coronal Resection Angle</td>
<td>0°</td>
</tr>
<tr>
<td>Tibial Sagittal Resection Angle</td>
<td>0°-6° matched to lateral tibial plateau</td>
</tr>
<tr>
<td>Tibial Rotational Angle</td>
<td>Tibial AP Axis - Centre of PCL footprint to medial border patellar tendon</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Combined Sagittal Resection Angle (FSRA + TSRA)</td>
<td>If tibial size &lt; femoral size, 8° combined flexion</td>
</tr>
<tr>
<td></td>
<td>If tibial size ≥ femoral size, 10° combined flexion</td>
</tr>
<tr>
<td>Resection Depths</td>
<td>Medial distal femoral resection – 6.5mm off subchondral bone (note 8mm for CAS-MA assuming cartilage intact). The lateral distal femoral resection is resultant.</td>
</tr>
<tr>
<td></td>
<td>Posterior medial femoral resection – 6.5mm off subchondral bone (note 8mm for CAS-MA assuming cartilage intact). The lateral posterior femoral resection is resultant.</td>
</tr>
<tr>
<td></td>
<td>Proximal lateral tibial resection – 7mm thickness for varus knee (note 9mm for CAS-MA). For valgus knees, 5mm thickness off medial plateau (note 7mm for CAS-MA)</td>
</tr>
<tr>
<td>Knee Balancing at 10° and 90°</td>
<td>Soft tissue releases only</td>
</tr>
<tr>
<td></td>
<td>Aim to achieve gap asymmetry ≤ 2mm</td>
</tr>
<tr>
<td>Balancing Method</td>
<td>Soft tissue release algorithm</td>
</tr>
<tr>
<td></td>
<td>• Medial tightness in extension ➔ pie-crust posterior fibres MCL at 10° then semimembranosus and posteromedial capsule release</td>
</tr>
<tr>
<td></td>
<td>• Medial tightness in flexion ➔ pie-crust anterior</td>
</tr>
</tbody>
</table>
fibres MCL at 90°

- Lateral tightness in extension → release arcuate ligament followed by ITB
- Lateral tightness in flexion → release popliteus off femur followed by LCL

| Final Extension Range of Motion | +/- 3 degrees of full extension |

Operative Technique:

1. Preoperative input of MA start plan
2. Resect ACL, menisci
3. Perform RAS Bone Registration
4. Remove osteophytes
5. Record the following alignments with extensor mechanism clipped
   - Resting HKA
   - Knee flexion angle
   - Corrected (stressed) alignment with knee at 10° (+/- 5°)
6. Record virtual gap balancing at 10° and 90°
7. Perform robotic-arm assisted MA femoral and tibial resections and validate cuts to within 1°
8. Trial implants
   - Maximum size insert to achieve extension (0° +/- 3°)
   - Perform gap balance assessment in extension
   - Perform gap balance assessment in flexion
9. Soft tissue balancing as per RAS-MA Summary Table if required
10. Insert definitive femoral, tibial and patellar implants

- Measure sensor pressures twice with screen turned away from surgeon to maintain blinding
- Insert definitive articular insert and record final HKA and knee flexion angle
4. Robotic-Assisted Surgery and Kinematic Alignment (RAS-KA) Group

Rationale: RAS+KA is the intervention arm for both surgical assistance and alignment groups. Alignment in this group is set intraoperatively by MPS and surgeon using matched resections. The only adjustments to the matched resections start plan is if restricted KA boundaries are exceeded. Secondary functional implant positioning is achieved by virtually gap balancing of the knee prior to bone resections.

RAS+KA Summary Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alignment Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKA Angle</td>
<td>6° varus to 3° valgus</td>
</tr>
<tr>
<td>Femoral Coronal Resection Angle</td>
<td>6° valgus to 3° varus</td>
</tr>
<tr>
<td>Femoral Sagittal Resection Angle</td>
<td>0°-6° flexion</td>
</tr>
<tr>
<td>Femoral Rotational Resection Angle</td>
<td>Boundaries -6° IR to + 6° ER to surgical TEA</td>
</tr>
<tr>
<td></td>
<td>Primary -set parallel to PCA (using 6.5mm matched resections) then adjusted according to intraoperative gap balancing targets</td>
</tr>
<tr>
<td>Tibial Coronal Resection Angle</td>
<td>6° varus to 3° valgus</td>
</tr>
<tr>
<td>Tibial Sagittal Resection Angle</td>
<td>0-6 flexion° matched to lateral tibial plateau</td>
</tr>
<tr>
<td>Tibial Rotational Angle</td>
<td>Tibial AP Axis - Centre of PCL footprint to medial border patellar tendon</td>
</tr>
<tr>
<td>Combined Sagittal Resection Angle</td>
<td>If tibial size &lt; femoral size 8° combined flexion</td>
</tr>
</tbody>
</table>
If tibial size ≥ femoral size, 10° combined flexion

**Virtual Gap Balancing Targets**

<table>
<thead>
<tr>
<th>Virtual Gap Balancing Targets</th>
<th>Ideal Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medial</td>
</tr>
<tr>
<td>Extension</td>
<td>20</td>
</tr>
<tr>
<td>Flexion</td>
<td>20</td>
</tr>
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</table>
### Minimum Acceptable Gaps

<table>
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<tr>
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<th>Lateral</th>
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<tbody>
<tr>
<td>Extension</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Flexion</td>
<td>20</td>
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### Maximum Acceptable Gaps

<table>
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<tbody>
<tr>
<td>Extension</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Flexion</td>
<td>20</td>
<td>26</td>
</tr>
</tbody>
</table>

### Final Virtual Gap Balancing

- **1. bony recut for >2mm gap asymmetry in extension**
  - Consider 1-2° femoral angular correction if not balanced at 10° only
  - Consider 1-2° tibial angular correction for unicompartmental tightness if gap asymmetry > 2mm at 10°, and >6mm at 90°

- **2. Consider soft tissue release**
  - a. if reached restricted alignment boundaries for HKA, implant or both
  - b. unicompartmental tightness in flexion only

- **3. Soft tissue releases**
  - Medial tightness in extension $\rightarrow$ pie-crust
posterior fibres MCL at 10° then semimembranosus and posteromedial capsule release

- Medial tightness in flexion $\rightarrow$ pie-crust anterior fibres MCL at 90°
- Lateral tightness in extension $\rightarrow$ release arcuate ligament followed by ITB
- Lateral tightness in flexion $\rightarrow$ release popliteus off femur followed by LCL

| Final Extension Range of Motion | +/- 3° of full extension |

**Operative Technique:**

1. Intraoperative input of KA matched resections and record FCRA, TCRA, and FRRA (relative to sTEA)
2. Resect ACL, menisci
3. Perform RAS Bone Registration
4. Remove osteophytes
5. Record the following alignments with extensor mechanism clipped
   - Resting HKA
   - Knee flexion angle
   - Corrected (stressed) alignment with knee 10° (+/- 5°)
6. Perform virtual gap balancing by adjusting resection angles and depths as per Surgical Summary Table
• Gap balancing will occur to, but not exceed, alignment boundaries

**Achieve extension gap balance first**

• Ideal extension target gaps 20mm lateral; 20mm medial

• Most common scenario to balance extension gap is to alter TCRA (usually increasing varus) by locking centre of rotation laterally. This will also assist in balancing flexion gap as this most commonly tighter medially

• Adjust FCRA if extension gap imbalance only
  - Avoid reducing femoral valgus (increasing LDFA) by more than 2° to minimise lateral column lengthening

**Flexion gap balance**

• Aim for matched medial gaps of 20mm in extension and flexion

• Most common scenario is medial gap tightness. Lock centre of rotation laterally and externally rotate.

• Flexion target gaps 20-26mm lateral; 20mm medial

• Due to vast combinations of alignment adjustments that can lead to a functionally balanced knee, no prescribed algorithm will be enforced; rather there will be a reliance on surgeon expertise, aiming to preserve coronal joint line obliquity in extension in the balancing process as well as following above principles.

7. Perform robotic-arm assisted femoral and tibial resections and validate cuts within 1°.

8. Trial implants

    Maximum size insert to achieve extension (0°+/- 3°)

    Perform gap balance assessment in extension

    Perform gap balance assessment in flexion
9. Balance knee as per RAS+KA Summary Table if required.

10. Insert definitive femoral, tibial and patellar implants

- Measure sensor pressures twice with screen turned away from surgeon to maintain blinding
- Insert definitive articular insert and record final HKA and knee flexion angle