Total Knee Arthroplasty: Steps and Strategies

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Introduction

Although total knee arthroplasty (TKA) is a routine procedure performed in more than a million cases per year worldwide, there are many different approaches to prosthetic design and the method of implantation. Our preferred operative methods for posterior stabilised TKA in varus and valgus knees are described in Chaps. 26 and 27. All described methods help to create a reliable and efficient workflow and standardise the procedure for the surgeon, department, hospital, or region. This reproducibility no doubt has raised minimum standards in many respects.

However, two important issues mean that a simply formulaic approach is undesirable. Firstly, there is significant variability between patients in both original and pathological anatomy, and therefore the details of one operative protocol may not be appropriate to either the individual patient or the ethnicity. The second one relates to the complexity of the procedure. There are multiple implant variables (geometry, sizing and level of constraint, etc.) and surgical variables (order and type of bone cuts and soft tissue releases, instrumentation system, component positioning, etc.), which are interrelated. The operation consists of many individual steps which are sequential and interdependent; each one affects the others. Total knee arthroplasty is like a complex algorithm, but in conventional TKA the procedure is linear; as the procedure progresses, each parameter is set and is often irreversible. The surgeon must therefore constantly reappraise the progress, anticipate the following steps and their effects, and be ready to deviate from the standard protocol because as each is completed, the options become more limited.

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"Like the chess player, the surgeon always has to remain one or more steps in advance."

The problem posed by the multivariate factors in the insertion of the different knee replacement systems may be illustrated by the possible paths passing through the points on a three-dimensional shape (Fig. 25.1). The path may start at any point, and then proceed along different routes until all points have been visited once. Once the first choices are made, there are a diminishing number of routes available; this emphasises the linear nature of the decision-making process. So the surgeon may for instance start at the tibial cut, or either femoral cut, and then proceed in different ways, with further dependent or independent cuts, and making soft tissue releases at different points. How he or she starts will, in turn, affect each one of the other factors. There will be trade-offs in any one chosen sequence, and the best one will minimise the impact on the final result. Many compromises must be made, and the ability to prioritise on the go is essential.

The possible remaining paths may also be predicted at any point with an algorithm, and the subsequent choice of route decided in advance. In this way, computer navigation and interactive robotics allow several steps to be carried out virtually, allowing some prediction of their effect before committing to some of the bone cuts or soft tissue releases. This is a powerful tool and although superior clinical outcomes have yet to be proven, the insights gained are informing the way the equation is understood and used in conventional TKA. Whether in navigated or conventional TKA, the ability to weigh up the options at any given point in the procedure and alter the usual surgical protocol depends on a solid understanding of both the functional anatomy and the logic behind each suggested step. This chapter aims to outline the thinking behind our preferred techniques, and by simplifying the algorithm of TKA to help surgeons improve both the reproducibility and individualisation of the procedure.

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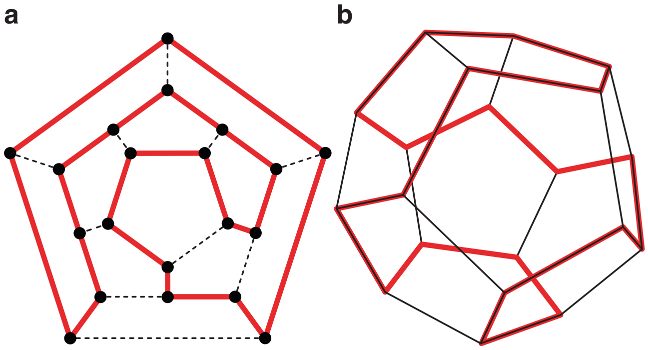


Fig. 25.1 (**a**, **b**) 'Hamiltonian' cycle on a decahedron; 2D and 3D representation. William Hamilton, an Irish mathematician, invented a game in 1857, where pegs were placed in holes on a wooden board showing a 2D representation of a dodecahedron. The challenge was to find a route that would include all points—a traveller visiting all cities just once in a twenty city world. In graph theory, of which this is an example, routes can also be found mathematically with an algorithm

Part I Definitions and Elementary Concepts

The technical goal of TKA is to insert the implants within the soft tissue envelope in such a way as to provide a well-aligned and balanced knee. Alignment and balance are a function of the level and orientation of the bone cuts and appropriately managed soft tissue tension, both of which create the spaces in which to place each component. The aim of this text is an understanding of the individual spaces, and the consequences of both the original deformity and the steps in their creation.

Due to the complexity of both the anatomy and the procedure, it is useful to consider some definitions and concepts, and these are covered in this first part. In Part II, we describe the fundamental concept of separate tibial and femoral spaces, which is the basis of our strategy. In Part III, we look at these spaces in the context of the priorities and principles of the procedure, and in Part IV, how this informs our daily practice.

Deformity

Apart from soft tissue laxity or contracture, deformity due to bone or cartilage pathology may be of two types:

- Intra-articular
  This is usually due to wear of the cartilage or bone (Fig. 25.2), or less commonly subchondral collapse due to avascular necrosis or intra-articular fracture (Fig. 25.3). Typically, the deformity can be corrected passively, and alignment and balance can be achieved without soft tissue management.

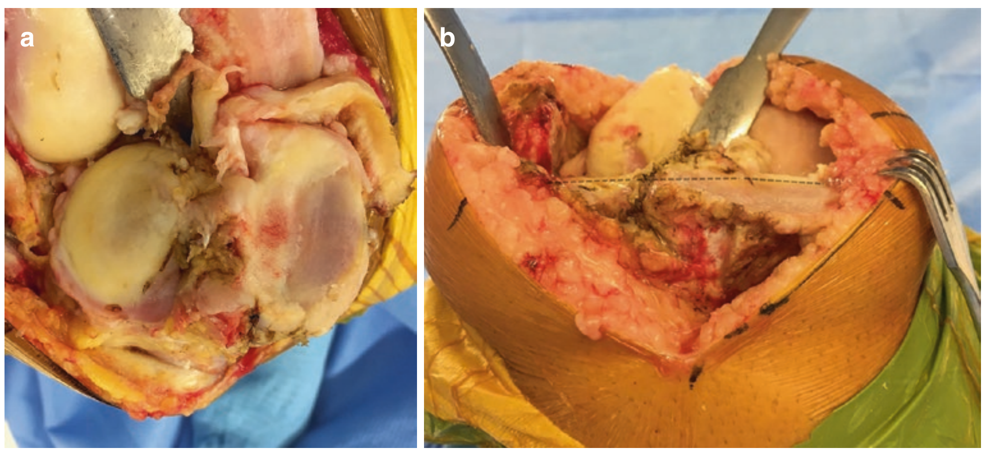


Fig. 25.2 (**a**, **b**): (**a**) Intra-articular deformity due to anterior medial wear (right knee) (**b**). Dotted line shows original intact posterior joint contour

Fig. 25.3 Intra-articular deformity due to medial condyle fracture with depression (right knee)

- Extra-articular
  This is due to deformity in the metaphysis or diaphysis, which may be developmental (Fig. 25.4), due to fracture (Fig. 25.5) or to metabolic bone disease. It cannot be corrected passively, and surgically correcting the deformity at the joint level and at the same time achieving balance will require alteration of the soft tissue envelope from its original natural state.

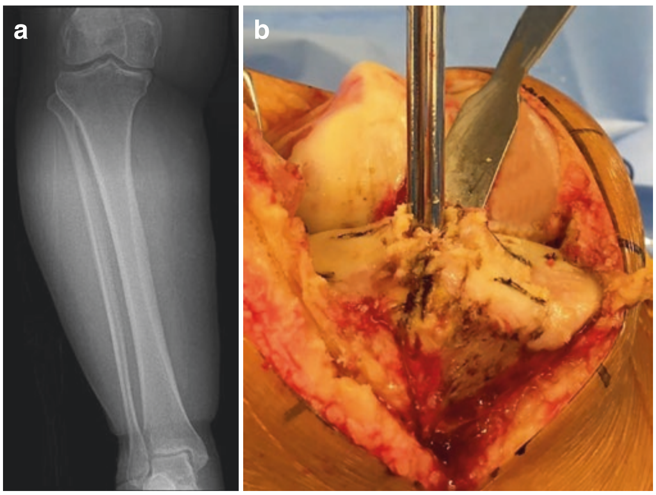


Fig. 25.4 (**a**, **b**) Proximal 'constitutional' varus deformity (**a**) X-ray (**b**) Intra-operative photograph showing the varus inclination of the joint surface in relation to the intra-medullary rod, which is fully inserted and shows the anatomical axis

Fig. 25.5 Valgus tibial deformity due to metaphyseal fracture malunion

Alignment

- Alignment, balance, and longevity are linked and need to be considered together. Always a compromise must be made.
- The coronal alignment at or near extension is dictated mainly by the tibial cut and the distal femoral cut. We aim for a mechanically aligned limb, with an orthogonal cut of the tibia, but we accept some varus of the femoral component if it is necessary to achieve rectangular gaps and soft tissue balance (Fig. 25.6). We do not attempt a kinematic or constitutional tibial alignment, in an attempt to prevent excessive varus tibial malalignment and possible premature loosening. Our femoral alignment, however, is more kinematic and discussed in Parts II and III.
- The coronal alignment in flexion is dictated by the tibial cut and the posterior femoral cut. This aspect is often neglected and is also discussed in Part III.
- Sagittal alignment of the tibial cut is orthogonal and referenced from the proximal tibia to prioritise balance. An orthogonal cut is appropriate for a PCL substituting design and prevents flexion laxity, anterior tibial subluxation, and excessive forces on the polyethylene. Sagittal alignment of the distal femoral cut is also dictated by the distal femoral anatomy, not the line between the femoral head and knee joint.

Fig. 25.6 An orthogonal tibial cut, but the proximal femoral deformity has been left uncorrected to improve ligament balance

Cuts

Bone cuts involve the tibia, the femur, and (where appropriate) the patella.

These are defined by:

- Level
  This may influence the size of the gap and is therefore linked to flexion/extension gap equivalence (gap balancing).

  The level of the cut is guided by a reference, which is usually a point on the least affected part of the joint (Fig. 25.7). The thickness of bone that is removed on the reference side will often be replaced by the implant, but not always. The bone and cartilage resection should be equal or less than the minimum implant height, and not more, to avoid unnecessary bone sacrifice. If there is a remaining defect on the concave side, this will be dealt with by augmentation, rather than increasing the depth of resection at the expense of bone on the convex side (Fig. 25.8).
- Orientation
  This influences the limb alignment. It also influences the shape of the gap (symmetry) and so is linked to ligament balancing. In many cases a priority, and thus a compromise, will have to be made between alignment and balance.

'The orthopaedic surgeon is often mistaken. He must be cognisant and choose the most acceptable error.'

The cuts may be described as:

- Independent
  Each cut is made separately and is referenced from bony anatomic landmarks or intra-medullary/extra-medullary guidance from the relevant bone (Fig. 25.9). The technique is often described as *'measured resection'*.
- Dependent
  The cut level is referenced using parameters of a previously formed gap (Fig. 25.10). The technique may be referred to as *'gap balancing' or 'gap resection'*.

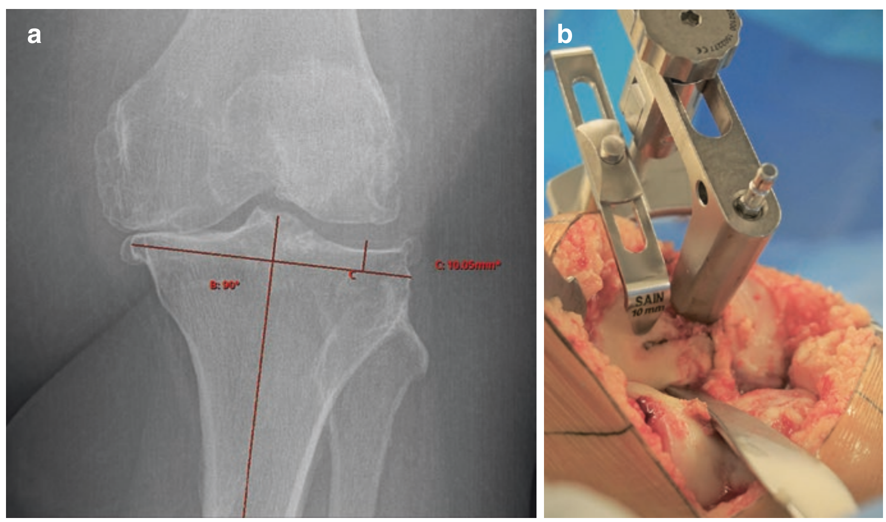


Fig. 25.7 (**a**, **b**): (**a**) The level of cut is 10 mm referenced from the unaffected convex side of the joint. Orientation is 90° to the mechanical/anatomical axis of the tibia (**b**). Intra-operative photograph showing a 10 mm stylus applied to the unworn lateral tibial condyle

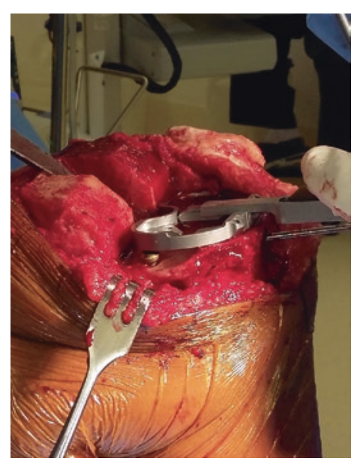


Fig. 25.8 This medial defect is being dealt with by screw and cement augmentation. The presence of the defect did not alter the thickness of the cut, which was referenced from the unworn convex side

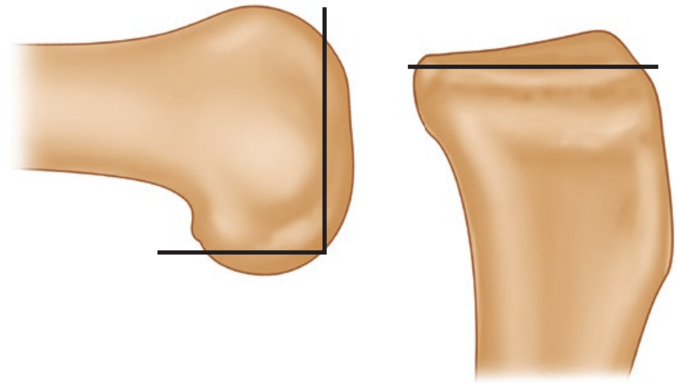


Fig. 25.9 The cuts are made independent of each other, based on anatomical landmarks of each bone

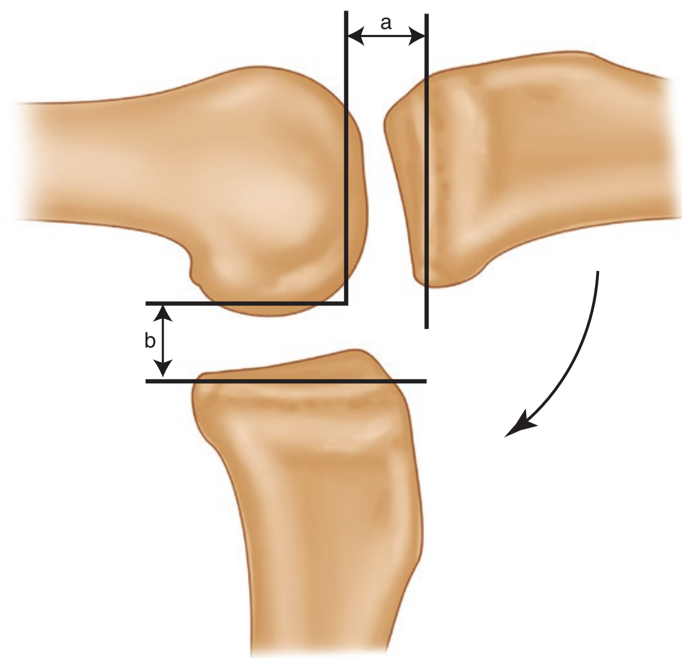


Fig. 25.10 The parameters of one gap are used to make the second. In this case, creation of the flexion gap follows that of the extension gap

Tibial Cut

There is only one tibial cut, except in the case of local bone defects (see Fig. 25.8, Chap. 31). The orientation affects both coronal alignment and symmetry of the gap throughout flexion. Orientation in the coronal and sagittal planes may be guided by intra, or extra-medullary references. Axial rotation is only set by component positioning and tibial preparation, rather than a cut (Fig. 25.11). The level affects the gap throughout flexion.

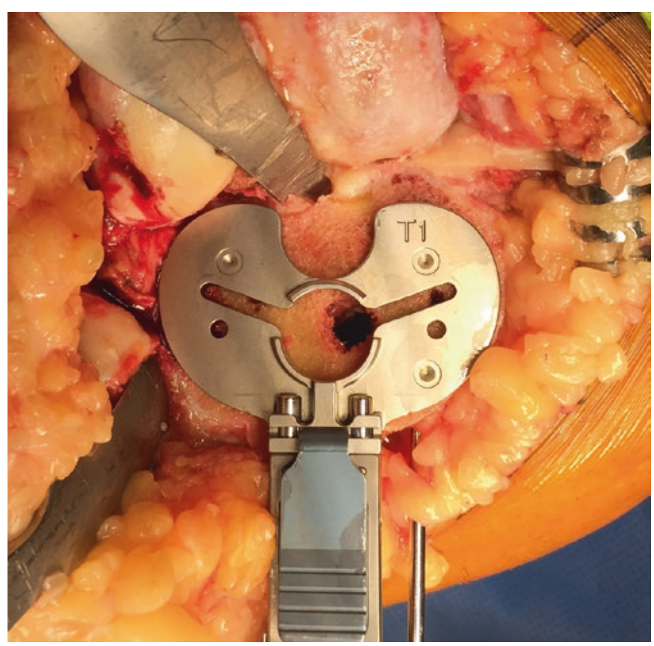


Fig. 25.11 Axial rotation set by trial positioning and keel preparation

Femoral Cuts

The orientation of the distal and posterior cuts contributes to the coronal alignment of the knee in extension and flexion, respectively (Fig. 25.12). The orientation of each also affects the symmetry of the gap in extension and flexion, respectively.

The level of each cut affects the relationship between the flexion and extension gaps (gap balance).

The anterior cut contributes to the patellofemoral articulation. The orientation of the posterior and anterior femoral cuts are fixed and linked by the femoral prosthesis (Fig. 25.13). A compromise may therefore be necessary to optimise both the flexion and anterior gaps. Additional cuts are usually required for anterior and posterior chamfering, and the box for posterior stabilisation if needed.

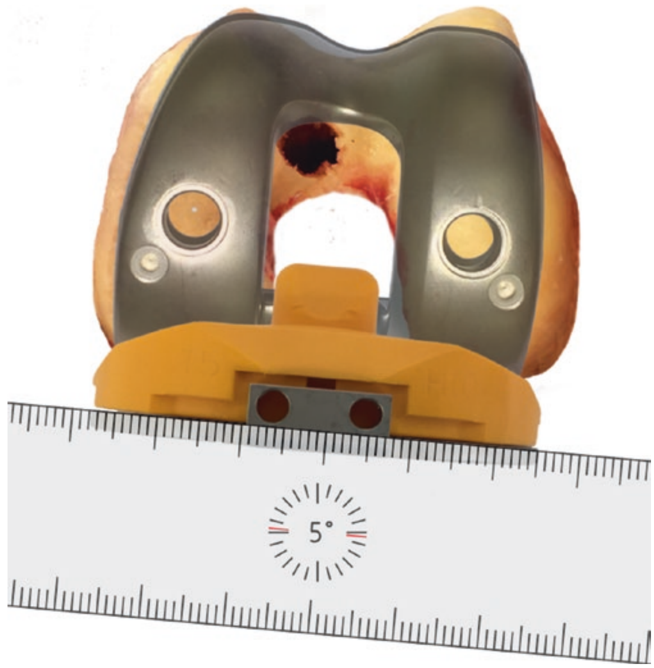


Fig. 25.12 Coronal alignment in flexion is dictated by the posterior femoral cut, as well as the tibial cut. Here, the external rotation of the femoral component contributes 5° varus

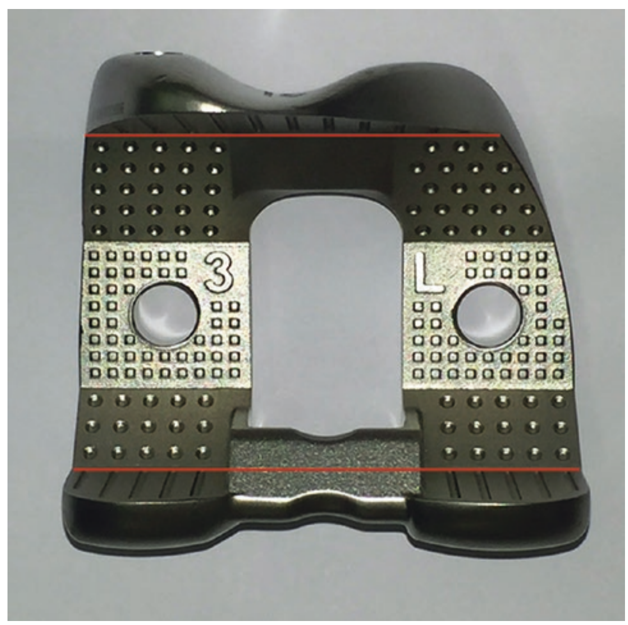


Fig. 25.13 The cuts for the femoral prosthesis are fixed and usually parallel

Gaps

The femorotibial gap is a space formed by the tibial cut, the distal and posterior femoral cuts, and influenced by the length of the soft tissues. Although often considered as separate flexion and extension gaps, they are clearly continuous with each other, and this is relevant when considering 'mid flexion' stability (Fig. 25.14).

The patellar femoral or anterior gap is formed by the patella (cut surface, or articular surface if the patella is not to be resurfaced), the anterior femoral cut in extension, and the distal femoral cut in flexion (Fig. 25.15). Again there is really only one patellofemoral gap, and it is in continuity with the femorotibial gap in flexion, hence being influenced by the distal femoral cut.

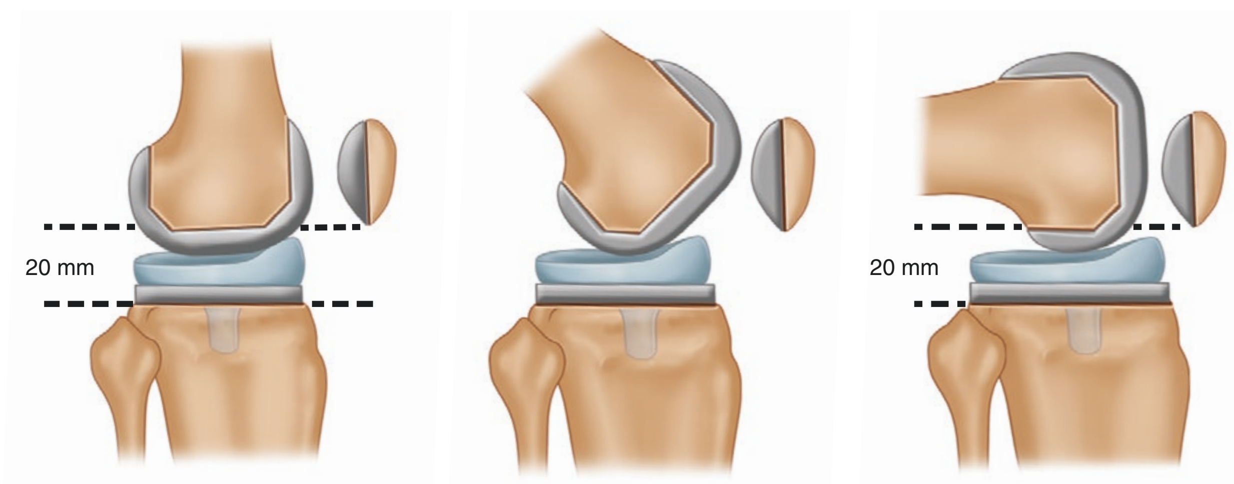


Fig. 25.14 Flexion and extension gaps are continuous with each other

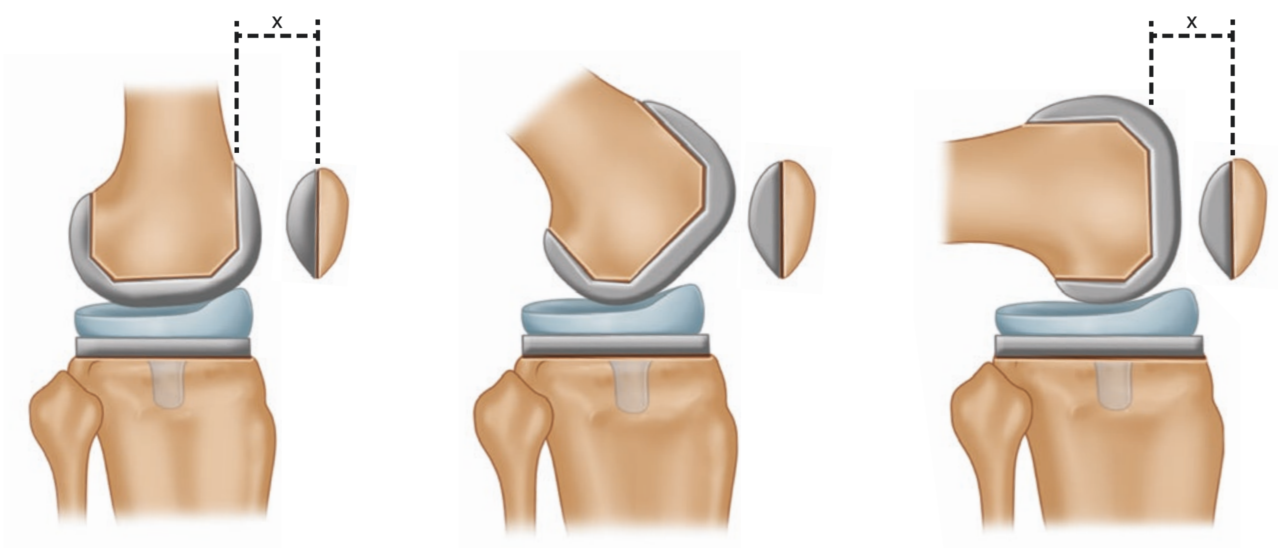


Fig. 25.15 Patellofemoral gap, in continuity with the femorotibial gap in flexion

Implant Space and Prosthetic Interface

The part of the gap that is taken up by the prostheses is termed the implant space. Ideally, the gap will be slightly larger than the implant space, so that there is slight laxity to avoid pain or stiffness from tissue tension, but not too much laxity, which may cause instability. This observed difference between the gap and the implant space is due to the soft tissue laxity and the loading conditions, including intrinsic and extrinsic moments. Loading conditions are dictated for the most part by the patient's position and the alignment. For instance when standing, if the joint is mechanically aligned and thus more symmetrically loaded in compression, the gap and space may be the same. If the limb is not mechanically aligned, there may be asymmetric loading and compression on one side but distraction on the other, causing the gap and space to be different (Fig. 25.16). In this regard, it is important to consider the coronal alignment in flexion as well as extension, for instance with crouching or stair climbing.

The two components of the prosthesis meet at the *prosthetic interface*. The goal is to place this as near as possible to the original native joint line, at the level of the meniscal rim, although this may not always be possible (Fig. 25.17).

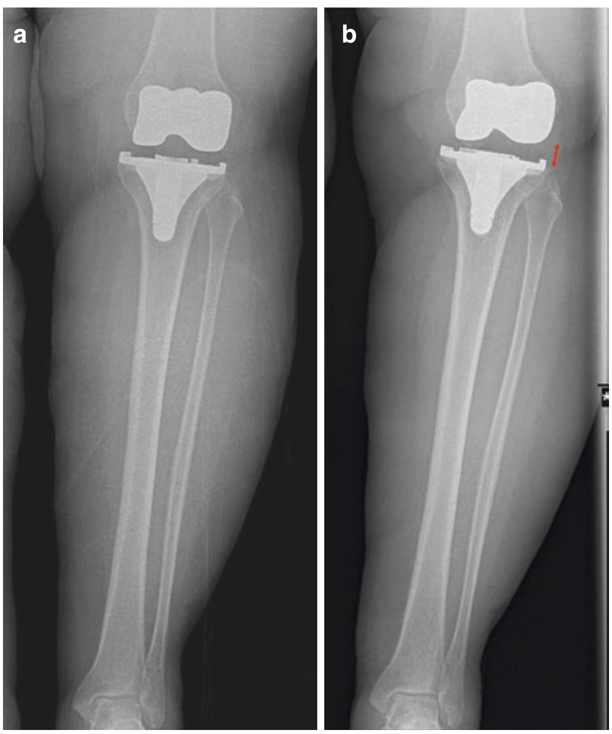


Fig. 25.16 (**a**, **b**) Different loading conditions produce different extrinsic moments. The intrinsic adductor moment results from the varus alignment of the femoral component

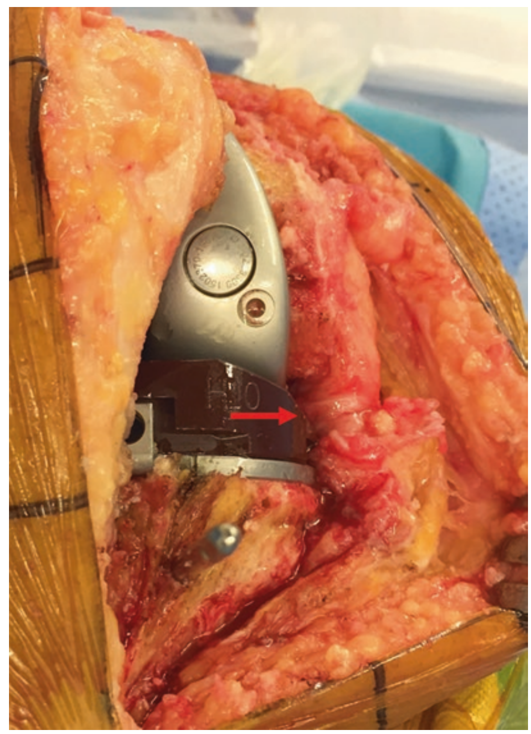


Fig. 25.17 Prosthetic interface located at the meniscal rim

Tibial and Femoral Segments

The segments are made up of the implant spaces and the remaining bone distal or proximal to the collateral insertions. They therefore depend on the chosen resection level, as well as the component thickness. The surgeon has control over both tibial and femoral resection levels, but in most primary systems only the thickness of the tibial component. The relative size of each segment determines the position of the prosthetic interface in relation to the soft tissue attachments. The aim will be to place the prosthetic interface at the same level as the native joint line to normalise the tension in the soft tissues (Fig. 25.18). The relative size of both segments in relation to the length of the soft tissues determines this tension or laxity. Increasing each segment means producing a prosthetic interface further away from the respective attachments of the collateral ligaments. As each segment is composed of bone and a component, increasing the segment would require more bone (less resection) or a thicker component (Fig. 25.19). This may possibly require more potential space from soft tissue release. Reducing the segment would require the opposite; more bone resection or thinner components. In a primary TKA, the latter is only possible with the tibial component, and this may not be possible in many cases where the minimum thickness polyethylene insert has already been used.

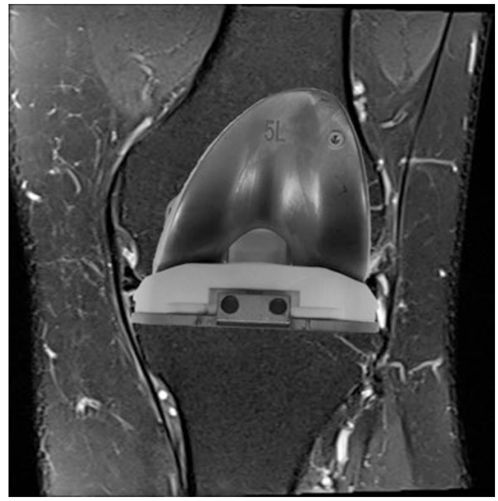


Fig. 25.18 The relative size of each segment determines the position of the prosthetic interface in relation to the soft tissue attachments. Here, it is at the original joint line, at the level of the meniscus

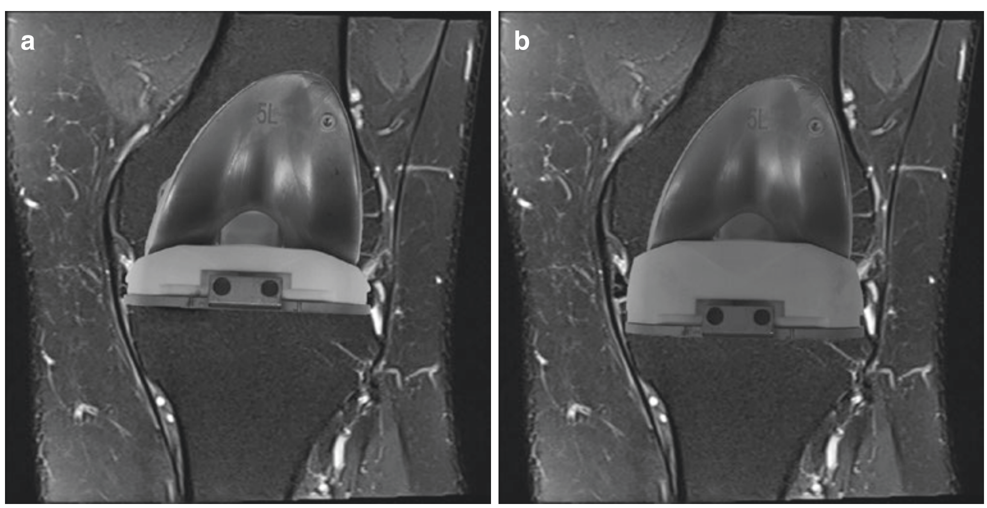


Fig. 25.19 (**a**, **b**): The tibial segment can be increased by resecting less (**a**), or using a thicker tibial component (**b**). In both illustrated cases, the soft tissues have not been altered, and the femoral segment has been reduced by bone resection. The overall distance between the collaterals is unchanged, but the prosthetic interface has been proximalised in relation to both femoral and tibial insertions

Soft Tissue Envelope and Ligament Balancing

The soft tissue envelope consists of all the active and passive stabilisers of the knee although certain structures predominate (Fig. 25.20). It includes the collateral ligaments, the extensor mechanism, the flexors, the iliotibial band, popliteus, anterolateral ligament, and patellar stabilisers as well as the various condensations of the capsule such as the posterior oblique ligament. Their practical contribution to the gaps is usually through contracture, or inadequate length due to a thinner bone resection on the concave side of an extra-articular deformity, and possibly through laxity on the convex side. All of these situations cause an asymmetric gap in the coronal plane. Ligament balancing, a technique common to any surgical strategy, refers to the release of soft tissue in order to create a rectangular, or 'symmetric' gap.

Gap Balancing

Whilst ligament balancing refers to a technique aimed at the formation of a rectangular, symmetric gap, gap balancing is a surgical strategy aimed at equalising the size of the flexion and extension gaps. After one gap has been formed by a cut (often the tibial), and possibly a release, the dimensions are used to guide the level of another 'dependent cut', thereby producing gaps of equal size (Fig. 25.10).

Tensors, Spreaders, and Spacers

The instrumentation required for gap balancing needs to incorporate a device which tensions the gap in a controlled manner, in order to measure and transfer the dimensions to another gap. This will likely be a tensor of some kind. There are other methods used to assess a gap (Fig. 25.21).

- A tensor allows a dynamic measurement of medial and lateral implant spaces separately (Figs. 25.22 and 25.23).
- A distractor (or spreader) allows dynamic measurement of the implant space, without separating medial and lateral (Fig. 25.23).
- A spacer provides a static measurement of the implant space. However, serial static measurements, plus the surgeons examination may provide some dynamism (Fig. 25.24).

Fig. 25.20 The soft tissue envelope consists of all the active and passive stabilisers of the knee

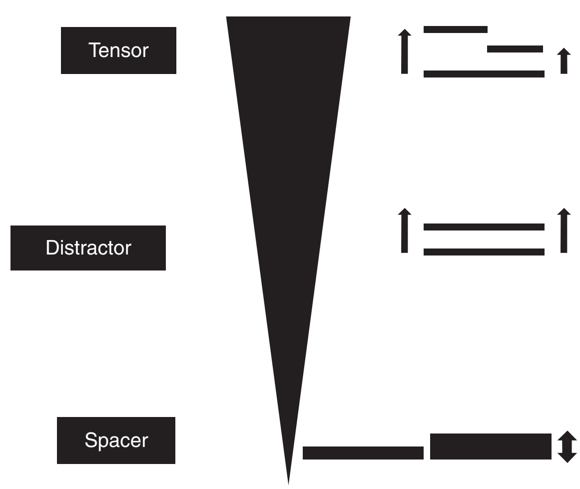


Fig. 25.21 Methods to assess the gaps. These may be static (spacer) or dynamic (distractor or tensor). A tensor allows independent assessment of medial and lateral sides of the joint

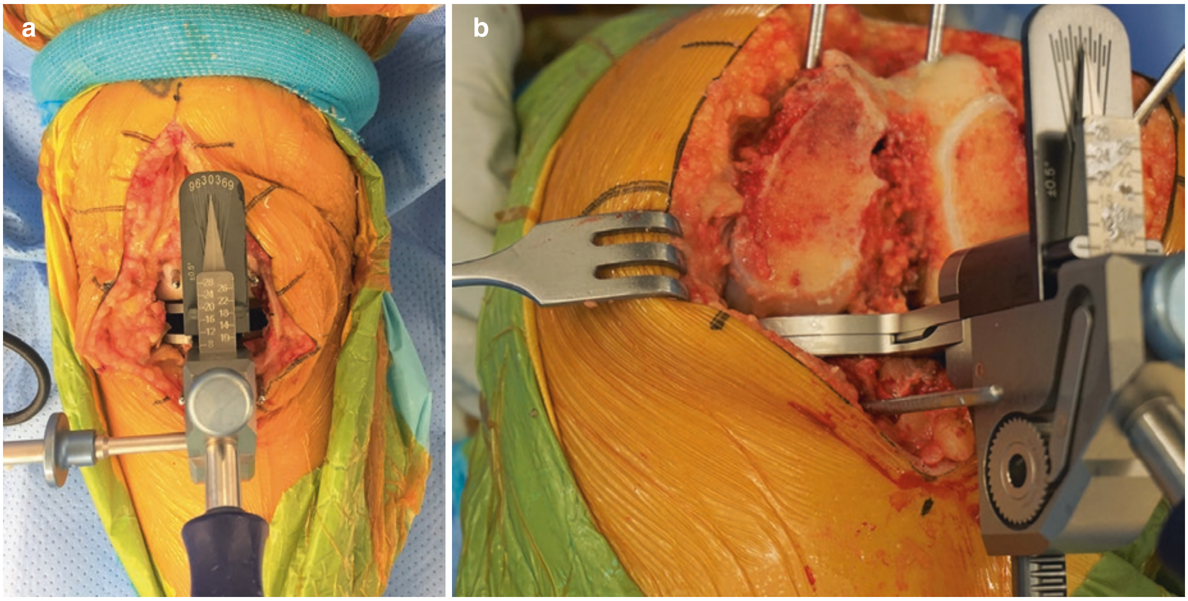
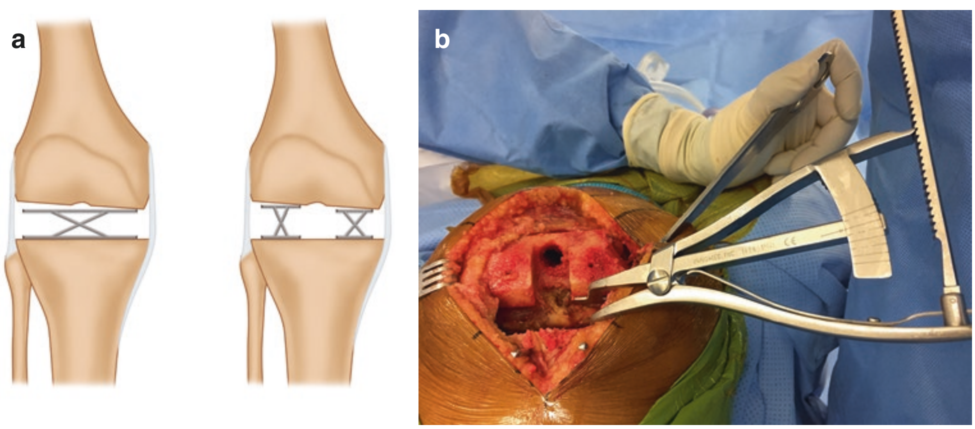


Fig. 25.22 (**a**, **b**): Use of a tensor to assess: (**a**) The extension gap. (**b**) The flexion gap

Fig. 25.23 (**a**, **b**): (**a**) Depictions of a spreader (left) and a tensor (right). (**b**) A spreader used on the lateral side. Use of two of these devices, one on each side of the joint, will act as a tensor



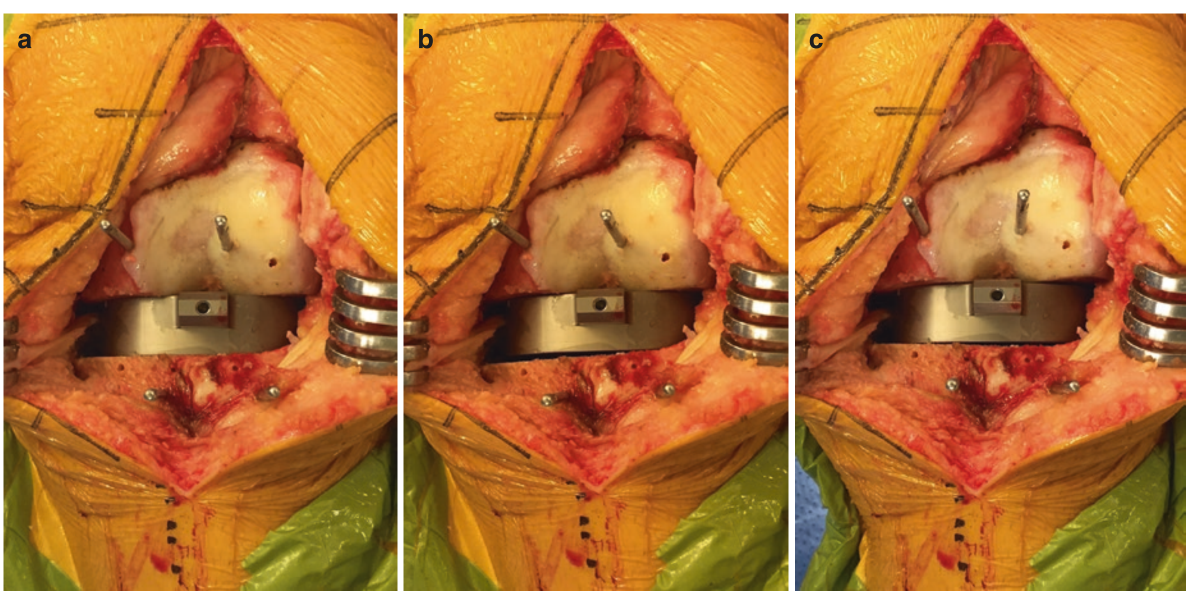


Fig. 25.24 (**a**–**c**): Use of a static spacer to evaluate the tibiofemoral extension gap in a left knee. (**a**) Neutral. (**b**) Valgus stress. (**c**) Varus stress

Computer-Assisted TKA

The dependent cut/gap balancing technique is taken a step further when using navigation; this allows the femoral cuts and the resulting two spaces and alignment to be simulated before committing to either cut or the soft tissue release (Fig. 25.25). The progress of the soft tissue balancing can also be assessed objectively in real time (see Chap. 29). In this way, the soft tissue and bone management can be planned independently, in theory allowing the priorities of balance and alignment to be considered separately. At this point, the decision-making process has ceased to be linear; different strategic scenarios can be rehearsed and the optimum parameters chosen independently.

The concepts in the next part are designed to help the surgeon separate some of these parameters during conventional TKA.

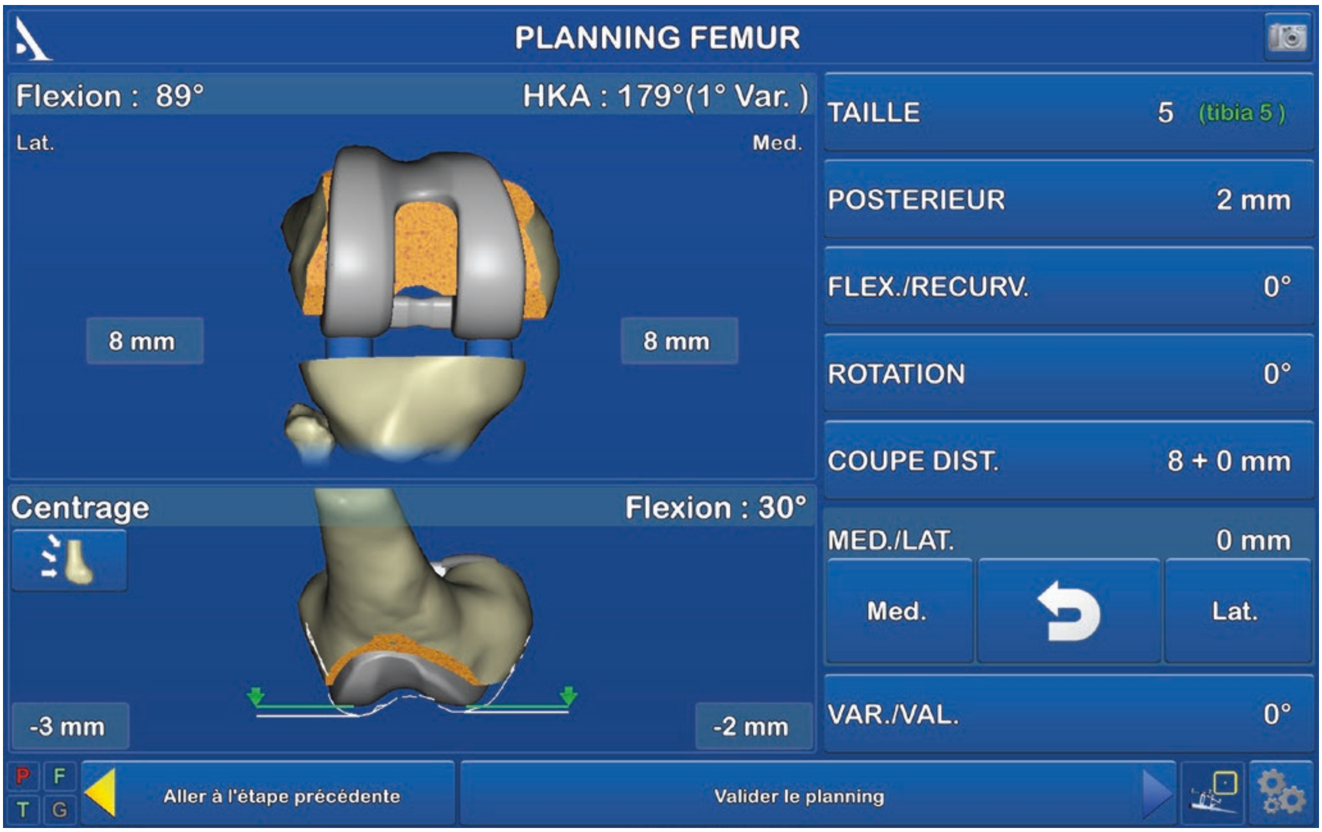


Fig. 25.25 Navigation allows the femoral cuts and their effect on alignment and balance to be planned simultaneously, prior to committing to them. Here, the effect of the chosen level and rotation of the posterior cut on coronal alignment and the gap symmetry is shown in the upper picture. The lower picture shows the level and inclination of the anterior cut in relation to the original anatomy

Part II Tibial and Femoral Spaces

The concept of flexion and extension gaps introduced by Insall can be expanded to separate the tibial and the femoral contributions (Fig. 25.26). This simplifies the analysis and process of making equal gaps, and inherently highlights the position of the prosthetic interface.

- **Tibial space**
  The tibial space is defined by the single tibial cut and a soft tissue release, if performed (Fig. 25.27). The flexion and extension spaces are continuous with each other, and the tibial space will be the same size and symmetry in both positions.

- **Femoral space**
  The posterior and distal femoral cuts define the femoral space in flexion and in extension, respectively. The aim of both femoral cuts is to produce a femoral space which is, like the tibial subspace, constant throughout flexion and extension (Fig. 25.28). In this technique, as the tibial space is constant throughout flexion, the gap balancing is achieved by gap balancing the femoral space.

In this part, the principles will be outlined. Further detail will follow in Part III.

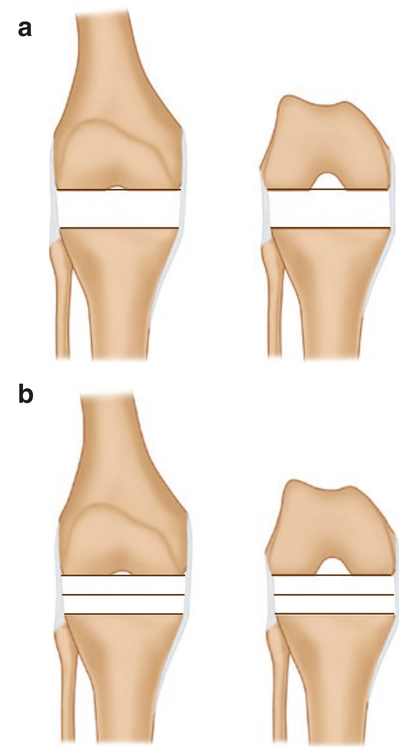


Fig. 25.26 (**a**) Flexion and extension gaps. (**b**) Tibial and femoral spaces

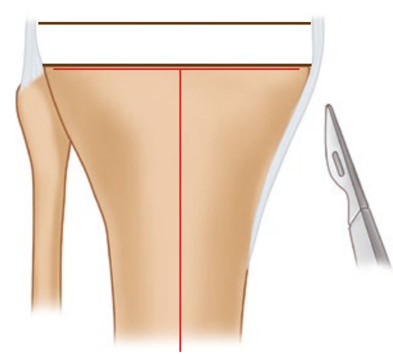


Fig. 25.27 Tibial space formed by the tibial cut, and possibly a soft tissue release if necessary

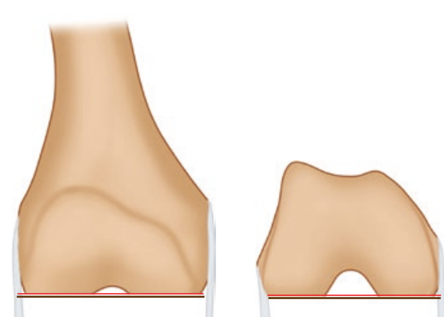


Fig. 25.28 The relationship between the soft tissue attachments and the distal and posterior cuts (i.e. the femoral spaces) is equalised in extension and flexion

Creation of the Tibial Space

Achieving a rectangular tibial space varies depending on the patient's pathoanatomy:

1. **No Extra-Articular Deformity**
   Here the deformity is intra-articular from cartilage and possibly bone wear. A cut orthogonal to the mechanical axis will be almost parallel to the original joint line (Fig. 25.29). The tibial space will be rectangular, or nearly so. No alteration of the soft tissue will be required.

2. **Extra-Articular Varus Deformity of the Tibia**
   The deformity is extra-articular. A cut orthogonal to the mechanical axis will produce an asymmetric cut, and an asymmetric tibial space with lateral laxity (Fig. 25.30). This is termed 'resection laxity'. A lengthening on the concave side of the joint will be necessary to achieve a rectangular space.

3. **Convex Side Laxity**
   The soft tissues of the convex side are stretched, due to chronic varus deformity and weightbearing. They will need to be tensioned to some degree by filling the gap with prosthesis. To achieve a rectangular gap, the concave tissues will also have to be lengthened, more than the original and natural length, to match the pathologically lengthened convex side tissues (Fig. 25.31). Attention will have to be paid to the prosthetic interface, which will be altered from the level of the natural joint line.

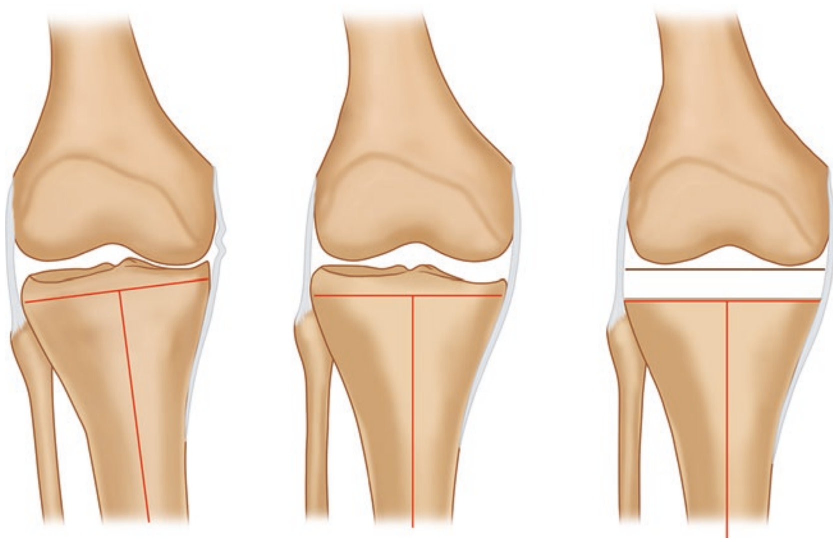


Fig. 25.29 The deformity of the proximal tibia is intra-articular due to wear

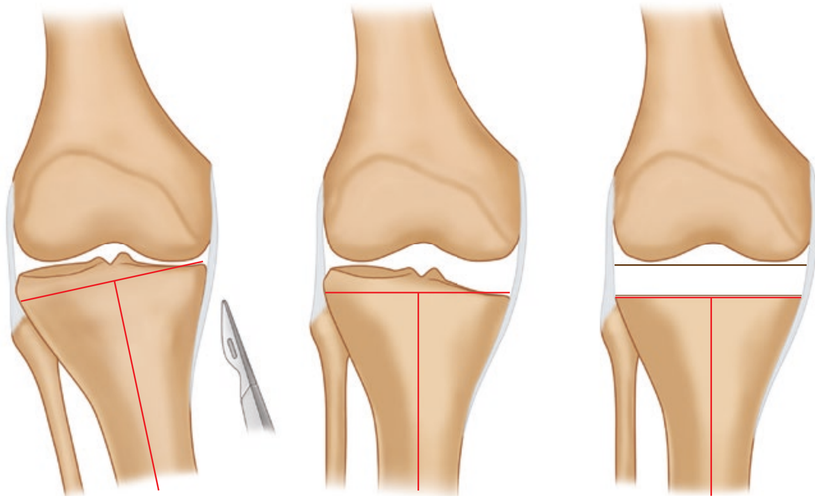


Fig. 25.30 The deformity is extra-articular. The orthogonal cut creates an asymmetric space, requiring a lengthening on the concave side

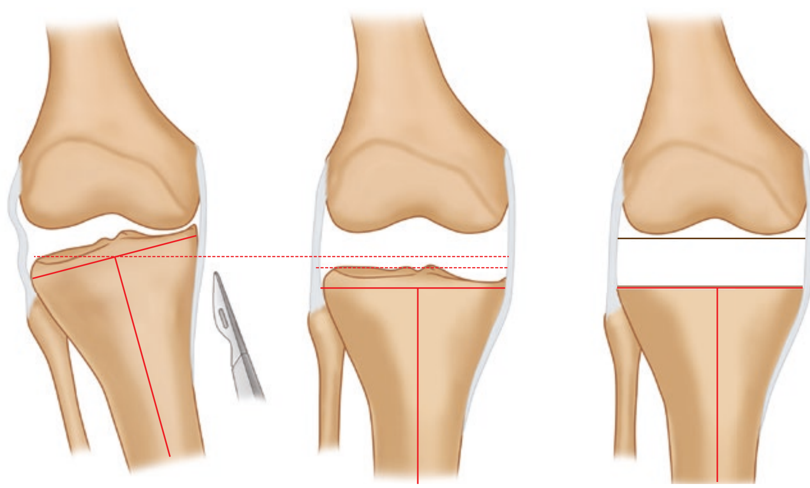


Fig. 25.31 The soft tissues of the convex side are stretched and may need to be tensioned. To achieve a rectangular gap, the concave tissues will also have to be lengthened, more than the original and natural length

Creation of the Femoral Space

To create equal rectangular femoral spaces in extension or flexion, the posterior femoral cut needs to match the distal femoral cut (or vice versa). If there is asymmetry of medial and lateral bone resection during the distal cut, this is reproduced in the posterior cut. In a measured resection strategy, this can be simply achieved by cutting the same amount of bone from the condyles distally and posteriorly (Fig. 25.32). This strategy, with allowance for wear of the cartilage and bone if necessary, should produce a joint line that maintains the natural flexion axis of the knee. Using this technique, the external rotation of the femoral component is influenced by the asymmetry of the distal femoral cut, not the asymmetry of the tibial cut. The asymmetry of the tibial cut will be dealt with separately by ligament balancing as previously described, and will have effect in extension and flexion.

As with the tibia, the different patterns of femoral deformity guide the management:

1. **Varus Knees**
    - ***Either no femoral deformity or proximal femoral varus deformity***. The deformity, when present, is from proximal or mid-shaft origin, i.e. proximal to an intra-medullary guide, and thus it will not be corrected (Fig. 25.33). The level of the distal cut is referenced from the less worn lateral condyle. If the cut is symmetrical, then so is the posterior cut—parallel to the posterior condylar line (PCA) (Fig. 25.34). If the distal cut is asymmetric and removes more lateral femoral condylar bone than medial (Fig. 25.35), the posterior cut is still made parallel to the PCA, as we do not wish the posterior cut to produce any internal rotation of the femoral component.
    - ***Femoral valgus in a varus knee*** (infrequent—less than 5% of cases in our experience). If the distal cut is asymmetric and removes more medial femoral condylar bone than the lateral, the rotation is set to do the same from the posterior part of the condyles, thereby externally rotating the femoral component (Fig. 25.36). The cartilage wear (2–3 mm) or bone wear on the medial condyle is considered, so that the joint lines are reproduced. The posterior cut is then a measured resection, but it is dependent on the distal cut.

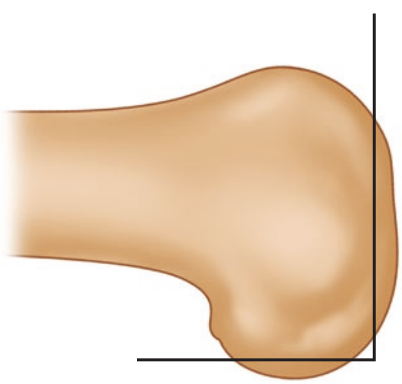


Fig. 25.32 The distal femoral bone resection can be used to guide the posterior resection. The femoral contribution to the flexion and extension gaps will be equal

Fig. 25.33 Proximal varus will not be corrected by the use of an intramedullary guide

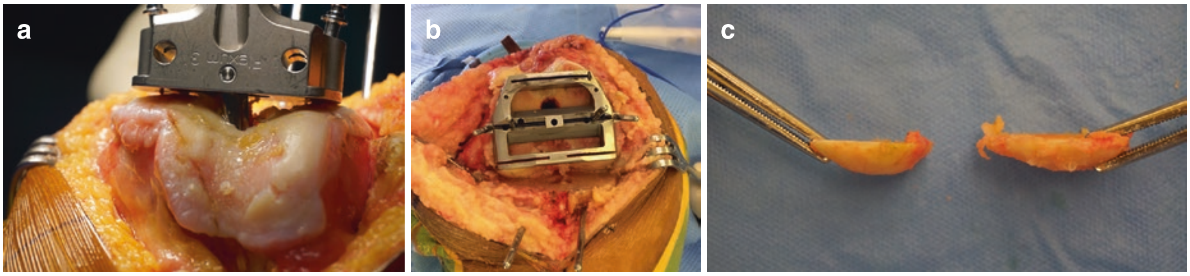


Fig. 25.34 (**a**–**c**): Right knee (**a**). Distal cut removes equal bone from the medial and lateral condyles. (**b**, **c**). The 4:1 cut block is placed to also remove symmetrical posterior bone from the condyles, i.e. 0° rotation

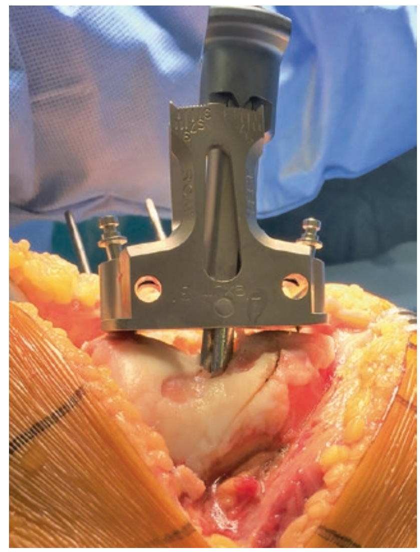


Fig. 25.35 Left knee. Here more bone will be removed from the lateral femoral condyle than the medial, even allowing for wear

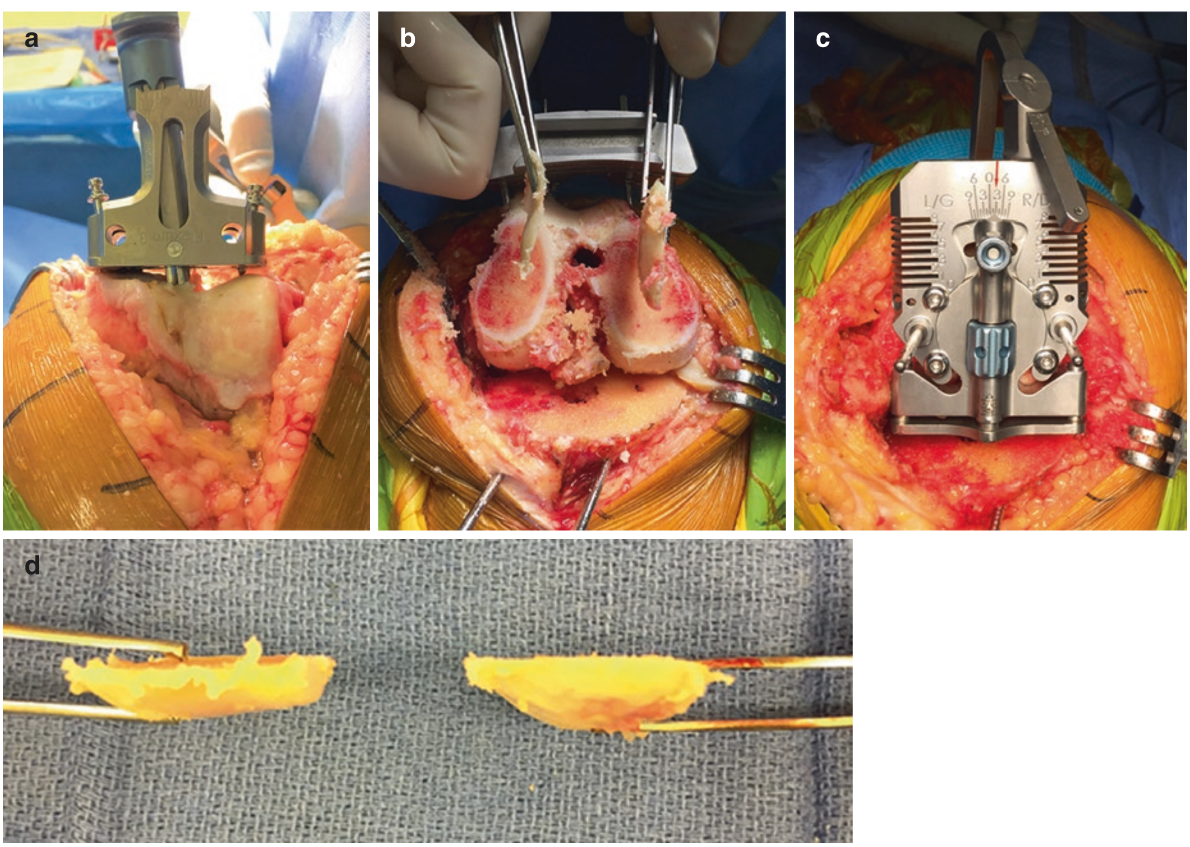


Fig. 25.36 (**a**–**d**): Right knee: (**a**, **b**) Distal cut removes more bone from the medial femoral condyle than the lateral. (**c**, **d**) External rotation is set to cut the same posteriorly—removing more bone medially than laterally and externally rotating the femoral component

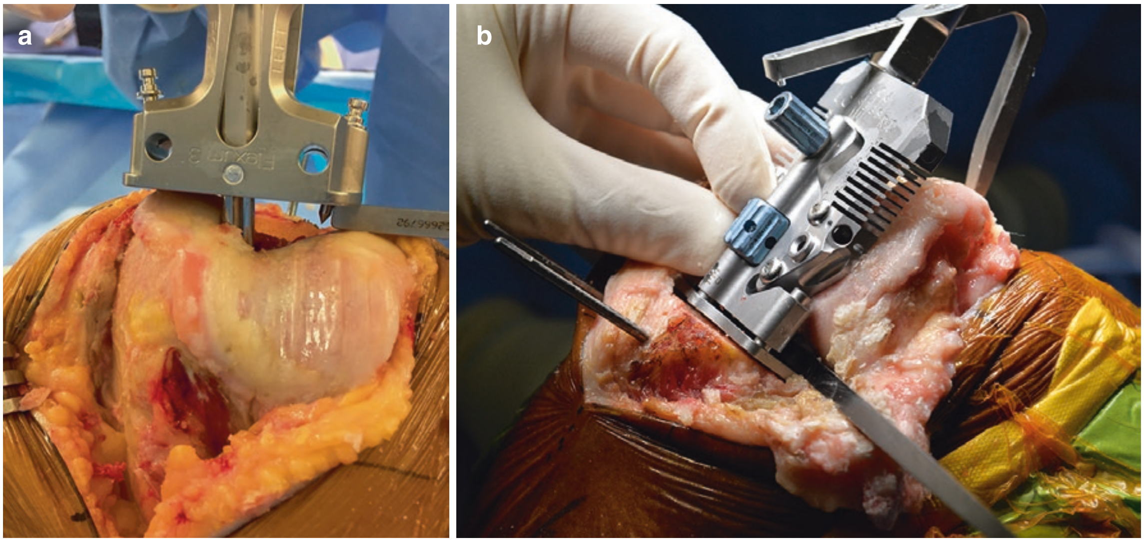


Fig. 25.37 (**a**, **b**): Right knee. (**a**) Distal cut removes significantly more medial than lateral bone due to lateral condylar hypoplasia. (**b**) The posterior cutting guide is externally rotated

2. **Valgus knees**
   This often results from lateral condylar hypoplasia, but may originate more proximally in the diaphysis.
   - ***Lateral condylar hypoplasia***. The intra-medullary guide is proximal to the deformity and will correct it. The level of the distal cut is referenced from the less worn medial condyle. The cut is asymmetric, removing significantly more bone from the medial condyle (Fig. 25.37). The rotation is set to do the same from the posterior part of the condyles, thereby externally rotating the femoral component.
   - ***Valgus resulting from proximal deformity.*** The intra-medullary guide is located distal to the valgus deformity and will not correct it (Fig. 25.38). The posterior cut will be dictated by the asymmetry of the distal cut as with the other examples. The extra-articular femoral valgus will remain after the procedure; the femoral space in flexion and extension (i.e. the joint balance) will have been prioritised over the alignment. If the remaining valgus is calculated to be unacceptable (rare, and usually due to malunion), then a femoral osteotomy should be considered first.

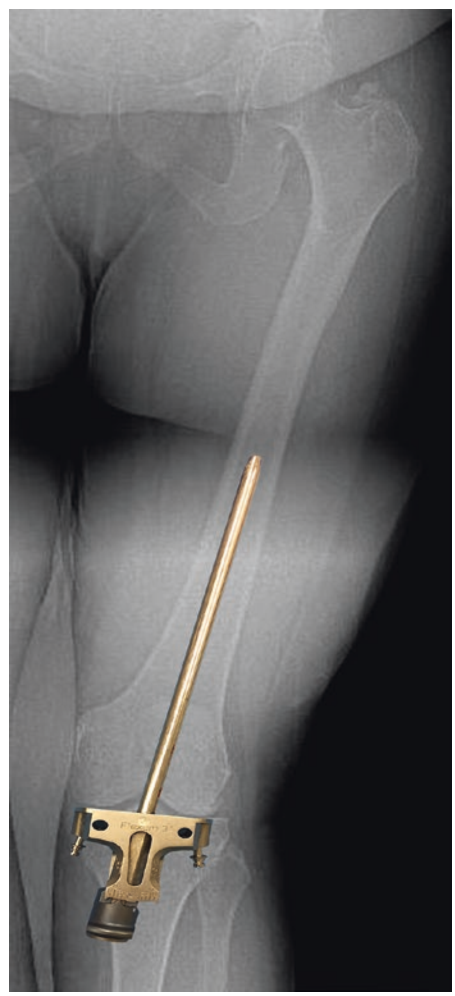


Fig. 25.38 The intra-medullary guide is located distal to a mild valgus deformity and will not correct it

Conclusion

The goal is not only to have a tibiofemoral space that is the same size and symmetrical shape in flexion and extension (perhaps slightly more space in flexion), but also with a constant prosthetic interface. This optimises the biomechanics of the collateral ligaments and the patellar femoral articulation. We prefer to separate the parts of the tibiofemoral gap into tibial and femoral to achieve this.

- The size of the tibial space formed by the cut is equal in flexion and extension. We make it symmetric with soft tissue release if necessary.
- The size and shape of the femoral space is equal in flexion and extension because the posterior cuts match the distal cuts.

Achieving the goal by considering the femoral and tibial spaces separately produces a prosthetic interface that is constant throughout flexion and extension.

In Part III, the steps in the creation of these spaces will now be considered in the context of the priorities of the procedure.

Part III Priorities and the Sequences of the Steps

Although we strive for the perfect knee in every aspect, it is helpful to have a basic order of priorities.

1. Alignment and balance in extension
2. Alignment and balance in flexion
3. Balance between flexion and extension
4. Joint line/Prosthetic interface

This order, however, is different to the sequence of the steps of the procedure. Many of the steps of the procedure contribute to multiple priorities, either directly, or indirectly, and this adds to the complexity of the TKA algorithm. First we will consider the priorities, and then the sequence of the steps.

1. Alignment and Balance in Extension

Overall coronal alignment: A rectangular extension gap without laxity, orientated to align the tibial component mechanically remains our first priority. The specific techniques for the femoral and the tibial cuts will be detailed, but first their contribution to the overall coronal alignment will be addressed:

- On the femoral side, although we aim for a mechanically aligned limb, we will not correct proximal femoral varus if in doing so it creates an asymmetric extension gap. In varus deformity of femoral origin, a strictly orthogonal distal femoral cut may not only contribute to an unacceptable asymmetry of the extension gap, but also the opposite asymmetry in flexion (Fig. 25.39) (see Priority 2,

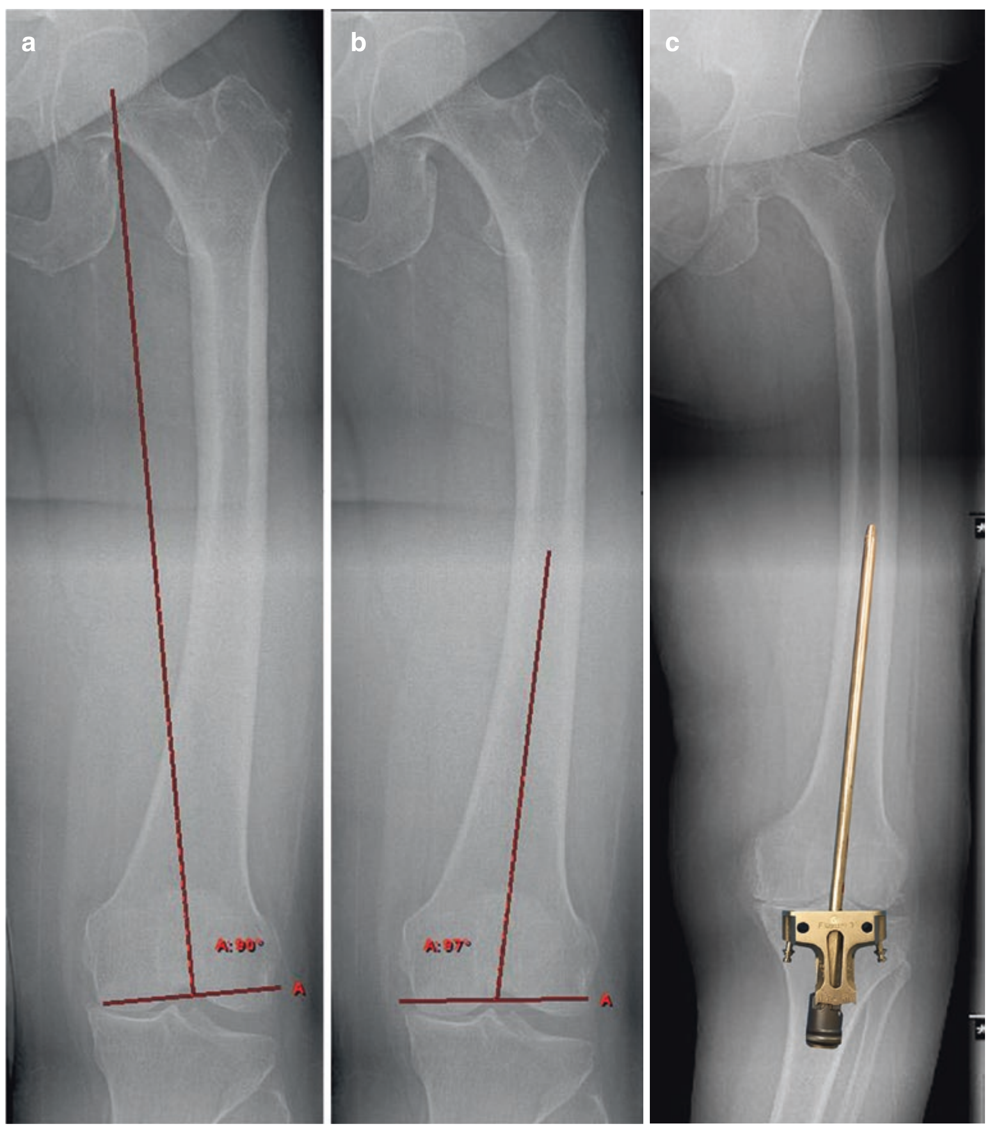


Fig. 25.39 (**a**–**c**): (**a**) A strictly orthogonal mechanical cut in this circumstance contributes to an unacceptably asymmetric gap. (**b**, **c**) Better balance is achieved by referencing from the distal femoral anatomy at the expense of alignment

Alignment and balance in flexion). We therefore do not vary our distal femoral cut according to pre-operative femoral mechanical axis measurement in varus knees, but reference the distal femoral anatomy with an intra-operative intra-medullary guide. Thus in many cases, we prioritise the balance of the knee over the overall coronal alignment. This allows good long-term results, as mild varus of the femoral component itself has not been shown to lead to loosening. The degree of overall varus accepted (perhaps 3–8°) will be a function of the quality of the ligament balancing (degree of laxity in the convexity), the level of activity, and the life expectancy of the patient.

- Despite this kinematic approach to the femoral space, we do not aim for either a mechanically aligned leg with varus of the tibia and valgus of the femur (for instance 87° and 93°, respectively, Fig. 25.40), or an overall kinematic alignment with varying degrees of varus on the tibial side, due to concerns over tibial component longevity.
- So in summary, we aim for a mechanically aligned limb, with an orthogonal cut of the tibia, but we accept some varus of the femoral component to encourage a balanced knee (Fig. 25.41).

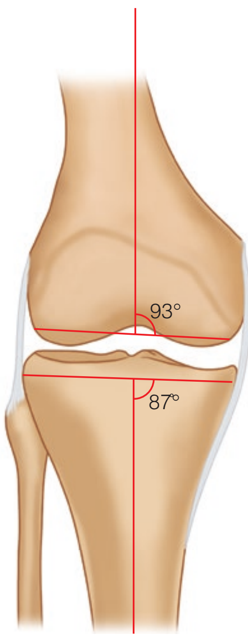


Fig. 25.40 Mechanical alignment with a varus tibial cut and a valgus femoral cut

Fig. 25.41 An orthogonal tibial cut, but the proximal femoral deformity is left to improve the balance

Distal Femoral Cut

Although navigation can estimate the mechanical axis of the femur, and identify the flexion axis, in conventional TKA intra-medullary guidance is usually used, partly as extra-medullary guidance using fluoroscopy for the femoral head is not reliable. The technique of insertion of the intra-medullary guide affects the alignment. We prefer to enter the distal femur anterior to the PCL insertion, which is a reproducible and functional landmark in coronal and sagittal planes (Fig. 25.42). This lies at a point nearer the exit of the line of the distal intra-medullary canal, termed *Femoral Anatomic* Axis *II*, than that of *Femoral Anatomic Angle I* (Fig. 25.43). If one chooses this point, when the prosthesis is then centred on the condyles, it will be translated laterally with reference to this starting point, inducing slight varus (Fig. 25.44). We have found that using a 7° valgus cut referenced from the intra-medullary rod then gives the most predictable and satisfactory alignment. If the distal femur is entered in the centre of the trochlea, the rod will be nearer the *Femoral Anatomic Angle I*, and require setting a lower valgus angle on the instrumentation.

Fig. 25.42 Entry for the intra-medullary reference guide, anterior to the PCL

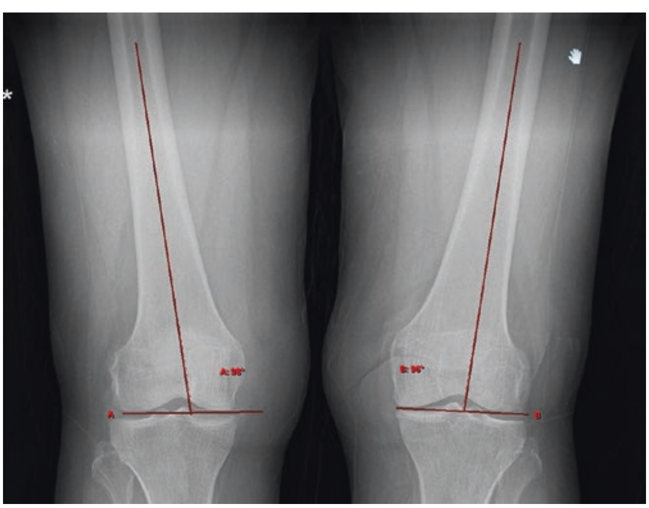


Fig. 25.43 Right knee; the *Femoral Anatomic Axis II*—midline of the distal femur. Left knee; the *Femoral Anatomic Axis I*—centre of shaft to centre of knee

Both of these methods use the distal femur as a reference, and thus ignore the proximal femur. If there is deformity in the proximal femur, it will not be corrected and the result is that the distal femoral cut prioritises the balance of the knee rather than the alignment. This is in contrast to a technique of pre-operative imaging, or intra-operative navigation, where the centre of the femoral head, and thus the femoral mechanical axis will serve as the reference. In this latter technique, and with proximal varus, there will be an asymmetric cut,

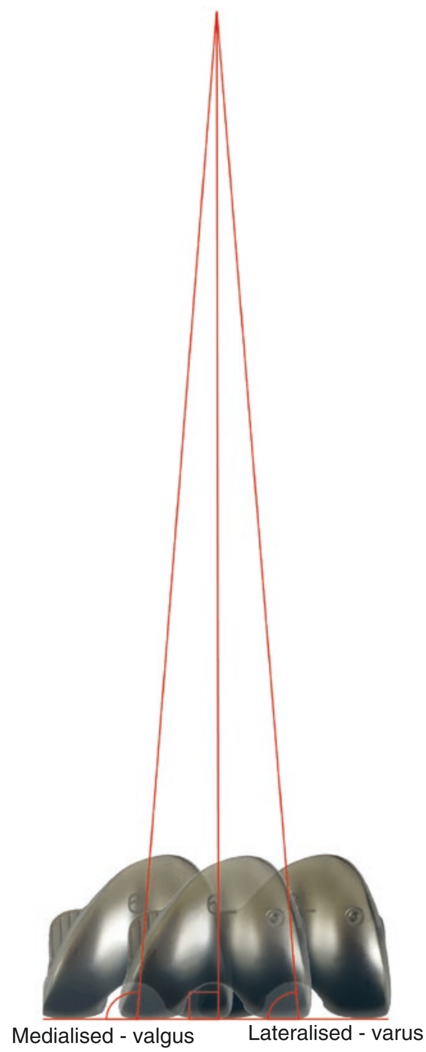


Fig. 25.44 Translation induces small mechanical angle changes

removing more bone laterally, creating an asymmetric gap, as shown above. It will thus prioritise alignment over balance.

We will alter the angle of the cut in two circumstances.

- Lateral femorotibial osteoarthritis. There is a tendency to post-operative valgus, and we cut at a 5° valgus angle.
- In obese patients where the distribution of fat is largely in the lower limb. These people may already have a clinical pseudovalgus of their knees despite having medial femorotibial osteoarthritis, and correcting the deformity either causes or exaggerates this. They often have a very wide based gait to prevent their knees impinging upon each other during swing phase (Fig. 25.45). This is most pronounced when the distance between the centre of the hips is smaller than the distance between the centre of the knees when standing, due to the thickness of the medial soft tissues (Fig. 25.46). The patients compensate with a Trendelenberg gait and a short stance phase, both of which are awkward and raise the energy consumption of ambulation. Correcting the true varus completely will aggravate this situation and so we reduce the cut angle to 6° valgus, rather than 7° (Fig. 25.47).

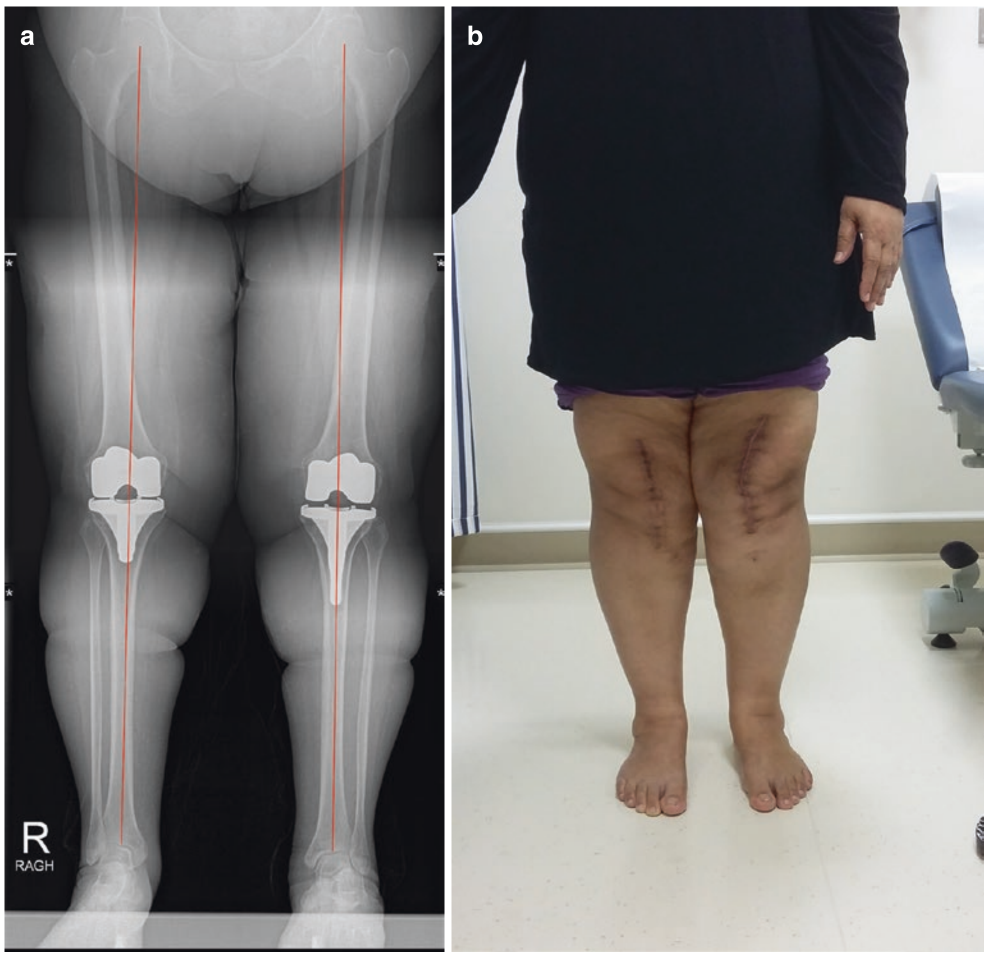


Fig. 25.45 (**a**, **b**): (**a**) Full deformity correction in obese patients may exacerbate or cause pseudovalgus and consequent difficulties of gait. (**b**) This patient attempts to reduce the wide based stance by crossing the knees, but will be unable to do so during gait

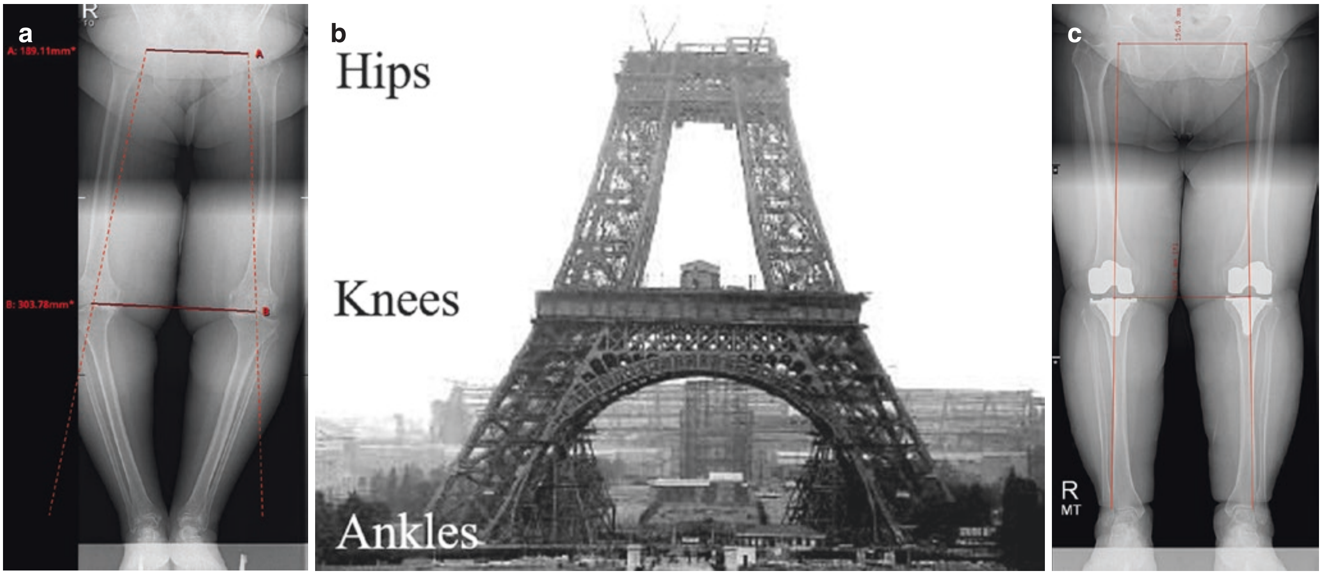


Fig. 25.46 (**a–c**): (**a**, **b**) Distance between knees exceeds that between hips. Full correction will cause a functional deformity of the lower limbs reminiscent of this famous landmark. A design for stability, but not mobility. (**c**) In this case, despite mild varus in both knees, there is still significant pseudovalgus

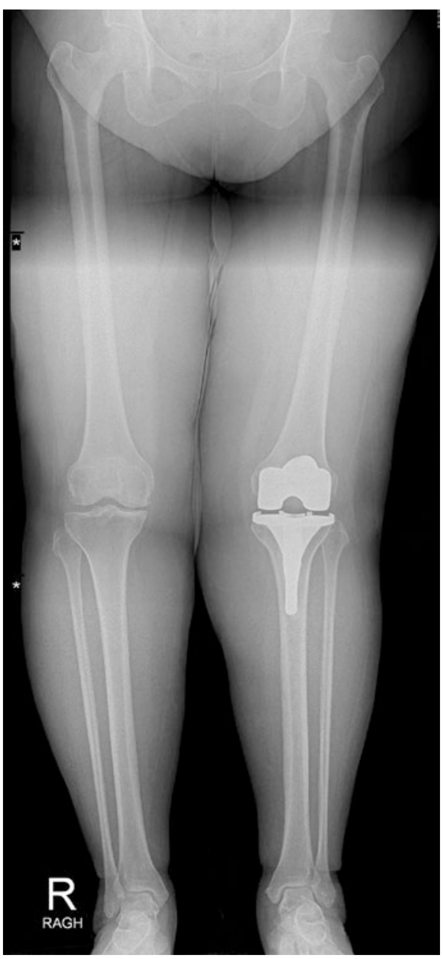


Fig. 25.47 The left knee has been slightly overcorrected (2°). If the right is fully corrected, the intermalleolar distance will be excessive

Tibial Cut

A. Inclination of Cut: Achieving an Orthogonal Cut

The tibial cut is orthogonal to the mechanical axis in the coronal plane and sagittal planes. The effect of sagittal slope on the flexion gap will be discussed later (in 'Balance between flexion and extension'). Combined independent intra-medullary and extra-medullary referencing is possible with our current instrumentation and is used routinely (Fig. 25.48). This caters for a number of clinical situations:

(i) In the case of a straight tibia:
- The intra-medullary (IM) guide is reliable in both coronal and sagittal planes, and is especially useful in obese patients (the tibia is often straight, as the deformity is mainly due to wear in these patients).
- The extra-medullary (EM) guide is satisfactory, but may be less precise in the obese, in both planes, due to the difficulty of identifying the bony landmarks at the ankle (Fig. 25.49).

Fig. 25.48 Right knee. Combined intra- and extra-medullary guidance. The arrow shows the intra-medullary rod, which is fully inserted to reach the ankle

(ii) In the case of extra-articular tibial deformity (simple or complex), or a narrow tibia:
- The IM guide may not reach the ankle. In the case of a tibial deformity, there will be a risk of under correction (Fig. 25.50). The chosen tibial aperture may be changed to pass the rod fully, but further asymmetry of the cut and difficulty balancing may result (Fig. 25.51) (see Chap. 30, TKA after valgus high tibial osteotomy). Subsequent tibial component translation away from the aperture in an attempt to obtain maximum bone coverage will introduce alignment change and needs to be considered. For instance, with a valgus tibial deformity, the aperture would need to be medialised to pass the rod, leading to more medial laxity. Subsequent lateral translation of the component produces varus. It is possible to exploit these facts when dealing with malunions that involve translation as well as angulation. This may be difficult to plan in the tibia, as tibial instruments do not generally allow variable angles of cut, unlike femoral instrumentation (see Chap. 42, Case 10).
- A narrow tibia may preclude the use of IM guidance completely (Fig. 25.52).
- With an EM guide, the proximal and distal reference points are chosen, providing the mechanical axis of the tibia, and ignoring the anatomic tibial axis and deformity in between (Fig. 25.53). Nevertheless, some aspects must be taken into consideration:
  - With severe deformity, previous HTO or metaphyseal malunion, templating is advised as unanticipated impingement of the keel and the tibial cortex may occur (Fig. 25.54) (see Chap. 30).
  - Sagittal plane alignment may be difficult to achieve accurately, especially in obese individuals. Whilst using EM referencing, we therefore recommend using additional IM referencing with a short rod in the proximal tibia, just for the sagittal alignment (Fig. 25.55). An advantage is that if there is sagittal extra-articular deformity, the sagittal cut will prioritise joint balance over sagittal alignment (Fig. 25.56). Pre-operative clinical assessment can anticipate if knee and ankle movement can compensate for the uncorrected deformity without functional loss.
  - Care must be taken when using the anatomy of the foot as a reference, as this may introduce error due to mobility or deformity (tibial torsion will also introduce error).

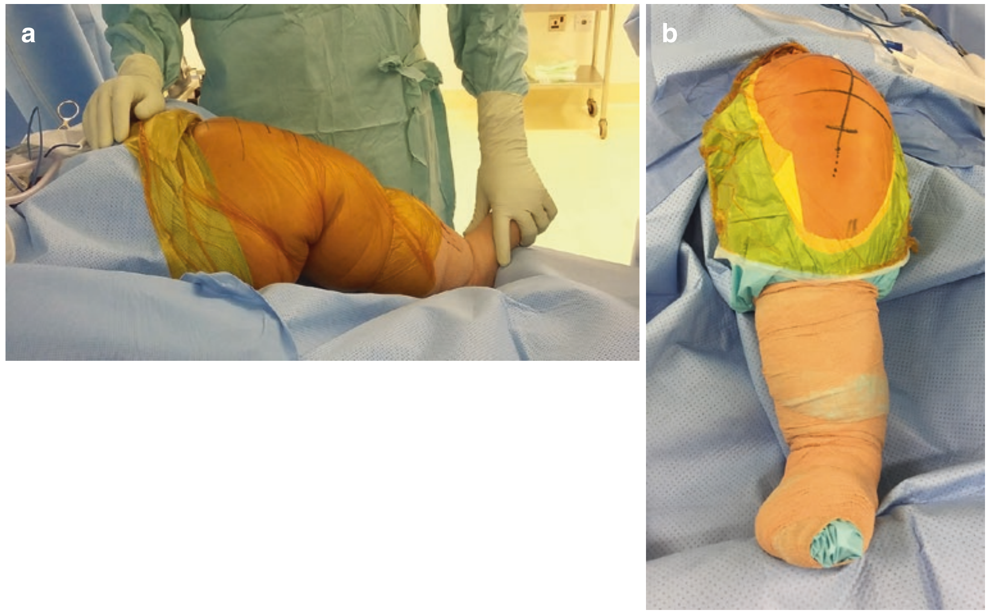


Fig. 25.49 (**a**, **b**) Landmarks at the ankle may be difficult to find when the patient is well covered

Fig. 25.50 Valgus will remain after a cut perpendicular to this rod. The distal reference is medial to the mechanical axis

Fig. 25.51 A medialised proximal reference point here will produce further cut asymmetry and difficulty balancing

– The proximal end of the EM guide must be aligned with the sagittal axis of the tibia (Fig. 25.57) and parallel to the distal end of the guide. Any rotation away from this will introduce a coronal plane change that will affect gap symmetry (Fig. 25.58). This is in contrast to the IM guide, which will still produce a predictable cut in both planes if it is rotated in the axial plane.

B. Inclination of Cut: Effect on Tibial Space Symmetry

The influence of deformity on the coronal space symmetry was discussed in Part II. Any asymmetry of the tibial space from the resection, as well as from contracture or convex side laxity will be dealt with by ligament balancing (Fig. 25.59). In the varus knee, this space is made symmetrical and rectangular by a medial collateral

Fig. 25.52 A narrow canal may preclude the use of an intra-medullary guide

Fig. 25.53 Extra-medullary guidance has been effective in creating an orthogonal cut in this mildly deformed tibia

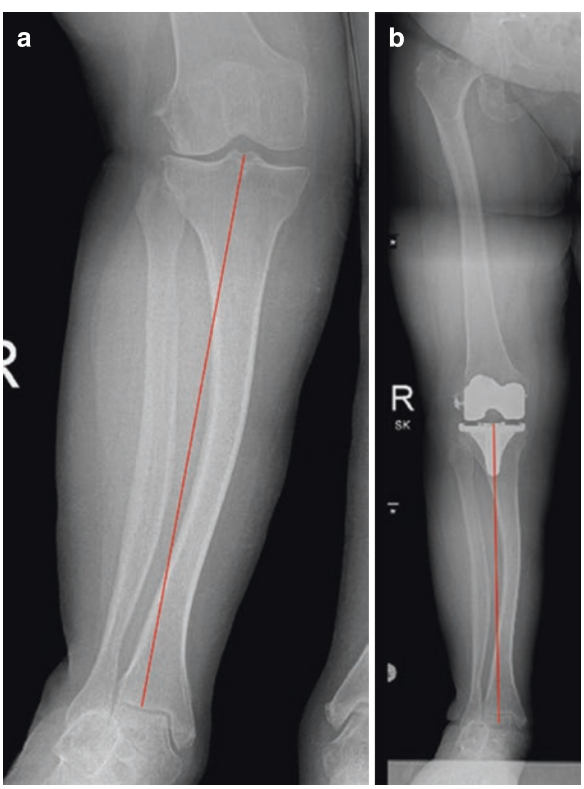


Fig. 25.54 Slight keel impingement was necessary to align the component properly in this more severely valgus tibia. Note the lateral femoral condyle osteotomy for soft tissue balance (See Chap. 30)

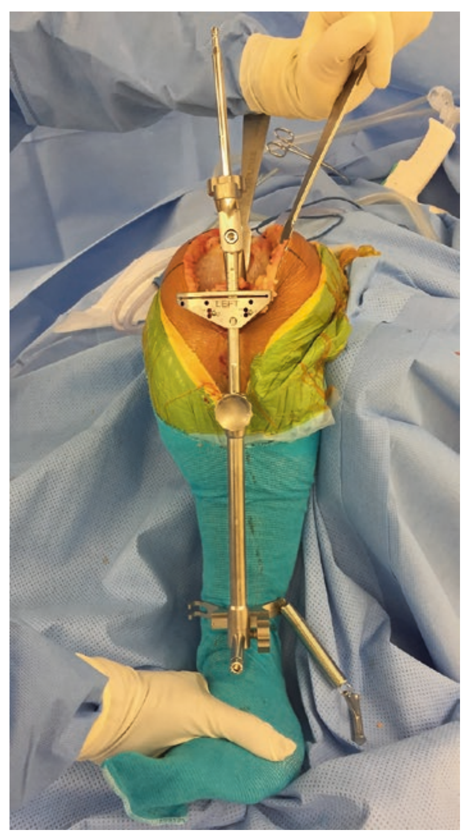


Fig. 25.55 Left knee. Combined intra- and extra-medullary guidance in a varus knee with a varus tibial deformity. The intra-medullary rod is not fully inserted and is used for sagittal alignment only

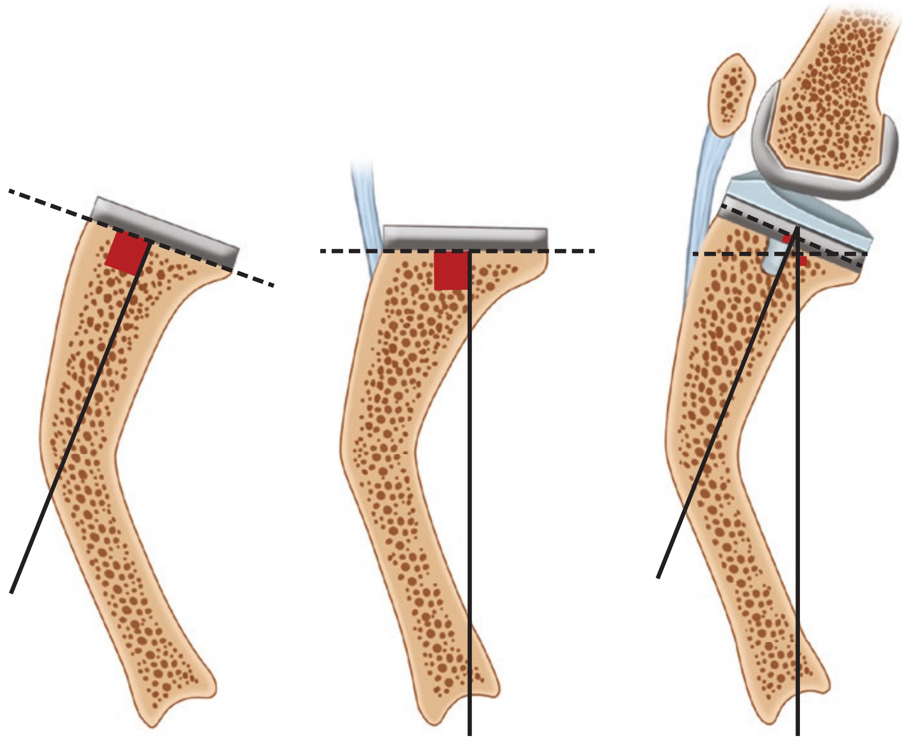


Fig. 25.56 The sagittal cut is prioritised for the joint (left), rather than the alignment (centre). Bone resection and balance would be unacceptable if sagittal alignment was mechanically referenced (right)

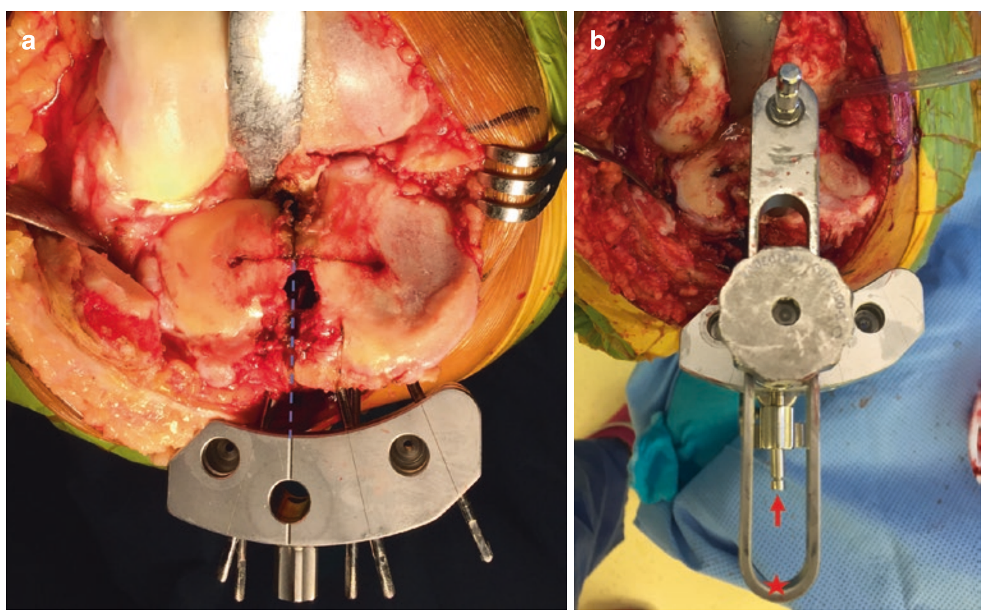


Fig. 25.57 (**a**, **b**): Right knee. (**a**) Care is taken to align the proximal end of the EM guide, and thus the cut block, with the sagittal axis of the tibia. Here, the rotation is guided by the centres of the tibial condyles, as well as the tibial tuberosity. (**b**) The proximal part (star) and distal part (arrow) of the EM guide are parallel

release. As there is only one cut, the symmetrical tibial space produced by the release will be the same throughout flexion and extension. We believe the influence of the MCL release will be the same in flexion and extension, with only minor adjustment between the two possible.

If the asymmetry of the cut is small, a medial release is not necessary. If it is moderate, either pie crusting or formal MCL release from the tibia can be performed. In the latter case, we prefer to add a longer stem (total length at least 75 mm) as the blood supply to the medial tibial condyle may be affected, with a risk of late collapse, especially if there is residual varus or obesity (Fig. 25.6).

There is a limit, however to how much deformity can be compensated by an asymmetric cut and soft tissue balancing without adding constraint to the prosthesis. Larger extra-articular deformities (in excess of 10°) nearer the knee will have a greater effect on the mechanical alignment and may benefit from combined osteotomy and TKA (see Chap. 42, Cases 2a and 2b).

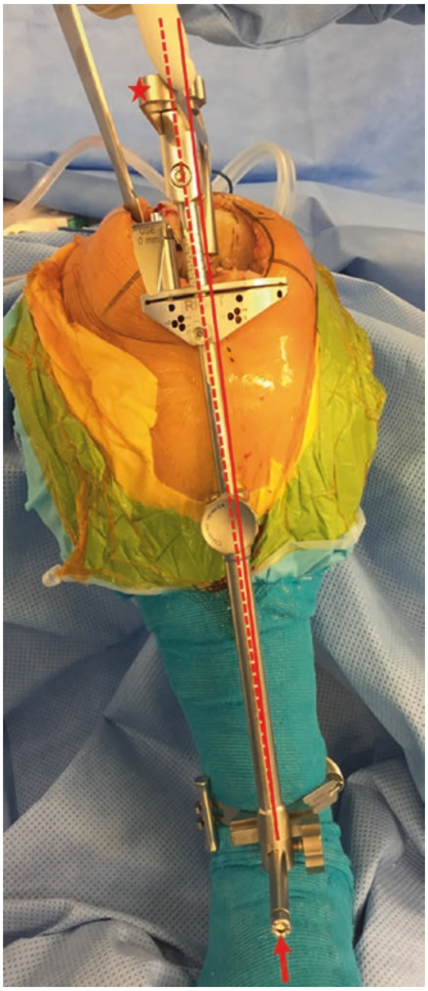


Fig. 25.58 Right knee. External rotation of the proximal end of the extra-medullary guide (star) in relation to the distal end (arrow) results in lateral translation and angulation of the cut block. The angle between the orthogonal intra-medullary guide (solid line) and the extra-medullary guide (dashed line) is visible proximally

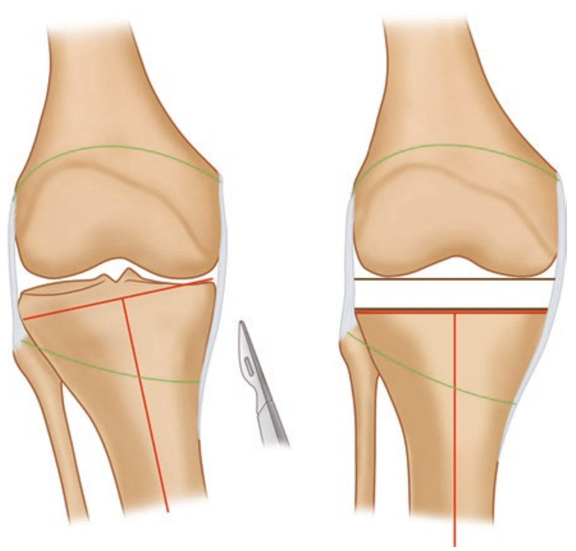


Fig. 25.59 The asymmetric tibial space is equalised by medial release

C. Level of Cut

The level of the tibial cut will affect the height of the tibial space and segment directly though removal of more, or less, bone. However, there may also be an indirect effect, as the level of the cut will also affect the degree to which the peripheral soft tissues are released from bone. The increased soft tissue laxity may cause the space produced by the cut to be larger than the thickness of bone removed, and this will be relevant to those using pre-operative templates. This principle is still relevant when using navigation, as it is currently impossible to anticipate or precisely predict this type of resection laxity by virtual surgery using any current CAS system. The effect may be most obvious laterally where the anterolateral ligament and lateral capsule insert over a proximal-distal distance of several millimetres (Fig. 25.60). This attachment is approximately at the level of a routine tibial cut, but cuts more than 14 mm in total on the medial side, made for instance to accommodate augments, or after HTO with severe deformity hypercorrection, have consequences for ligament balancing too. These effects may be more pronounced when the patient is short. This is because all component sizes require the same thickness of bone resection, and the cut is thus proportionally deeper in a shorter tibia.

Fig. 25.60 Coronal MRI showing insertion of the anterolateral capsular structures on the proximal tibia (white arrow). A 10 mm resection level is depicted (white dotted line). These structures may be more easily damaged in a small knee

2. Alignment and Balance in Flexion

The 'flexion gap' represents the situation through most of the arc of movement, even though for simplification we consider it at 90°. Consideration of this gap is challenging in two ways:

- The femoral cut which forms the flexion gap also defines the patellofemoral gap. Consideration of both become increasingly relevant as TKA is performed more widely in cultures which spend a high proportion of their time in postures of flexion such as squatting, sitting on the floor, or praying. The surgeon faces a double compromise; he/she must consider the coronal alignment of the knee in flexion, ensuring there is no malalignment during stair climbing and squatting, yet avoid significant asymmetry of the tibiofemoral gap. At the same time, with one cut angle and one component, he/she must optimise the mechanics of the patellar femoral joint.
- The success of the flexion gap balancing is less obvious to the surgeon post-operatively:
  - Detection of both malalignment and laxity in flexion through clinical assessment is challenging (Fig. 25.61).
  - Radiographic assessment in flexion is difficult, especially under loaded conditions, and is therefore not commonly performed (Fig. 25.62).

Intra-operative assessment is therefore key, and this is one area where the documentation and focus achieved in navigated knees may be an advantage.

The coronal alignment in flexion is dictated by the posterior femoral cut and thus the rotation of the femoral component. Our technique for this has been described in Part II and relies on equalising the femoral cuts in extension and flexion, thereby equalising the femoral extension and flexion spaces. It is recognised that if the natural axial alignment of the femoral condyles is preserved in TKA by reproducing the PCA (0° external rotation of the posterior femoral cut), but the tibial cut is orthogonal and asymmetric, the knee may be in mild valgus in the flexed position, compared to the pre-operative situation. However, this will match the alignment of the knee in extension, as a mechanically aligned limb will be in mild valgus compared with the average natural knee. This is in keeping with a principle of maintaining equal alignment and tension throughout the range of motion.

Other techniques of deciding the femoral rotation include:

- *Using the epicondylar axes:* If it is decided that the posterior cut needs to be parallel, or at a certain angle to an epicondylar axis, then it follows that the distal cut would also have to be the same angle to this axis to achieve symmetrical femoral extension and flexion spaces (Fig. 25.63). The relationship of the epicondylar axes to the femoral mechanical axis, and the distal and posterior femoral articular surfaces (distal femoral angle and condylar twist) is variable between patients with significant standard deviation (Fig. 25.64). One can utilise pre-operative multiplanar imaging, or estimation of the flexion axis intra-operatively to guide the cuts, but in practice we simply equalise the resection from the distal and posterior part of the condyles.
- *Using a fixed external rotation:* Using a standard external rotation in relation to the PCA for the posterior cut (such as 3°) ignores the variable distal femoral angle and condylar twist found across the population and this may represent an unnecessary compromise for many individuals. The variation is particularly significant in valgus knees.

Fig. 25.61 Assessing lateral laxity in flexion. The limb is taken into full external rotation, and then relaxed until the contact between lateral femoral condyle and polyethylene is felt at the joint line. Repeated examination gives an approximation of the maximum lateral gap. A similar test in internal rotation is made for the medial laxity

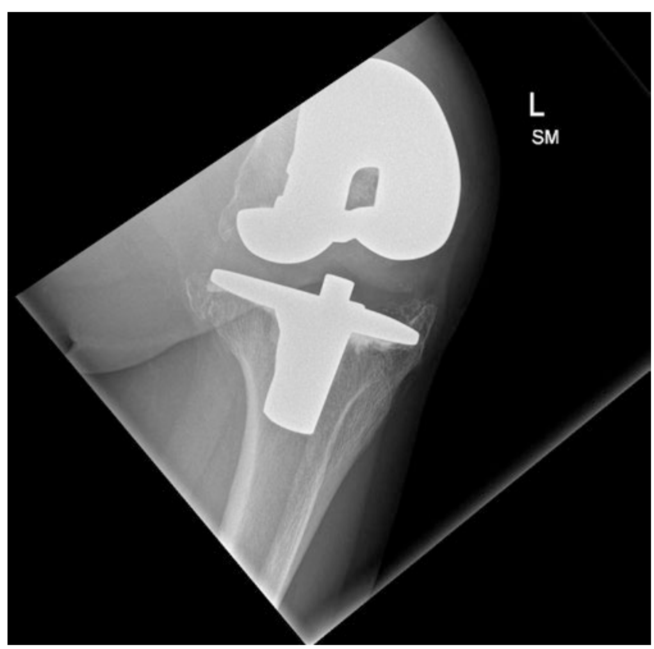


Fig. 25.62 Varus stress view in 90° flexion showing 12 mm lateral opening

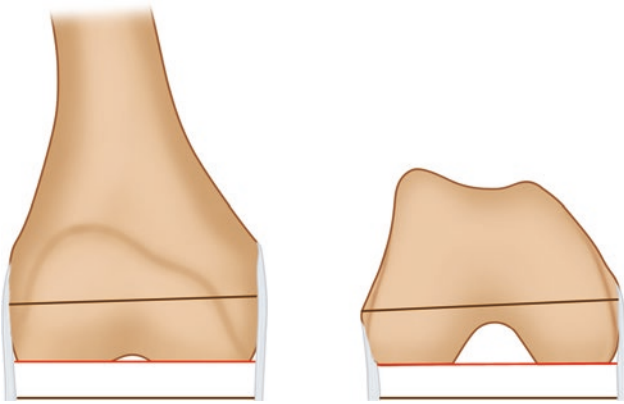


Fig. 25.63 Posterior and distal cuts at the same angle to the transepicondylar axis

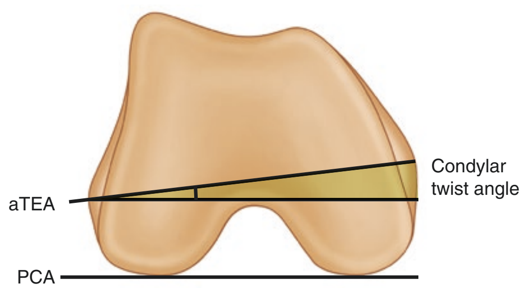


Fig. 25.64 Condylar twist angle

- *Prioritising the femoral rotation on a significant tibial deformity, i.e. using the asymmetry of the tibial cut*: Using 3° external rotation when an orthogonal tibial cut is in 3° of valgus in relation to the natural joint line is logical if the orthogonal distal femoral cut is also 3° varus from the natural joint line. This situation does occur outside of textbooks, but certainly not in all knees. Moreover, if the deformity of the proximal tibia is greater than 3°, say 8°, it would not be logical to externally rotate to that degree. In this bone balancing technique, the flexion balance is prioritised over the flexion alignment. The tibial varus has been removed by the tibial cut, but subsequently recreated in the posterior femoral cut, in the desire to gain flexion balance. Subsequently, one would have to make a similar asymmetric distal femoral cut and accept a similar varus alignment in extension, or alternatively accept different shaped gaps in flexion and extension (with medial tightness in extension).
- *Using gap balancing:* If the surgeon chooses gap balancing instrumentation, the femoral rotation then depends on the asymmetry of the tibial cut and any ligament release. A careful compromise must be found between balance and alignment; prioritising the flexion gap first in a varus knee may mean accepting either varus or medial tightness in extension. Simulating both cuts and gaps in parallel with navigation may be the best way to find this compromise without excessive rotation, or malalignment. Using conventional instruments, the release needs to be considered and performed carefully, and secondary checks utilised to verify the posterior cut angle, for instance information from pre-operative multiplanar radiology, or from intra-operative distal cut thicknesses. The natural laxity of the lateral compartment in flexion, and any persistent medial tightness, may result in excessive external rotation. The effects of varus alignment in the flexed weightbearing TKA are not clear, but external rotational deformity of the distal femur after fracture malunion is known to increase medial compartmental stress, and the overall varus in flexion needs to be considered.

  The other consequences of excessive or inappropriate external rotation of the femoral component may be summarised as follows:
  - Notching of the lateral femoral cortex or an increase in size of the femoral component. An increase in AP size, and thus ML size, increases the chance of medial or lateral overhang, and consequent soft tissue irritation or tightness of the knee. The chance of size mismatch between the two components also increases, depending on the prosthetic system used.
  - Abnormal patellar femoral kinematics.
  - Flexion-extension gap shape mismatch in proximal femoral varus deformity (see Fig. 25.39a); where the distal cut has removed more bone laterally, but the externally rotated posterior cut has removed more bone medially. The extension gap is trapezoidal, wider laterally. The flexion gap is trapezoidal, wider medially (Fig. 25.65). In this type of deformity, we perform a posterior cut in a neutral position, accepting mild medial laxity in flexion. Only internal rotation of the posterior cut would equalise the shape of the tibiofemoral gaps, but at the expense of the patellar femoral joint.

Our approach to rotation is the natural result of considering the femoral space separately. The cut orientation, and therefore the space and balance, is the same in extension and flexion. The advantages are that the technique is individualised, reproducible, and does not require special instrumentation, navigation or pre-operative imaging.

Tibial component rotation is chosen to optimise the patellar tracking as well as the femorotibial congruency, and here a further compromise may be necessary. Our method is to mark the natural AP and ML axes on the tibial plateau prior to the tibial cut using the centre of each condyle, the PCL, and the tibial tuberosity as references (Fig. 25.66). The axes can be transferred to the rest of the tibia for use after tibial resection by marking an anterior point on the anterior tibia for the sagittal axis, and a drill hole for the centre of each condyle for the transverse axis, allowing triangulation (Fig. 25.67).

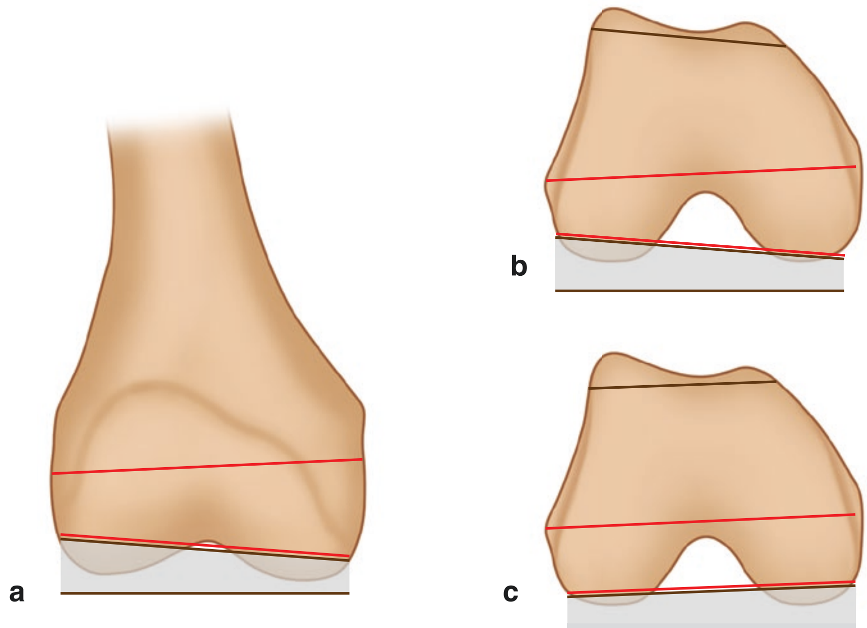


Fig. 25.65 (**a**–**c**): Right knee. Equalising the spaces in flexion and extension would require cutting the femur at the same angle to the transepicondylar axis distally and posteriorly, thereby internally rotating the prosthesis. (**a**) Distal cut removing more lateral than medial condyle. Trapezoidal gap wider laterally. (**b**) Posterior cut internally rotated, at the same angle to the transepicondylar axis as the distal cut. Trapezoidal gap wider laterally so flexion and extension gaps can be balanced, but unacceptable for patellar biomechanics. (**c**) Posterior cut externally rotated, removing more bone medially. Flexion gap wider medially, extension gap wider laterally

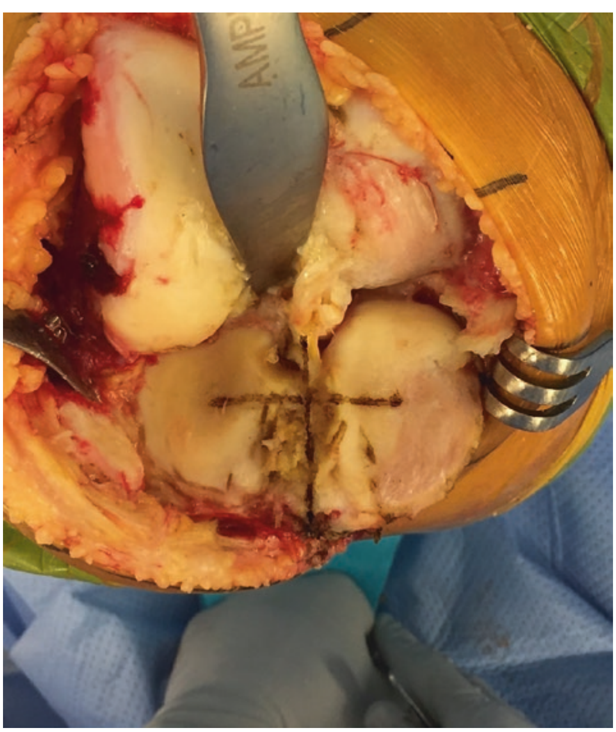


Fig. 25.66 AP and ML axes on the tibial plateau prior to the tibial cut, using the centre of each condyle, the PCL, and the tibial tuberosity as references

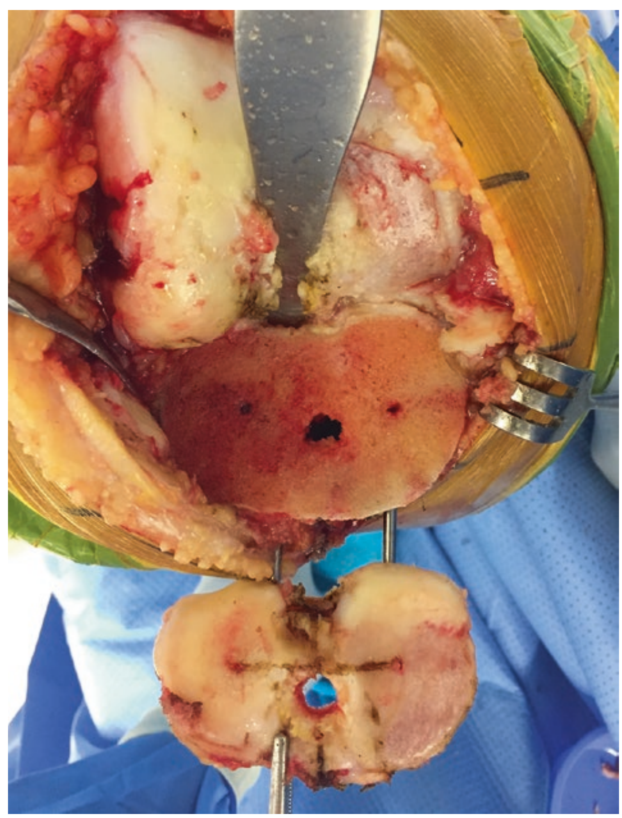


Fig. 25.67 The axes can be transferred to the rest of the tibia for use after tibial resection by marking an anterior point on the anterior tibia for the sagittal axis, and drilling the centre of each condyle for the transverse axis

3. Balance Between Flexion and Extension (Gap Balance)

The balance between flexion and extension is a reflection of the relative size of each part of the gap. It is recognised that this traditional analysis ignores the mid flexion balance, but the better the flexion and extension gaps are balanced, the less likely there will be instability between them. The priority for us however is the balance in extension, and a small degree of flexion laxity is acceptable, especially with appropriate orientation of the cuts.

In the absence of pre-operative fixed flexion deformity, equalising the level of the distal and posterior femoral cuts will usually produce symmetry, and our method to achieve this is described in Part II, and below (see 'Prosthetic interface'). However, there are a number of factors to be considered:

Pre-Operative Factors

- Pre-operative fixed flexion deformity (Fig. 25.68)
- Large posterior osteophytes (Fig. 25.69)

Fixed flexion deformity is usually and conveniently dealt with by proximalising the femoral cut, thus reducing the femoral segment, although the pathology often lies with contracture of the active and passive posterior soft tissue structures. However, after removal of posterior osteophytes, controlled posterior release from femur or tibia is difficult, and the consequence of over-release (uncontrolled recurvatum during gait) is difficult to treat without changing to a constrained prosthesis. This particularly is the case with the posterior medial tissues including the menisco-tibial ligament and posterior oblique fibres. They may not heal and require mechanical stabilisation with a hinged prosthesis rather than soft tissue management. A compromise of slight residual fixed flexion deformity in combination with mild flexion laxity will be more acceptable to the patient than uncontrolled recurvatum with a perfect flexion gap. There is a trend of improvement in post-operative fixed flexion deformity over time.

Fig. 25.68 Pre-operative fixed flexion deformity

Operative Factors

- Femoral component condylar geometry.
- Resection or insufficiency of the Posterior Cruciate Ligament (PCL). The flexion gap increases preferentially.
- Femoral cut levels.
  - The AP position of the femoral starting hole may affect both orientation and translation depending on the instrumentation, and using the PCL as a landmark is reliable. It is appropriate to reference the sagittal orientation of the femoral component from the distal femoral anatomy, not a line from the centre of the femoral head to the centre of the knee. However, an IM rod placed from our recommended entry hole to the isthmus of the femoral canal may be in some extension compared to the distal femur, and we reference 3° flexion from the rod (Fig. 25.70).
  - The level of anterior and posterior femoral cuts is determined by
    - the chosen reference; anterior or posterior
    - the component size
    - the chosen centre of rotation (see below Part 4, Prosthetic interface)
- A priority must be made for the level of the anterior or posterior cut, at the same time accommodating the off-the-shelf prosthetic sizes.
- The level of the posterior cut in relation to the level of the distal cut affects the gap balancing. It also determines the correct posterior offset to maximise flexion by preventing posterior impingement (Fig. 25.71).
- The level of the anterior cut will affect the patellar femoral gap, and in most cases the anterior offset will ideally remain unchanged to maintain physiological

Fig. 25.69 Posterior osteophytes, usually femoral, limit range of movement

patellar loads. The level of the anterior cut is ideally adjusted to resect the same thickness of bone from the anterior condyles and trochlea as will be replaced by the components although most systems' anterior femoral reference is simply from the anterior cortex proximal to the trochlea (Fig. 25.72). The trochlear depth and condylar height will therefore also be dictated by the geometry of the femoral prosthesis.

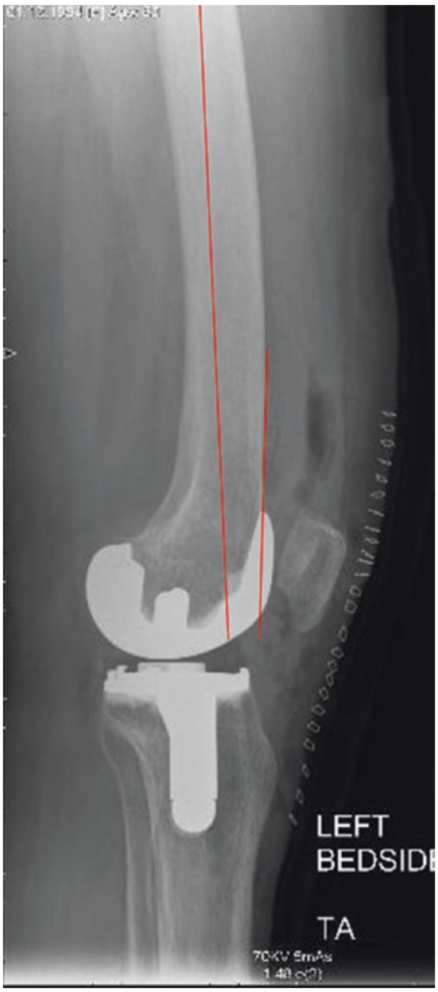


Fig. 25.70 The distal cut is flexed in relation to an IM rod due to the femoral bow

- The compromise between anterior and posterior cuts and component size is further complicated as the choice of AP component size will dictate the ML dimensions too, which will in turn affect the tension of the medial and lateral patellar restraints. To this end, we recommend choosing a smaller femoral prosthesis, if bone quality allows.
- Tibial cut sagittal orientation.
  – We use a posterior stabilised prosthesis, and a 0° sagittal tibial slope, referenced from the proximal tibia (Fig. 25.73). This reduces the forces on the posterior part of the polyethylene, prevents anterior tibial subluxation during weightbearing, and avoids excessive laxity in flexion in a PCL substituting design.
  – Conversely, a 0° cut in a tibia with an exaggerated pre-operative slope will tighten the flexion gap in relation to the extension gap. Using a positive slope will loosen the flexion gap preferentially, due to the more posterior position of the femoral condyles on the tibia with increasing flexion and may be more appropriate to achieve balance in a PCL conserving TKA.

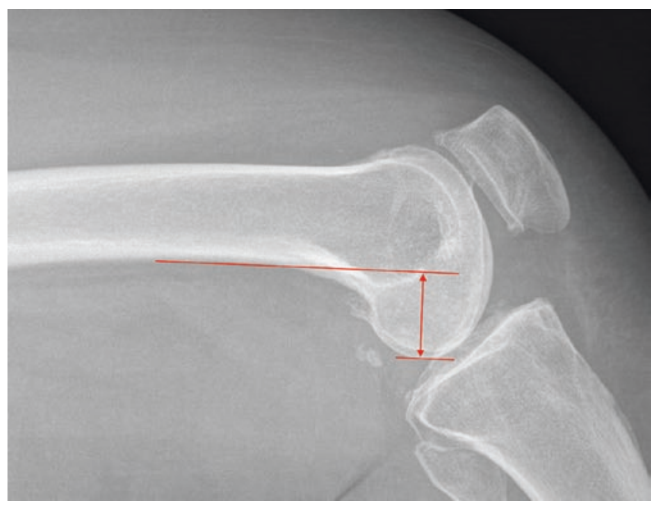


Fig. 25.71 The correct posterior offset will affect gap balancing and prevent posterior impingement in flexion

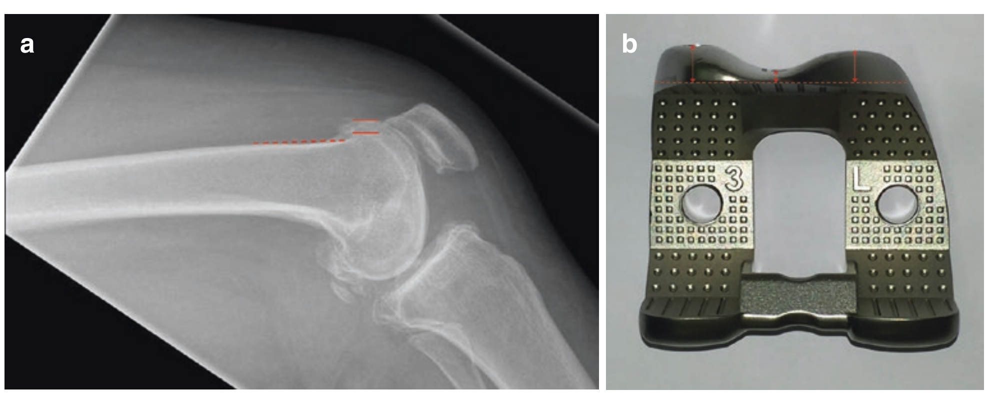


Fig. 25.72 (**a**, **b**): The most common anterior femoral referencing is from the anterior cortex proximal to the trochlea (dotted line). The anterior offset of the trochlea and the femoral condyles (solid lines) will also be influenced by the femoral component geometry

Fig. 25.73 Zero degree tibial slope, referenced from the proximal tibia

4. Prosthetic Interface

General Principles

In the natural knee, the articulating interface is termed the joint line. In a TKA, the femoral and tibial and patellar segments meet at the prosthetic interface. The position of this is important in relation to:

- The origins of the collaterals, and other components of the femorotibial soft tissue envelope
- The position of the patella and the origins of the patellar femoral and patellar tibial restraints

Several pathological situations may exist, which dictate the likelihood of a change in the position of the prosthetic interface, compared to the native joint line:

A. No Change in Prosthetic Interface

Intra-articular deformity, from joint wear (Fig. 25.29). Where there is no deformity correction needed apart from that due to intra-articular wear, keeping the prosthetic interface at the level of the native joint line is straightforward. The cut is usually symmetric, or almost so. The thickness of bone that is removed on the convex reference side will be replaced by the implant. On the tibia, this reference is usually situated on the convex, longer side. This will be the centre of rotation of the angular correction and thus there will be no change in level of joint line on this reference side. The soft tissues on the concave side are brought out to length, or surgically lengthened with a release if necessary, in order to restore the height of the native joint line on the concave side and produce a rectangular space. This may be guided by the level of the meniscal rim.

B. One-Sided Change in Prosthetic Interface

Extra-articular bone deformity (unreducible) (Fig. 25.30). Where unilateral lengthening has to be performed because of an asymmetric cut due to deformity, the level of the prosthetic interface may still be established from the reference side. On the side of the lengthening, there will be an increase in the size of the segment, and an increased height of the prosthetic interface in relation to the native joint line. With increasing extra-articular deformity, there is increasing change in the level of the interface.

C. Both Sided Change in Prosthetic Interface

Most often in these cases, there is lengthening on both sides of the joint; the gap produced by the pathology, bone cut, and soft tissue balancing exceeds the thickness of the bone resected. The cause may be bony or soft tissue pathology:

- *Convex side laxity* (Fig. 25.31). This may occur with chronic and severe deformity (Fig. 25.74). In this case, both sides of the joint will need to be addressed to produce a rectangular gap; on the concave side, soft tissue release will need to be performed (becoming longer than the pre-disease state), whilst the slack on the convex side will need to be taken up. This will result in a potential both sided lengthening, with an increase in limb length by a few millimetres (Fig. 25.75). The space produced will exceed the thickness of bone resected. The segment may need to be increased by using a thicker component to tension the soft tissues adequately, and the level of the prosthetic interface will have been altered.
- *Iatrogenic lengthening of the ligaments or soft tissue*. This may occur when the anterolateral ligament and capsule is sectioned during a routine tibial cut, increasingly likely with greater cut depth (Fig. 25.60). If there is metaphyseal deformity, for instance after an HTO, the obliquity of the orthogonal cut may increase the likelihood of convex side soft tissue injury.
- *Iatrogenic extra-articular deformity*. This is seen in patients who have previously undergone high tibial

Fig. 25.74 With chronic and severe deformity, there may be true convex side laxity

osteotomy. The usual reference point will be in a different location with regard to the rest of the plateau (Fig. 25.76). Less bone will need resecting on the reference side to avoid an unacceptably large gap from the bone removal, or damage to the peripheral soft tissue envelope (see above and Chap. 30). There is potential for change in the level of the prosthetic interface.

- *Significant intra-articular deformity from bone wear*. This is more common in lateral tibiofemoral compartment osteoarthritis (Chap. 27) and in rheumatoid arthritis. There may be no natural point of reference due to tri-compartmental disease, and thus the exact natural joint line may be difficult to define.

Where the lengthening is both sided, thicker implants will need to be used, or bone resection will have to be more sparing. The degree to which these are required will be dictated by the accepted laxity.

- If less bone is removed from the tibial side, or if a thicker polyethylene component is used, the tibial segment will be increased, i.e. there will be a greater distance between the prosthetic interface and all the soft tissue insertions on the tibia (MCL, patellar tendon, capsule) and on the fibula (LCL) (Fig. 25.77). This will clearly have an effect on femorotibial biomechanics. The prosthetic interface will have been 'raised' (proximalised) in relation to the original native joint line and the patella (Fig. 25.19). If the tibial segment is larger due to the thickness of the polyethylene rather than a sparing tibial cut, an additional consideration will be the resulting forces at the implant bone interface. These will be a function of the relative distances of the prosthetic interface (where torque forces are applied) and

Fig. 25.75 Uncommonly, laxity on one side of the joint may require some lengthening to achieve stability

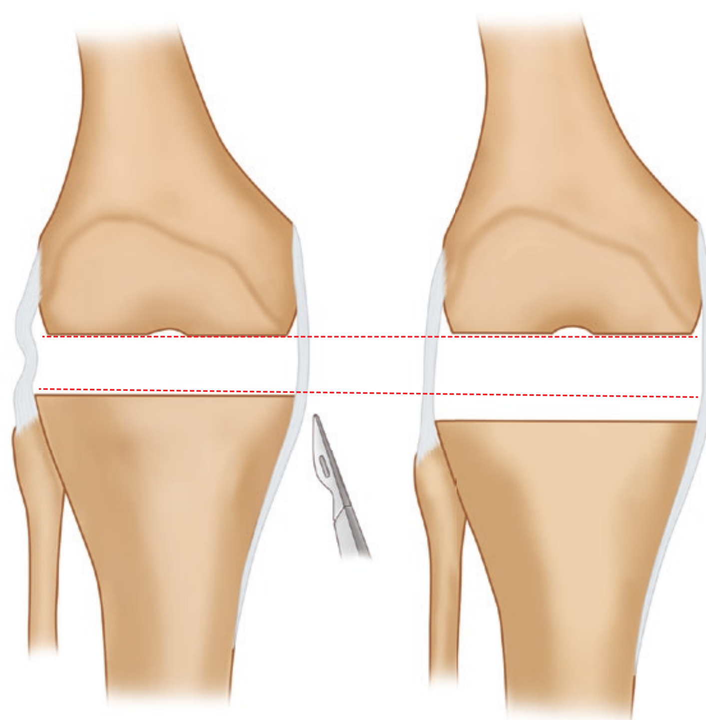


Fig. 25.76 The lateral joint reference point in this varus knee is altered by previous surgery. If the cut is made at the usual distance (e.g. 10 mm) from the lateral plateau, there will be an excessive cut of the medial tibia. A thinner cut is appropriate, perhaps like that shown here in red

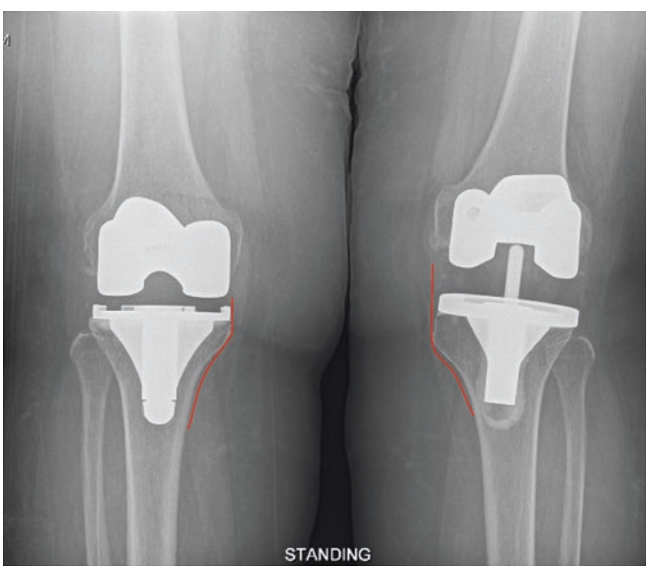


Fig. 25.77 Greater distance between the prosthetic interface and MCL origin in the left knee

the distal tip of the prosthesis (where the forces may be maximally resisted) to the implant bone interface (which can be debonded by repetitive stress) (Fig. 25.78). As the distance between the prosthetic interface and implant bone

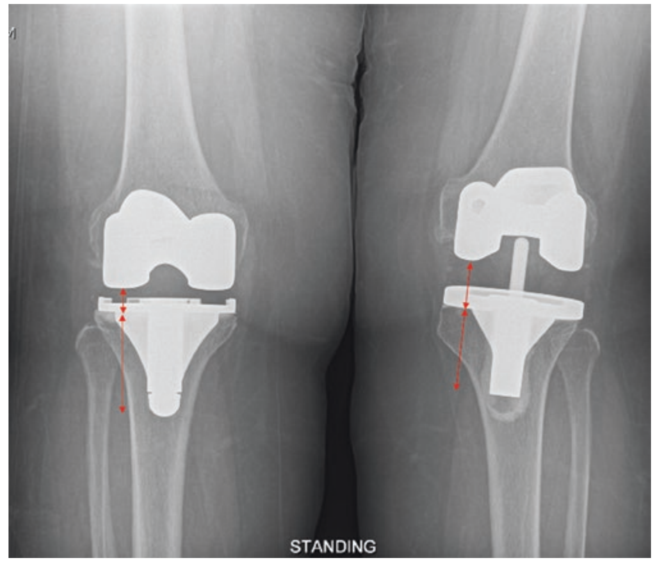


Fig. 25.78 Torque at the plateau cement bone interface will be proportional to the length of keel and height of the prosthesis

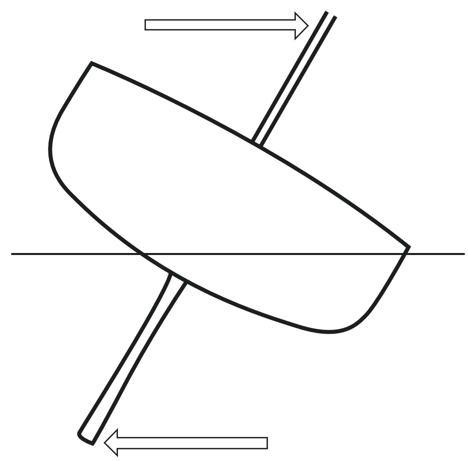


Fig. 25.79 The analogy of a keelboat

interface becomes larger, so too must the support from the prosthetic keel. One analogy is a keelboat, where the keel provides counter-torque to the forces acting on the sail (Fig. 25.79). If balancing the knee requires a very thick polyethylene insert, consideration should be given to achieving joint stability by changing the type of prosthetic constraint instead, for instance, by using a rotatory hinge knee. The prosthetic interface and the biomechanics can then be kept within acceptable limits.

- If less bone is removed from the femoral side, or if the bearing surface of the femoral component is moved more distally by the use of augments, the femoral segment will be increased, i.e. there will be a greater distance between the prosthetic interface and the soft tissue insertions on the distal end of the femur (MCL, LCL, capsule), especially in extension (Fig. 25.80). Again there will be effects on the femorotibial biomechanics; more so than with tib-

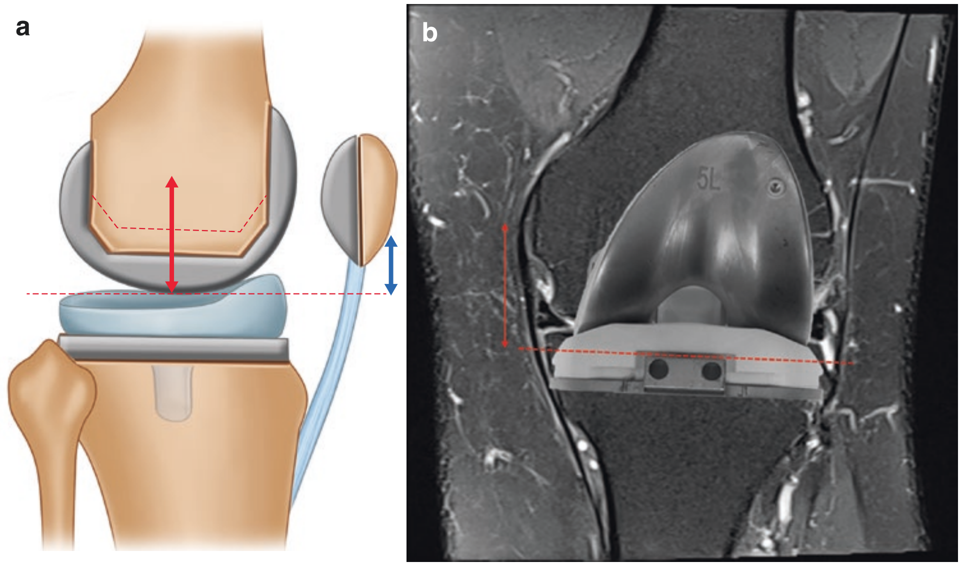


Fig. 25.80 (**a**, **b**): (**a**) As the femoral segment is lengthened (red arrow), the tibiofemoral biomechanics will change, but the relationship between the prosthetic interface and the patella remain constant (blue arrow). (**b**) The femoral segment has been increased by under-resection and tibial decreased by over-resection. The total length of the soft tissues is unchanged from the natural state, but the joint line is distalised

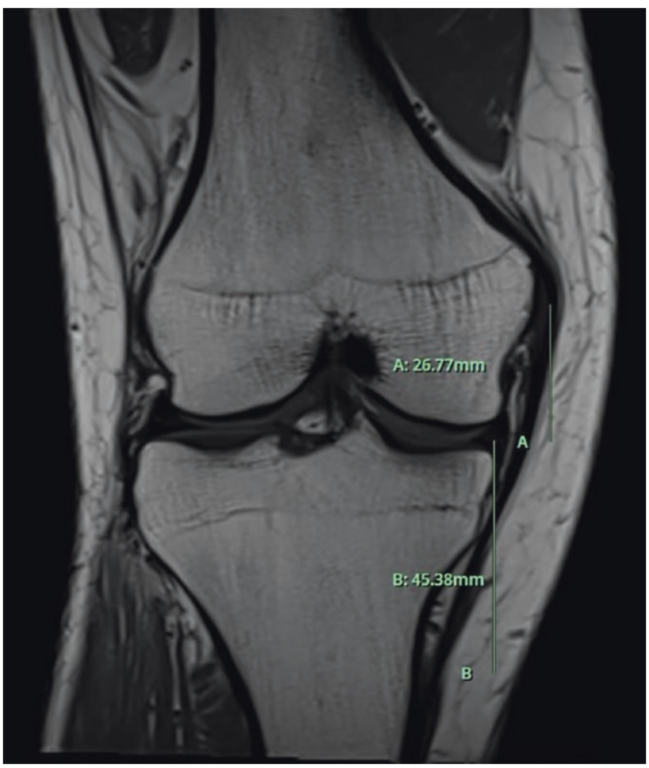


Fig. 25.81 The proportional length of the tibial and femoral parts of the MCL in this patient are shown

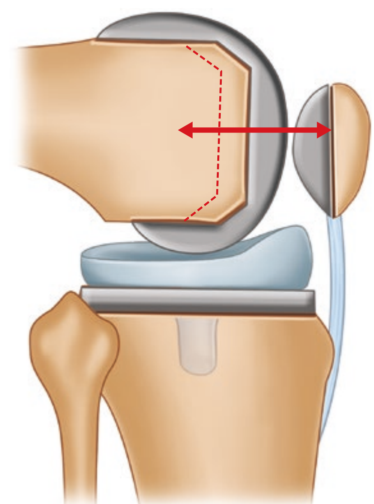


Fig. 25.82 The patellar restraints will be subject to length change and tension, especially in flexion

ial segment lengthening, due to the shorter distance to the collateral insertions (Fig. 25.81). With isolated femoral segment lengthening there will be no change in patellar height in relation to the femorotibial prosthetic interface or trochlea; however, the distance from the patellar femoral interface to the origins of the lateral and medial patellar restraints on the femur (MPFL, retinaculum, etc.) will increase, especially in flexion (Figs. 25.80a and 25.82), causing increased tension in these tissues.

The limits of lengthening of tibial and femoral segments relate to the kinematics of the patellar femoral joint and the collateral ligaments, bearing in mind that the effect of changes in femoral segment will be proportionally larger. We suggest a lengthening of tibia and femur in the ratio 2:1. In absolute terms, the limit is probably around 4 mm for the tibia (e.g. standard 10 mm tibial cut, and increase of polyethylene of 4 mm, total tibial component 14 mm), and 2–3 mm for the femur. More than this will suggest the use of a more constrained prosthesis (rotating hinge) to preserve the level of the prosthetic interface. The limit of accepted laxity is multifactorial and it is difficult to state an absolute figures. It relates to the alignment and adductor moments, whether the laxity is medial or lateral, the flexion/extension balance, activity level, age and weight of the patient.

Level of Prosthetic Interface in Flexion

This level is a function of the relative sizes of the tibial segment and the femoral segment in flexion. Certain factors will particularly influence the posterior condylar offset, and thus the interface in flexion:

- *Type of cut*. A measured resection (using independent cuts) is less likely to alter the level than a dependent cut, which may do so.
- *Reference system*. A posterior referencing system will help keep the interface at the same level as the native joint line, as opposed to an anterior referencing system which will prioritise the anterior space.
- *Prosthetic design and inventory*. Increasing number of sizes and femoral/tibial compatibility will reduce the need to anteriorise a femoral component to prevent notching.
- *Sagittal flexion*. Flexion of the distal cut may increase the femoral segment (Fig. 25.71).
- *The centre of rotation.* If the centre of the knee is chosen for an externally rotated cut, the thickness of medial condylar bone removed will be more than the replaced metal, and the level of the medial interface will have changed from the native joint line, albeit by a small amount (Fig. 25.83). The centre can be chosen however to influence the level change. For instance, in a valgus knee, there is often pre-existing medial laxity, and the external rotation can be achieved by 'building up' the lateral condyle, rather than resecting more posterior medial condyle. The term 'build up' will apply to the use of spacers of some kind to add to the foot of the rotation guide to remove less bone than is replaced with metal (Fig. 25.37b), increasing the lateral segment. Here, the centre of rotation is the posterior articular surface of the medial condyle, and exactly the same amount of medial bone will be removed as replaced with metal (Fig. 25.84). The concave lateral side will have been lengthened (in flexion) to match the lengthening in extension that is required to correct valgus deformity in extension. This technique helps to prevent medial laxity in flexion, especially when there is a flexion extension mismatch due to pre-operative fixed flexion deformity. In this situation, the flexion gap

a

b

Fig. 25.83 (**a**, **b**). Centre of rotation central left knee. External rotation centrally requires resection of more bone posterior medially and anterior laterally, compared with a neutral rotation

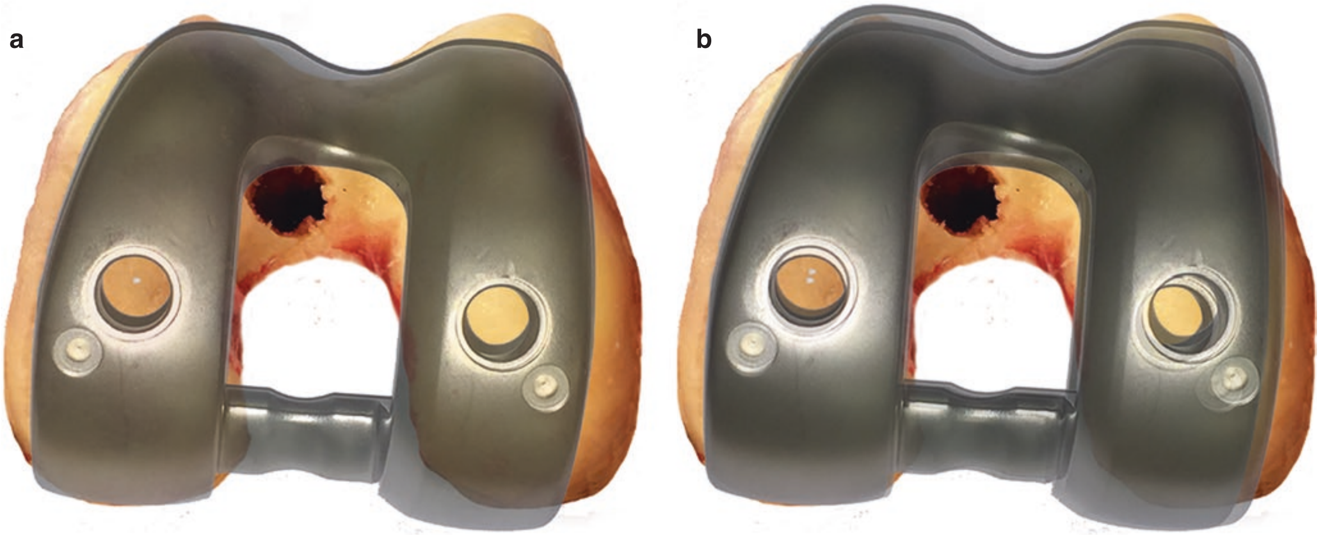


Fig. 25.84 Centre of rotation at posterior medial condyle left knee. (**a**) The medial joint level is unchanged from pre-operative, but more anterior lateral resection is required, increasing the chance of anterior notching. (**b**) Smaller and larger sizes are superimposed, both with the same rotation. Upsizing reduces the notching, but may cause medial or lateral overhang

will tend to be more lax already, especially on the medial side. The disadvantage of this technique is the resulting increase in AP dimension of the femoral prosthesis (already necessary with external rotation), which can lead to ML overhang, and component mismatch. A solution is to use a combination of the two techniques as a compromise, placing the centre of rotation on a line between the centre of the knee and the posterior medial condyle (see Chap. 27, Fig. 25.17).

Sequence of Steps in TKA

The sequence of the steps is often different to the sequence of priorities. This discrepancy is large due to the currently used surgical instrumentation. The challenge is to proceed with the steps but keeping in mind the priorities, thinking a few steps ahead.

Although various sequences are possible, most often the tibial cut is made first. This is in part because practically it can be the first step in all of the general approaches of TKA. There are several advantages:

- It contributes to the first priority of TKA—alignment and balance in extension.
- The coronal orientation of the tibial cut is probably more critical than the femoral in terms of long-term fixation and can be set at the start of the procedure.
- There is only one cut, and only one tibial space, which affects the femorotibial gap throughout flexion and extension. This simplifies the subsequent intra-operative decisions.
- If necessary, the tibial segment can be adjusted:
  - It can be reduced easily later in the procedure by distalising the level of resection (e.g. if the gap is tight throughout extension and flexion) (Fig. 25.85). Proximalising the femoral cut is less simple once the chamfer/box cuts have been performed.
  - It can be increased with modular polyethylene inserts or monobloc components of different thickness (e.g. if the gap is lax throughout extension and flexion). Adjustment to increase the femoral subspace after the femoral cut is not possible without augmentation, due to fixed distal thickness of the component. This means that if there is laxity in extension, either pre-operative and missed in the pre-operative assessment, or iatrogenic caused during the tibial cut, it will be difficult to correct without resorting to a revision prostheses. This will require augments, stems, and suitable instrumentation, often not available at the time of the primary surgery. Initially making a conservative distal cut guards against this, but may require more frequent re-cutting.
- The extent of the resection laxity due to the tibial cut is impossible to predict with accuracy. There is therefore an advantage to perform this step early in the procedure, even when using navigation.

Occasionally in a very stiff knee, and sometimes when there are posterior tibial osteophytes, it may be difficult to sublux and cut the tibia first safely (Fig. 25.86). In this situation, one can start with the femoral cuts. A sizing and rotation guide which has smaller posterior ‘feet’ facilitates this part of the procedure (see Chap. 27, Fig. 27.8).

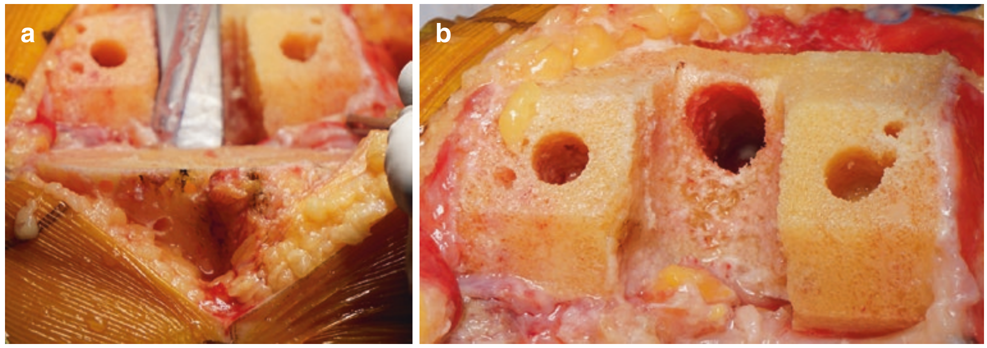


Fig. 25.85 (**a**, **b**): (**a**) Distalising the level of the tibia is straightforward with one cut (**b**). Due to the number of cuts, complexity of the shape, and the lower stability of the instruments on small areas of bone, proximalising the femoral cut with accuracy is less straightforward, and more time consuming

Fig. 25.86 Posterior tibial osteophyte can prevent anterior subluxation of the tibia

The procedure may progress in a number of ways; the surgeon chooses a planned sequence of cuts and ligament releases. At one end of the spectrum, all the cuts are made initially, in a way that is designed to make balancing predictable (Fig. 25.87). The releases, also anticipated, are performed afterwards. At the other end of the spectrum, with navigation, one cut is made, and a stage follows where ligament release and gap simulation with virtual cuts precedes the definitive bone resection. In between, there are other possible sequences. The chosen basic sequence is a reflection of the surgeon's training, experience, and equipment available to him.

Our preferred sequence is to start with the tibial cut, for the reasons stated above. This initiates the tibial space, and if no ligament balancing is required, completes it. We then create the femoral spaces, starting with a measured resection of the distal femur. Our alignment in extension is thus set and prioritised. The balance in extension is prioritised in many cases by using intra-medullary guidance and ignoring mild proximal femoral varus if it exists. Also, the medial release can be performed at any stage as our only dependent cut does not rely on ligament tension, and so balance in extension can still be prioritised. Size and shape of the femoral flexion space is then matched to the extension space by the dependent posterior cut, completing the alignment/balance in flex-

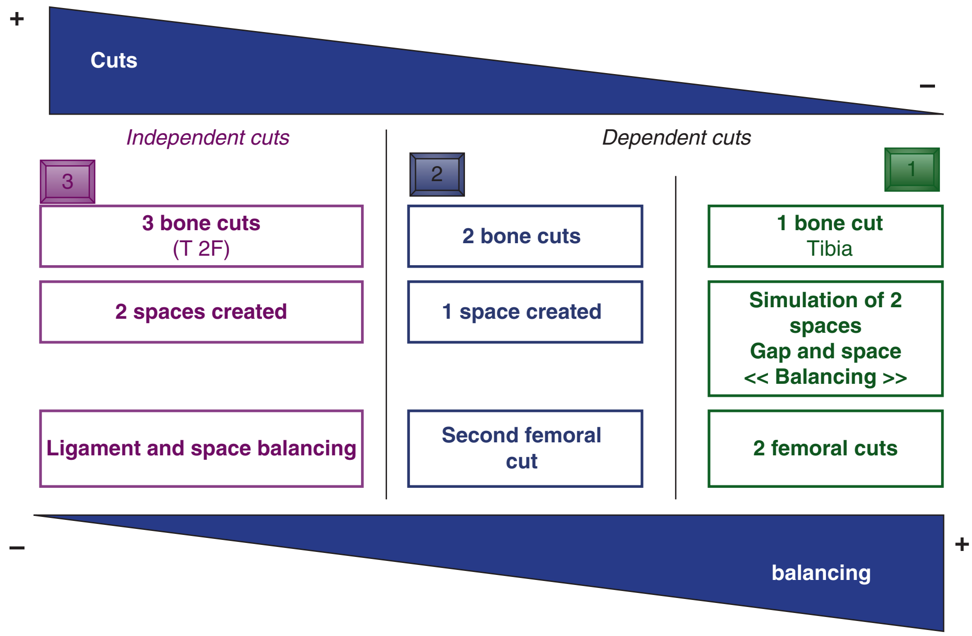


Fig. 25.87 This table depicts the different ways of proceeding with TKA and shows the emphasis on either cuts or balancing

ion, and the gap balancing. One aspect that is set early is the sagittal inclination of the tibial and femoral cuts. These are not straightforward to revisit. In practice, we find performing PCL sacrificing TKA with 0° tibial, and 3° femoral cuts lead to satisfactory gap balancing, but like in any conventional TKA sequence, there has been an inevitable compromise in the order of priorities.

Although in most cases the sequence will be a routine for each surgeon, there are a number of variations of the procedure which can be anticipated pre-operatively, by clinical and radiological assessment as outlined in the next section.

Part IV Everyday Practice

There are various surgical pathways that can be utilised to perform a TKA. The aim of the clinical and radiological examination is to identify anatomical and pathological features that predict the need for certain steps, and their consequences. In doing so, some of the algorithm of TKA may be considered prior to entering the operating room.

The main factors to consider are:
- Soft tissue envelope
- Presence of deformity
- Site of deformity: Tibia vs femur; intra-articular vs extra-articular

A. Examination

The presence and location of deformity is most accurately identified by long leg standing radiology, Rosenberg views, lateral views of the knee, as well as the skyline view. However, clinical examination gives some important information that is not supplied by routine studies and may alert the surgeon to the need for special studies such as stress views, or long lateral views.

1. Deformity
   - Is the deformity reducible? If so, it may be possible to restore the orientation and level of the natural joint line. If it is not, there may be concave side contracture requiring release, or extra-articular deformity requiring an asymmetric cut and ligament balancing.
   - Is there evidence of sagittal deformity? This may determine the type and reliability of referencing, and/or affect the flexion/extension gap balance (Fig. 25.56). Long lateral views may be required, as the deformity may have been missed on standard lateral films, and not be visible on long leg frontal views.
2. Limited range of motion
   - Is there fixed flexion deformity? This may predict difficulty with gap balancing requiring extra distal femoral resection, attention to posterior osteophytes, and certain releases. This also informs the interpretation of the frontal long leg X-rays; flexion deformity and rotation of the limb will produce apparent coronal deformity.
   - Is there limited flexion? This may be from an intra or extra-articular pathology, but either way predicts difficulty with exposure, and subluxing the patella or the tibia. The sequence may need to be altered, with femoral first preparation, and techniques for exposure employed such as a quadriceps snip, or tibial tubercle osteotomy.
3. Laxity
   - On formal collateral testing is there coronal laxity on the convex side, or a lateral thrust during gait (Fig. 25.74)? This predicts the need for a significant concave side release, a large gap, and an altered prosthetic interface in relation to the natural joint line (Fig. 25.31).
   - Is there recurvatum? This suggests a cautious approach to bone resection to avoid the need to fill the space with thick polyethylene (Fig. 25.88). There may be generalised laxity, but the neurology also needs to be assessed to exclude weakness as a cause. In both situations, the possibility of needing increased constraint must be considered. In these cases, exposure is likely to be straightforward.

B. Radiology

Plain radiology allows a functional assessment from weightbearing views, which inform about soft tissues as well as bone and joint deformity. They can be supplemented by stress views to look for reducibility or maximum laxity (see Chap. 26, Figs. 25.3 and 25.5).

Analysis of long leg weightbearing frontal views, and 45° flexion weightbearing views (Rosenberg) reveal the location of the deformity. If sagittal deformity is suspected, long lateral views can be obtained. Deformity needs to be defined as:

- intra-articular or extra-articular
- tibial, femoral, or both bones
- metaphyseal or diaphyseal

There are certain ‘families’ of deformity. In the varus knee, it originates most commonly in the proximal tibia (Fig. 25.4, and see Chap. 14, Figs. 14.8, 14.9 and 14.10). It may also arise more proximally in the femoral diaphysis, the proximal femur, or the rest of the tibia (Figs. 25.33 and 25.89). In valgus deformities, the pattern is often mixed; lat-

Fig. 25.88 Pre-operative recurvatum

Fig. 25.89 Varus in the shaft, as well as the proximal tibia

Fig. 25.90 Valgus deformity in the shafts of both femur and tibia, as well as lateral femoral condylar hypoplasia

eral condylar hypoplasia may coexist with valgus in the shafts of the tibia and femur (Fig. 25.90).

Measurements are made to localise and define the deformity:

- mechanical limb alignment (Fig. 25.91)
- mechanical and distal anatomic alignment of the femur (Fig. 25.92)
- alignment of the tibia (Fig. 25.93)

Care needs to be taken that the alignment X-rays are taken with the leg in neutral rotation. External rotation will exaggerate the difference between the mechanical and distal anatomic femoral angle (Fig. 25.94), and a combination of external rotation and flexion will increase the apparent mechanical limb varus (Fig. 25.95). Planning the distal femoral cut on the basis of these angles must be done with caution.

Rotational deformity is often neglected as a cause of osteoarthritis and needs to be sought clinically and, if necessary, radiologically by CT. External rotational deformities of the femur are most common after fracture and produce increased adductor moments, leading to medial compartment overload. This could potentially be relevant when planning a TKA in a young patient, with the potential of corrective osteotomy as an adjunctive procedure.

Fig. 25.91 Hip Knee Ankle angle—HKA

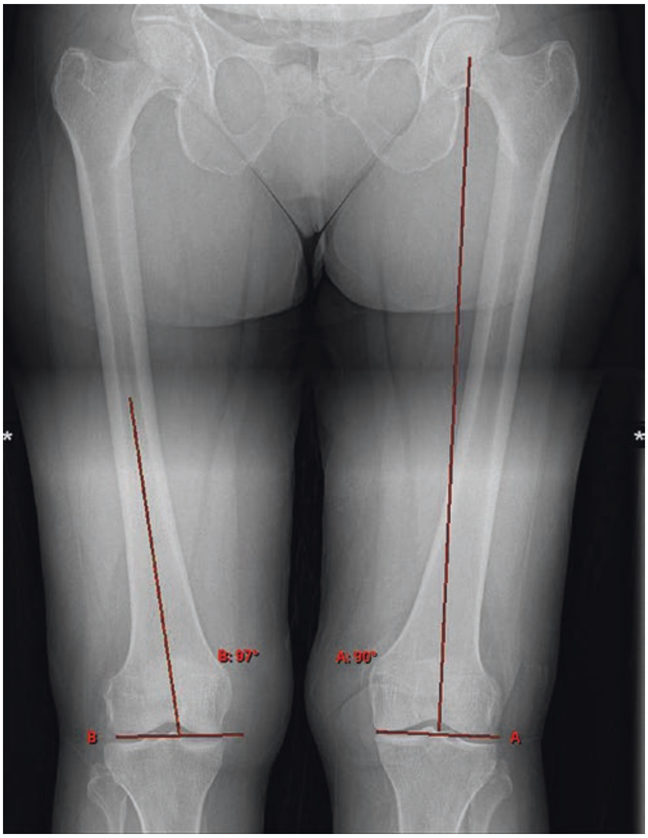
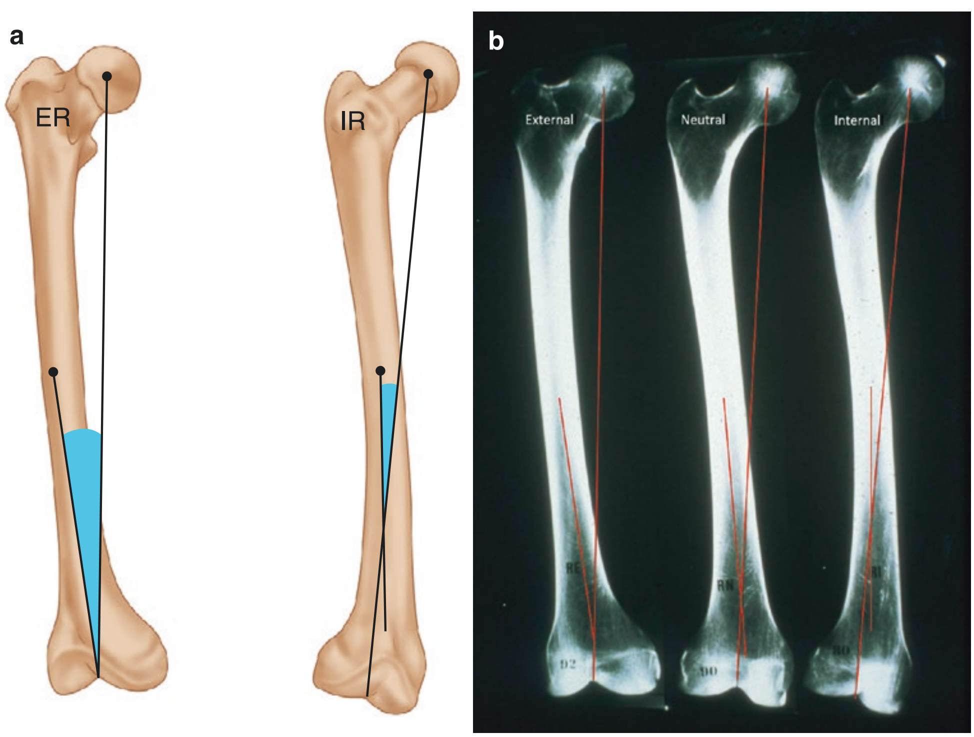


Fig. 25.92 Right femur; medial distal anatomic femoral angle. Left femur; medial (mechanical) femoral angle *MFA*

Fig. 25.93 Medial tibial angle *MTA*

Fig. 25.94 External rotation exaggerates the difference between the mechanical and distal anatomic femoral angles



The intended type of referencing is then considered; mechanical or anatomic referencing of the femur? Intra-medullary or extra-medullary referencing of the tibia? Appropriate reference lines are drawn, and thus the inclination of both femoral and tibial cuts, and balance and post-operative alignment anticipated. For instance:

- *In the case of the femur*. If there is no deformity in the femur, mechanical axis referencing from the femoral head may be appropriate for both alignment and balancing. If there is deformity, and the degree is acceptable, distal anatomic referencing will prioritise the balance of the knee over the alignment and may be preferable (Figs. 25.38 and 25.39).
- *In the case of the tibia*. If there is no deformity, intra-medullary referencing is possible, accurate, and an advantage in the obese. If there is deformity, extra-medullary guidance needs to be considered for coronal alignment; even if an intra-medullary guide can be passed, it may lead to error (Figs 25.51 and 25.96). Intra-medullary guidance may still be advantageous for appropriate sagittal alignment however (Fig. 25.56). Potential conflict between the tibial keel and the cortex can also be anticipated at this stage (Fig. 25.54, and see Chap. 27).

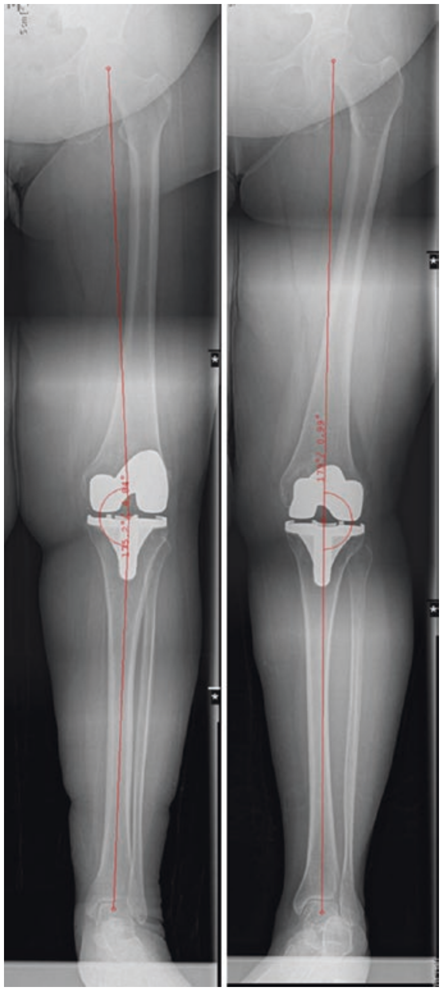


Fig. 25.95 Long films of the same limb on the same day. With slight external rotation and flexion, the limb appears in varus (left x-ray). With slight internal rotation it appears slightly valgus (right x-ray)

The extent of extra-articular deformity will predict the asymmetry of bone resection in relation to the origin of the collateral ligaments. In turn this will predict gap asymmetry and the need for ligament balancing:

- *Intra-articular deformity due to wear*—cut less asymmetric, and soft tissue release less likely (unless soft tissue contracture significant) (Fig. 25.29).
- *Extra-articular deformity*—cut always asymmetric, and soft tissue release likely (Fig. 25.30).
- *Deformity near the knee joint*—greater effect on asymmetry of cut (Fig. 25.96).
- *Deformity far from knee joint*—less effect on asymmetry of cut.

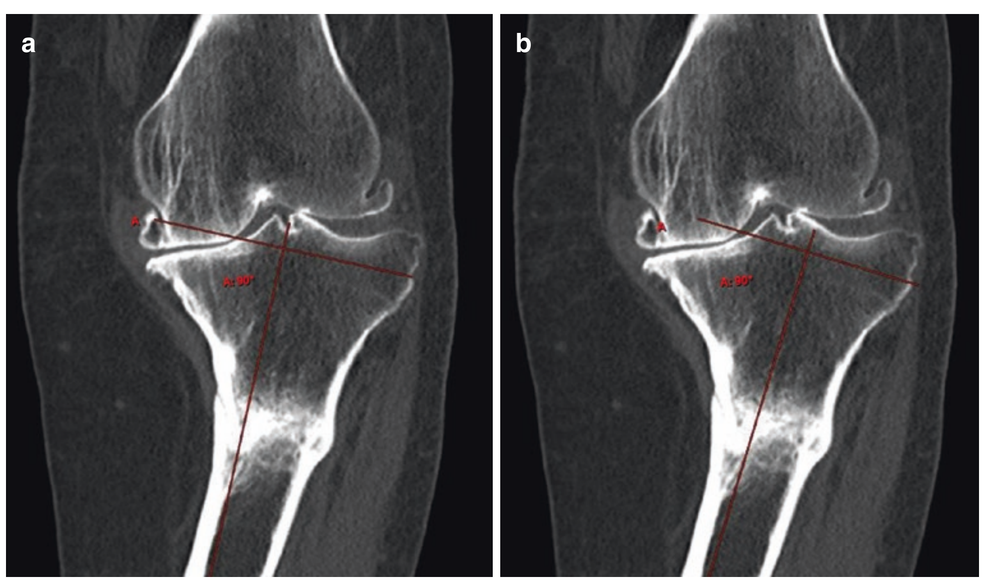


Fig. 25.96 (**a**) Deformity near the knee creates an asymmetric cut. This is exaggerated when the reference point is lateralised in an attempt to pass an IM rod (**b**). Planning at this stage is also important to anticipate keel and cortex impingement

Examples

1. **Medial compartment OA in a knee with no extra-articular deformity.**

There is reducible varus, no laxity, and a good range of motion. The HKA is 176°, MFA 91°, and MTA is 89° (Fig. 25.97). An orthogonal 10 mm tibial cut referenced from the lateral side using combined IM and EM referencing, removes almost the same amount of bone from the medial and lateral tibial condyles (Fig. 25.98). The 8 mm, 7° valgus, 3° flexion, distal femoral cut removes almost the same bone from the medial and lateral condyles (Fig. 25.99). The rotation is set to do the same, a 0° posterior cut (Fig. 25.100). No AP adjustment is necessary to use a size 3 femur, compatible with a size 2 tibia. Gap symmetry does not require ligament release, and the gaps are balanced. Post-operative alignment is mechanical (Fig. 25.101).

- As there is no extra-articular deformity, achieving the desired alignment for longevity does not require alteration of the patient's original soft tissue envelope, and gap symmetry and balancing is automatic.

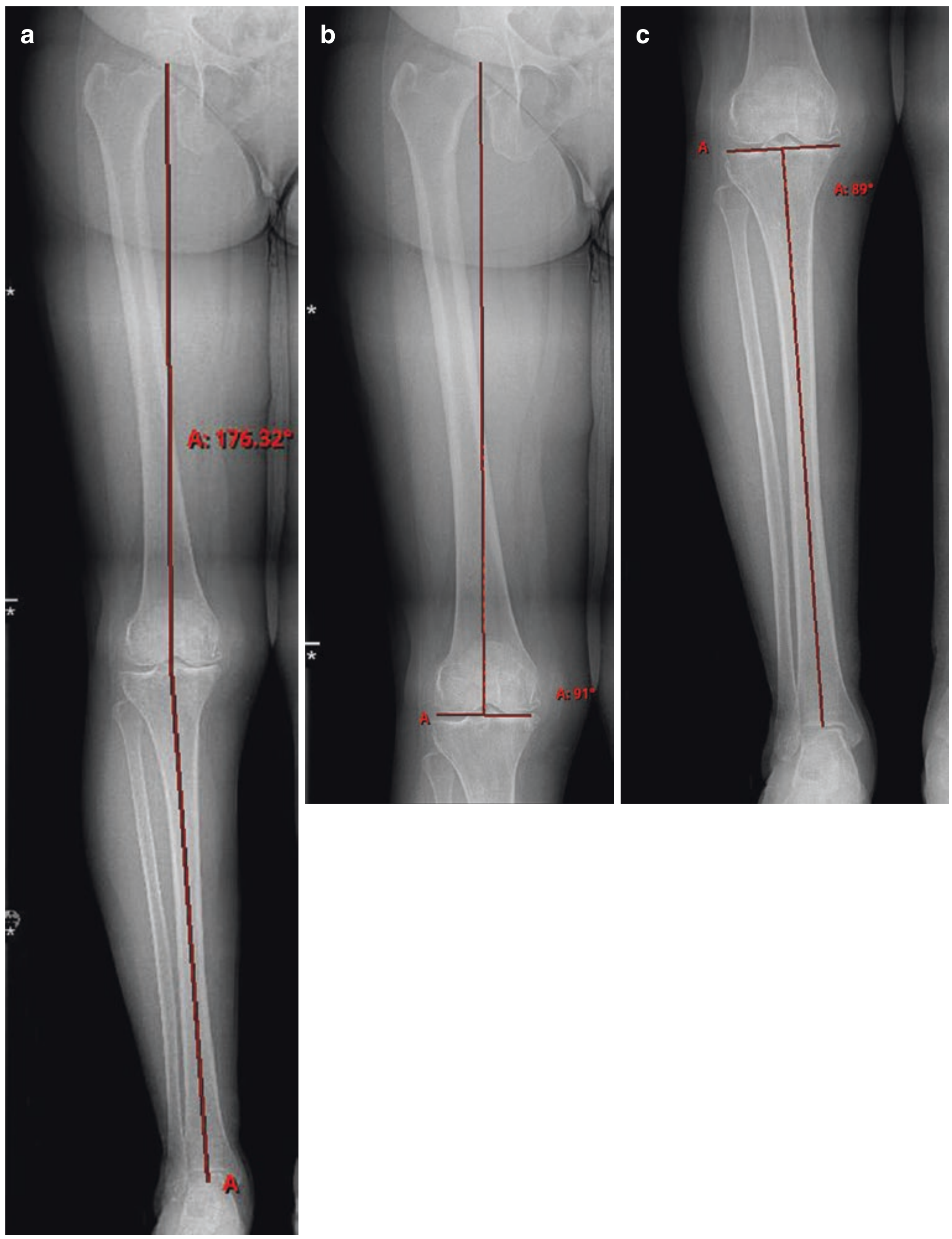


Fig. 25.97 (**a–c**): Case 1. Minimal varus from joint wear and no bone deformity

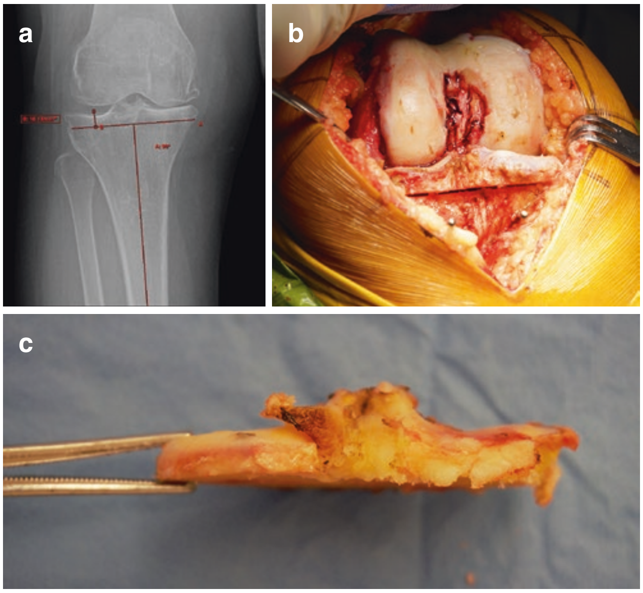


Fig. 25.98 (**a**–**c**): Case 1. The tibial resection is almost symmetrical (the excised tibial plateau is more easily viewed from posterior)

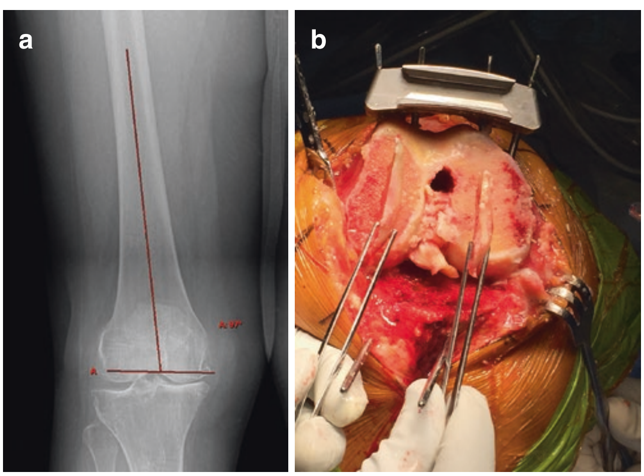


Fig. 25.99 (**a**, **b**): Case 1. Equal distal resection of the femoral condyles

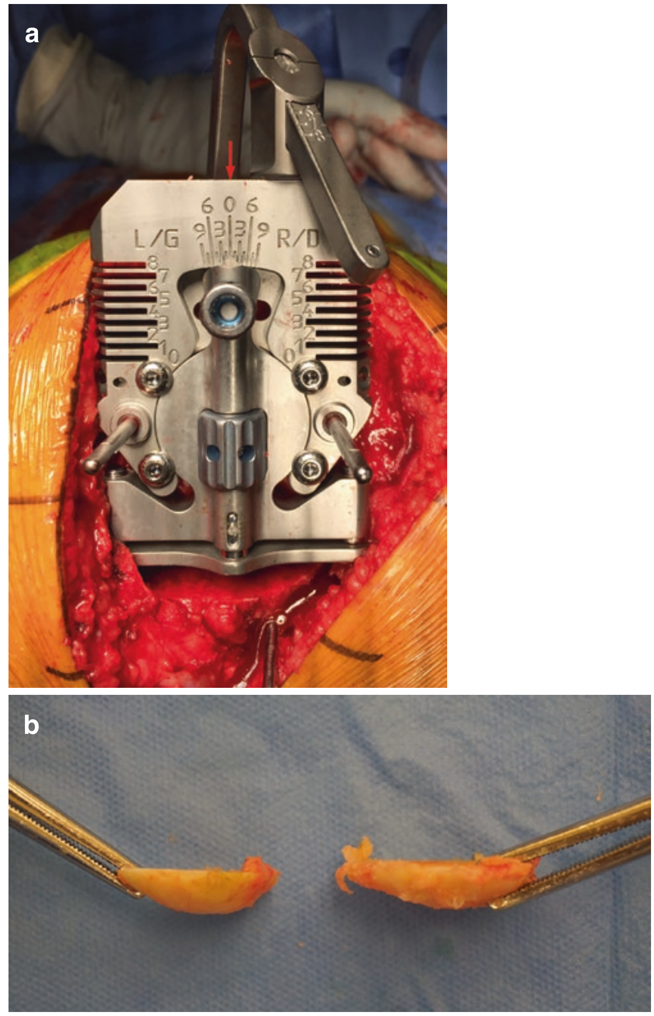


Fig. 25.100 (**a**, **b**): Case 1. Equal posterior resection of the condyles; the result of setting the rotation/sizing guide to 0° external rotation

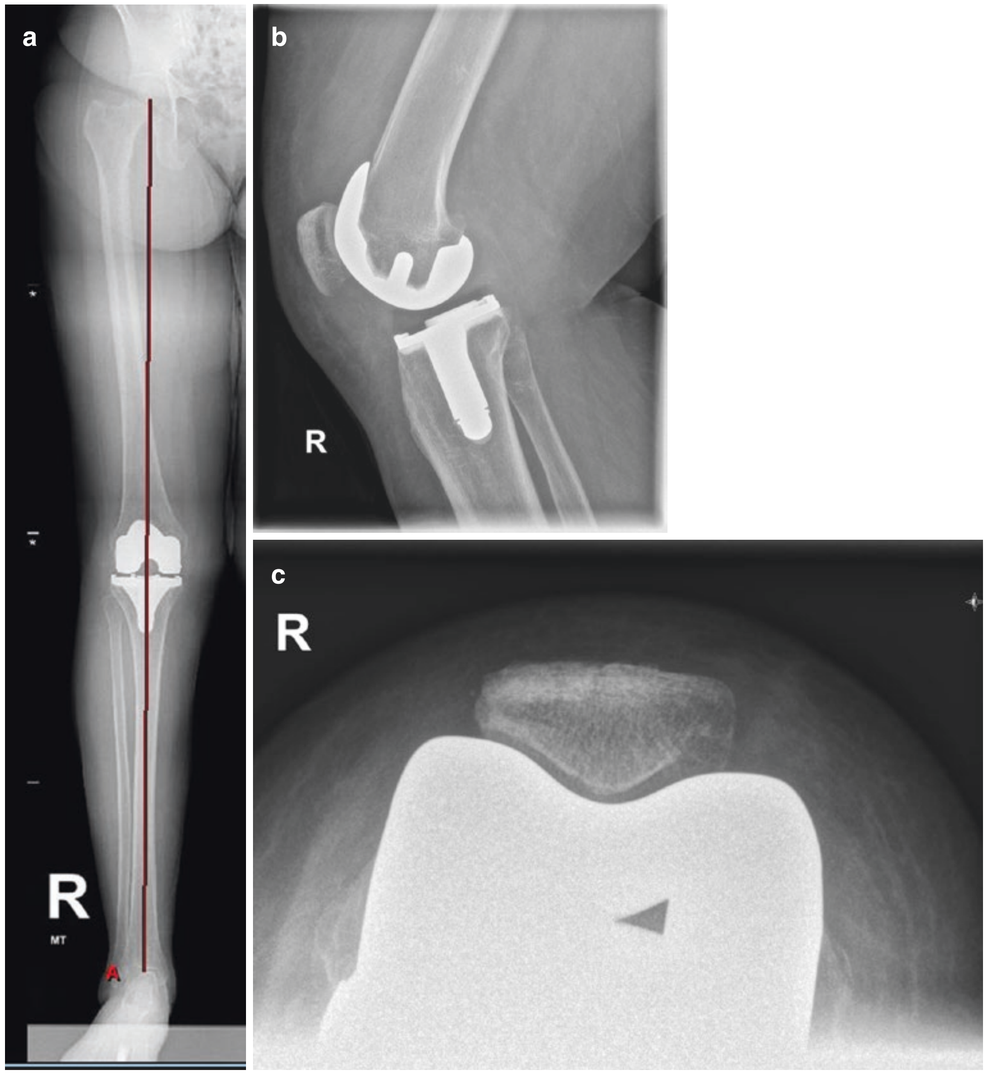


Fig. 25.101 Case 1. Alignment is mechanical in this case

2. **Medial compartment OA in a knee with a varus deformity of tibial origin.**

There is unreducible varus, slight lateral laxity, and a good range of motion. HKA is 170°, MFA 93°, and MTA 82° (Fig. 25.102).

An orthogonal 10 mm tibial cut referenced from the lateral side, using combined IM and EM referencing, removes more bone from the lateral condyle of the tibia than the medial (Fig. 25.103). The 8 mm, 7° valgus, 3° flexion, distal femoral cut removes more bone from the medial condyle than the lateral condyle (Fig. 25.104). The rotation is set to do the same, 3° centrally, to equalise the femoral spaces (Fig. 25.105). An anterior cut adjustment of 1 mm is made to reduce notching, allowing the use of a size 5 femur, compatible with a size 4 tibia. The resulting extension and flexion gaps are trapezoidal, larger laterally, but they are balanced. Release of the MCL from the tibia is performed to obtain symmetry (Fig. 25.106). Gap balance is satisfactory. A 12 mm polyethylene insert is used to provide appropriate tension in the mildly stretched lateral envelope. A longer tibial stem is used to protect the medial tibia, which may be devitalised by the MCL release. The overall post op alignment is mechanical although with 2° valgus of the tibial component (Fig. 25.107).

Points of interest:

- The inclination of the posterior femoral cut is not dictated by the tibial deformity or the asymmetrical cut of the tibia, but dependent on the distal femoral cut.
- The asymmetry of the tibial cut can be converted into balanced flexion and extension gaps only by soft tissue release. This rule applies regardless of the actual amount of asymmetry.
- In this case, there was overcorrection of the tibial varus. Although an orthogonal cut is the goal, undercorrection would have been preferable to overcorrection, and would have reduced the extent of medial release necessary.

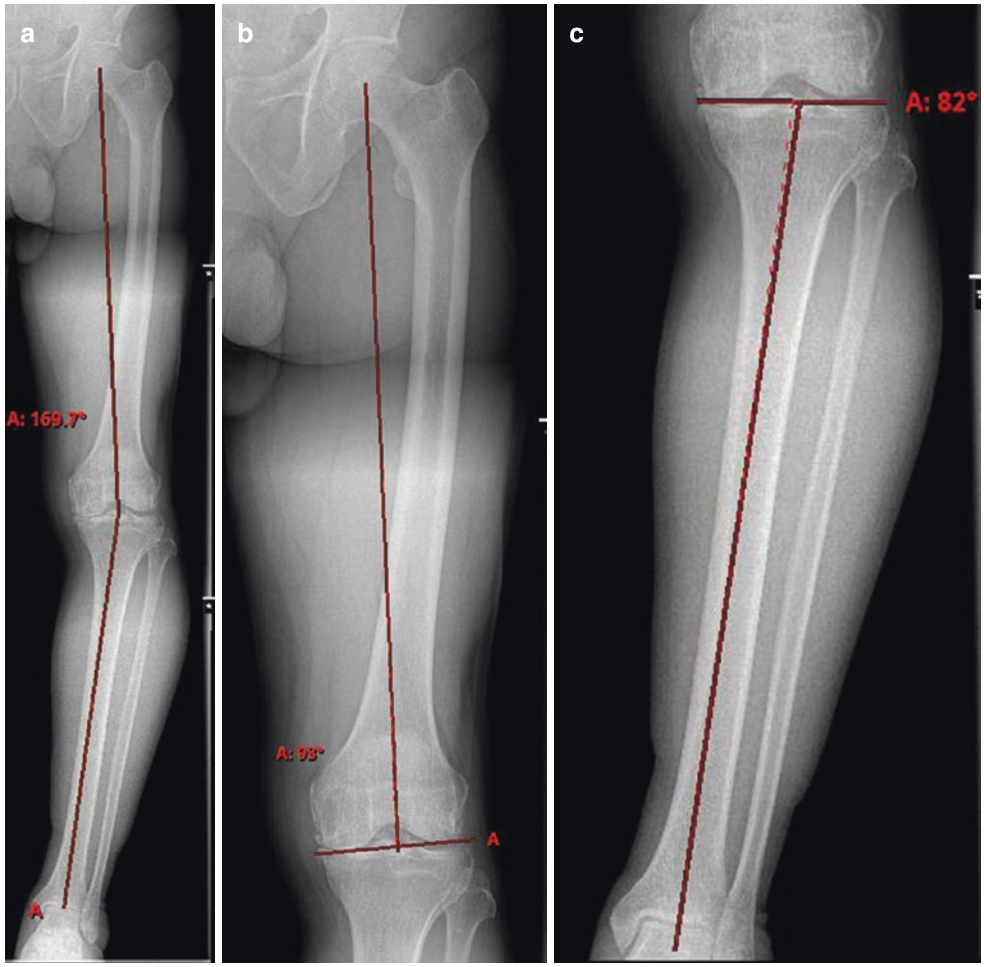


Fig. 25.102 (**a**–**c**): Case 2. Varus in the joint from wear, but also of the proximal tibia

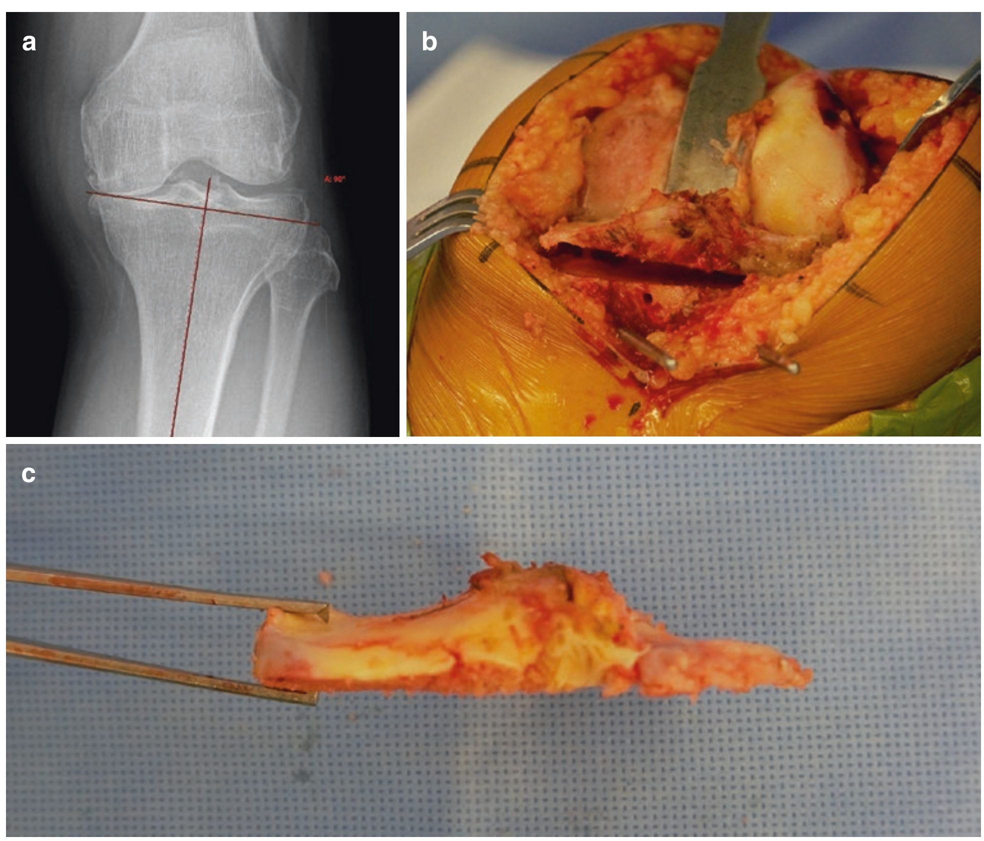


Fig. 25.103 (**a**–**c**): Case 2. The tibial cut is asymmetrical (the excised tibial plateau is more easily viewed from posterior)

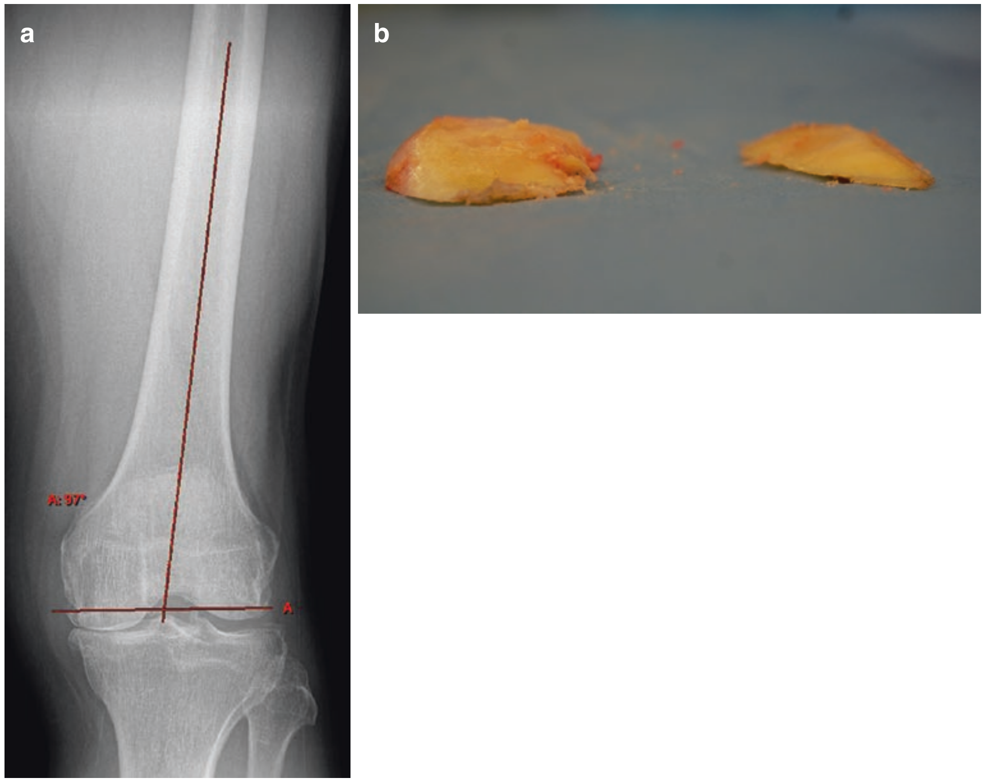


Fig. 25.104 (**a**, **b**): Case 2. The distal femoral cut removes more bone from the medial condyle than the lateral

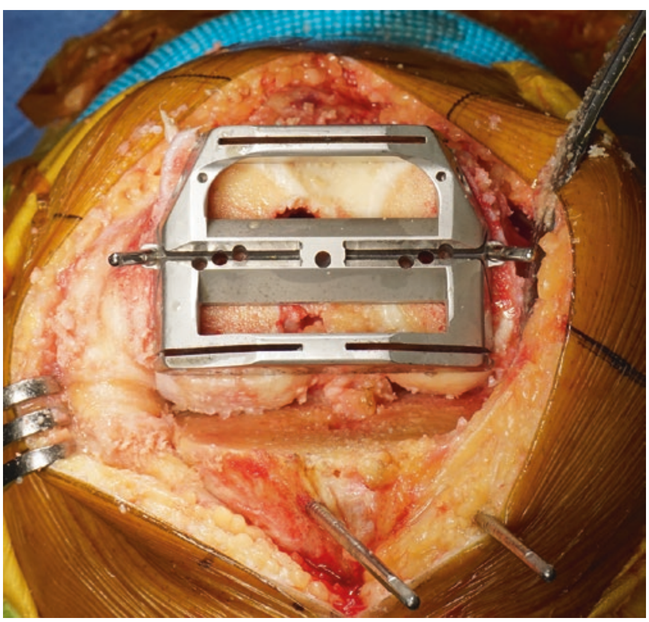


Fig. 25.105 Case 2. Cutting guide placed to remove more bone from the posterior medial femoral condyle than the lateral

Fig. 25.106 Case 2. Release of the MCL (arrow) from the tibia is performed to obtain symmetry. The MCL is slightly tensioned with a laminar spreader, and gently separated from the proximal tibia with a curved instrument, with repeated assessment of gap symmetry to prevent over-release. The intact pes anserinus is labelled with the star

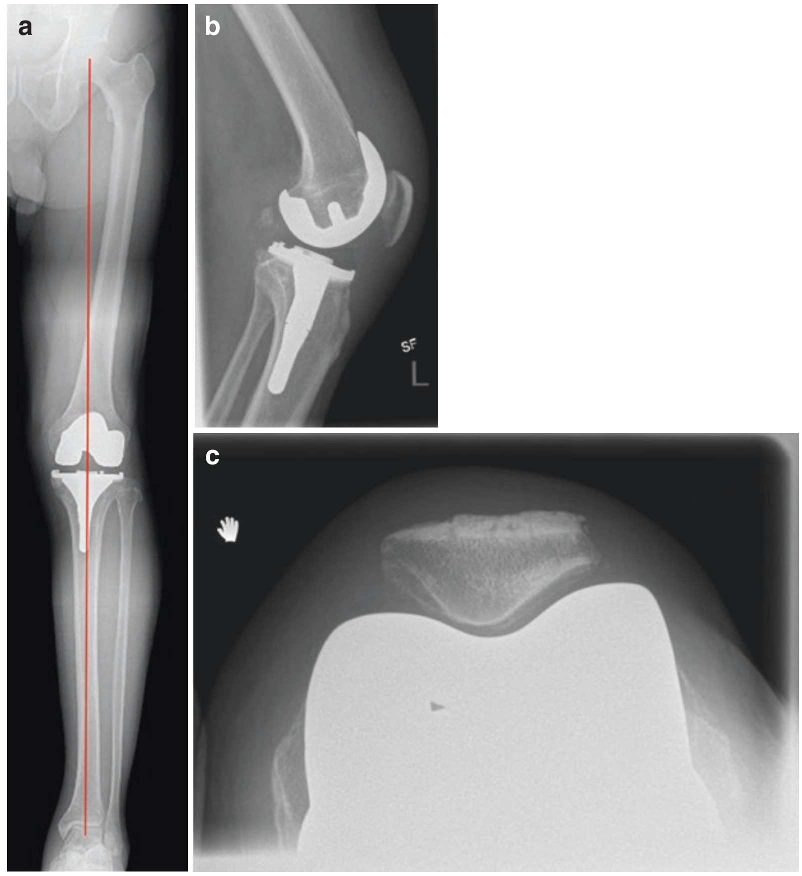


Fig. 25.107 (**a**–**c**): Case 2. The overall post op alignment is mechanical although with 2° valgus of the tibial component

3. **Medial compartment OA in a knee with a varus deformity of proximal femoral origin.**

There is unreducible varus, no lateral laxity, and a good range of motion of 0/0/120. The HKA is 160° MFA 85° and MTA 83° (Fig. 25.108). The femoral varus is situated proximally. An orthogonal 10 mm tibial cut referenced from the lateral side, using combined IM and EM referencing, removes more bone from the lateral condyle of the tibia than the medial creating an asymmetric gap, wider laterally. The 8 mm, 7° valgus, 3° flexion, distal femoral cut is referenced from the distal femur and removes almost the same bone from the medial and lateral condyles. The rotation is set to do the same, with 0° external rotation, to equalise the femoral spaces. Symmetry of the gaps in flexion and extension is achieved with a pie crust of the MCL. There is good balance. The residual limb varus is significant, but the tibial component is almost orthogonal (Fig. 25.109).

Points of interest:

- A distal femoral cut orthogonal to the mechanical axis would remove significantly more bone laterally than medially, resulting in a more trapezoidal extension gap, larger laterally (see Fig. 25.39a). Instead of performing this, it is decided to accept residual post-operative varus due to the proximal deformity, and a routine 7° valgus cut is made, referenced from the distal femur with an intra-medullary rod (Fig. 25.39c).
- The distal cut in this case produced equal distal femoral resection. In those cases where there is more resection from the lateral condyle, it is possible to produce a rectangular flexion gap that matches the extension gap (trapezoidal, wider laterally), but this would require internal rotation of the posterior cut to remove more bone laterally than medially (see Fig. 25.65). Any position of femoral external rotation will remove posterior bone medially more than laterally, producing a flexion gap that is trapezoidal, wider medially. In these cases, we recommend a posterior cut parallel to the posterior condylar axis at an acceptable inclination for patellar femoral biomechanics. Some medial laxity in flexion is then accepted. A considered compromise has thus been made between alignment correction, balance in flexion, balance between flexion and extension, and patellar femoral biomechanics— to avoid an unacceptable extreme of any one (see also Chap. 42, Figs. 42.44 and 42.45).
- The degree of varus that is acceptable depends on the patient's age, activity, BMI and bone quality, and is controversial. This case is probably at the limit, and surgical strategy could be discussed. When proximal femoral varus is considered unacceptably high, the alignment can be prioritised by performing a femoral osteotomy and subsequently a routine TKA.

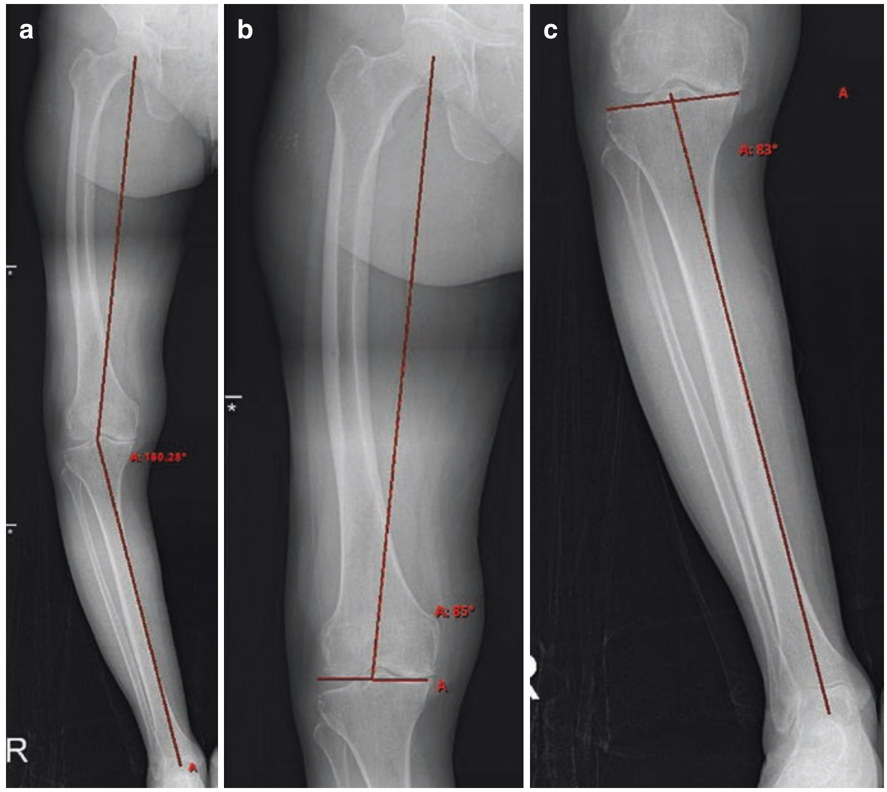


Fig. 25.108 (**a**–**c**): Case 3. Varus deformity in the joint, tibia, and femur. The femoral varus is proximal

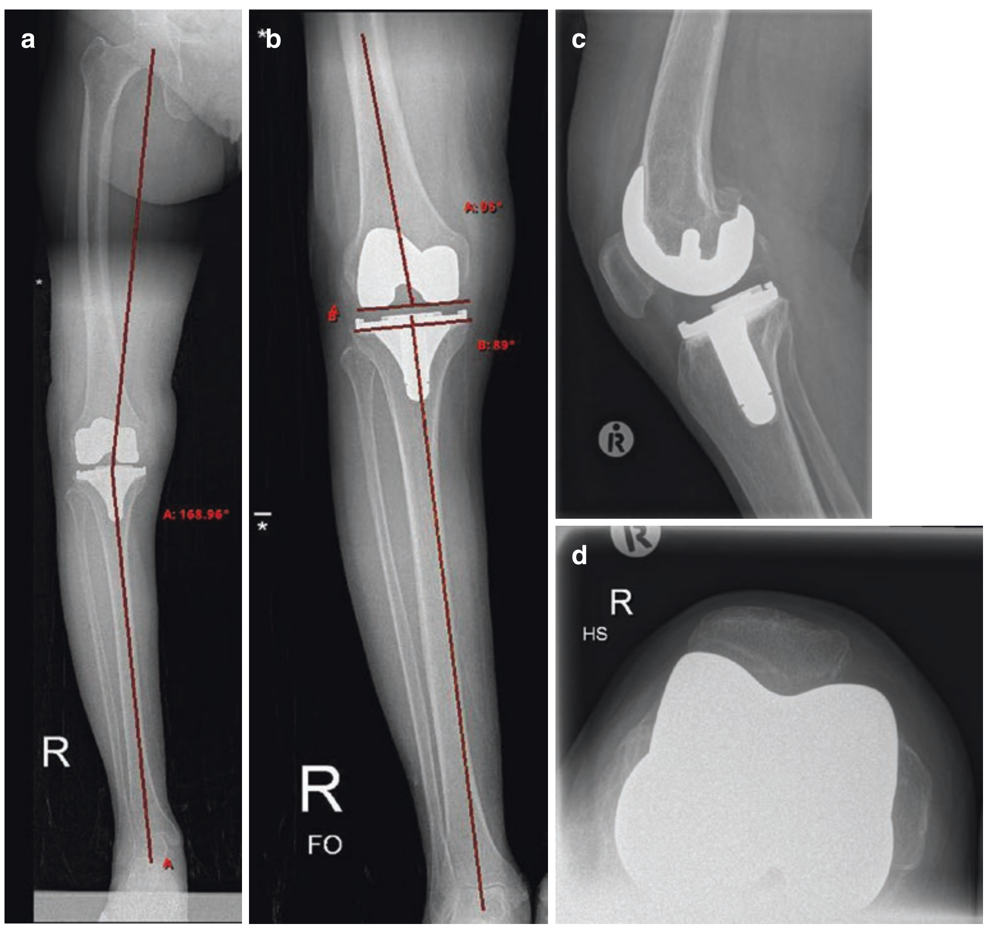


Fig. 25.109 (**a**–**d**): Case 3. Significant varus alignment from the femoral deformity, but well-aligned tibial component. Symmetry and balance has been prioritised over overall alignment. Without access to long films, the picture is less controversial (**b**)

4. **Lateral compartment OA with lateral condyle hypoplasia.**

Clinically there is unreducible valgus, minimal medial laxity, and a fixed flexion deformity of 35° with further flexion to 140° (Fig. 25.110). The HKA is 197°, MFA 96°, and MTA 91° (Fig. 25.111). There is stage IV lateral compartment osteoarthritis with a lateral tibial defect more than 5 mm.

Referencing is intra-medullary in the proximal tibia only for sagittal alignment and extra-medullary for coronal. The orthogonal 7 mm tibial cut is referenced from the medial condyle, taking a symmetric cut. The resulting tibial defect is less than 5 mm deep and less than 10% of the plateau. The 5° valgus, 3° flexion, distal femoral cut is referenced at a level 10 mm (thickness of the prosthesis +2 mm) from the medial condyle and removes only 1 mm of lateral condyle (Fig. 25.112). The posterior femoral cut is externally rotated partly by building up the lateral condyle (5 mm) and partly by central rotation (2°) (Fig. 25.113). The resulting flexion and extension gaps are trapezoidal, wider medially. The extension gap is smaller than the flexion gap, due to the pre-operative flexion deformity, and the central femoral rotation. Ligament balancing is carried out in this case by the lateral approach (releasing ITB) and a lateral femoral condyle osteotomy, distalising more than posteriorising the fragment to help achieve balanced gaps (Fig. 25.114). Full extension is achieved, but some laxity in flexion is however accepted. Alignment post-operatively is mechanical (Fig. 25.115).

Fig. 25.110 Case 4. Pre-operative lateral X-ray in full extension; fixed flexion deformity of 35°

Points of interest:

- A kinematic approach has been taken to the femoral cuts, and the femoral spaces, by building up the deficient lateral condyle in extension and flexion.
- The lateral femoral condyle osteotomy is well suited to the intra-articular deformity and can be thought of as creating space for the enlarged femoral segment. It can preferentially create more space in flexion or extension to contribute to gap balancing.
- External rotation of the femoral component often forces a compromise: one can either upsize the femoral component with potential overhang, or if there is femoral/tibial size mismatch, use a smaller femoral component with femoral notching or posterior cut level adjustment. Rotating by build-up of the lateral condyle alone maintains the posterior condylar level on the medial side, and optimises the gap balance, but at the expense of a larger femoral size. Using central rotation is an alternative method to restrict the size of the implant. In this case, it facilitated the use of a femoral size 2 which was compatible with the tibial size 1, which in turn was dictated by overhang. Adjusting the level of the posterior femoral cut is a third option. This and the central rotation technique reduce the femoral segment in flexion and exacerbate the gap imbalance which arises when there is pre-operative flexion deformity.

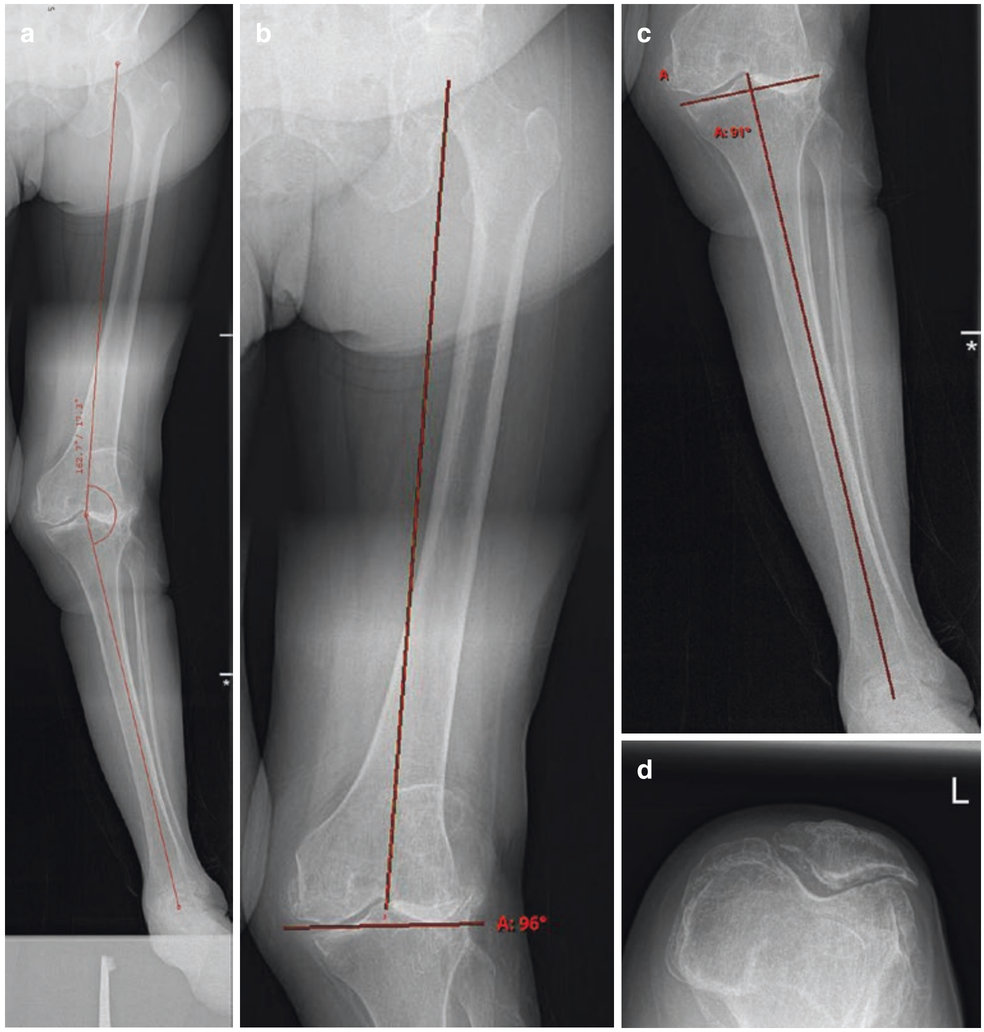


Fig. 25.111 (**a**–**d**): Case 4. There is stage IV lateral femorotibial osteoarthritis. The valgus arises from joint wear, tibial deformity, and lateral femoral condyle hypoplasia

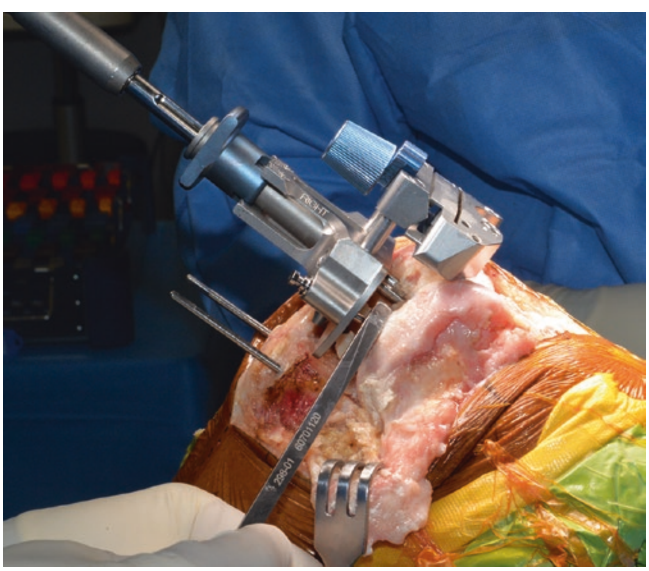


Fig. 25.112 Case 4. Lateral femoral condyle hypoplasia is obvious. The distance between bone and guide is assessed with an osteotome of known thickness to help reproduce the build-up posteriorly

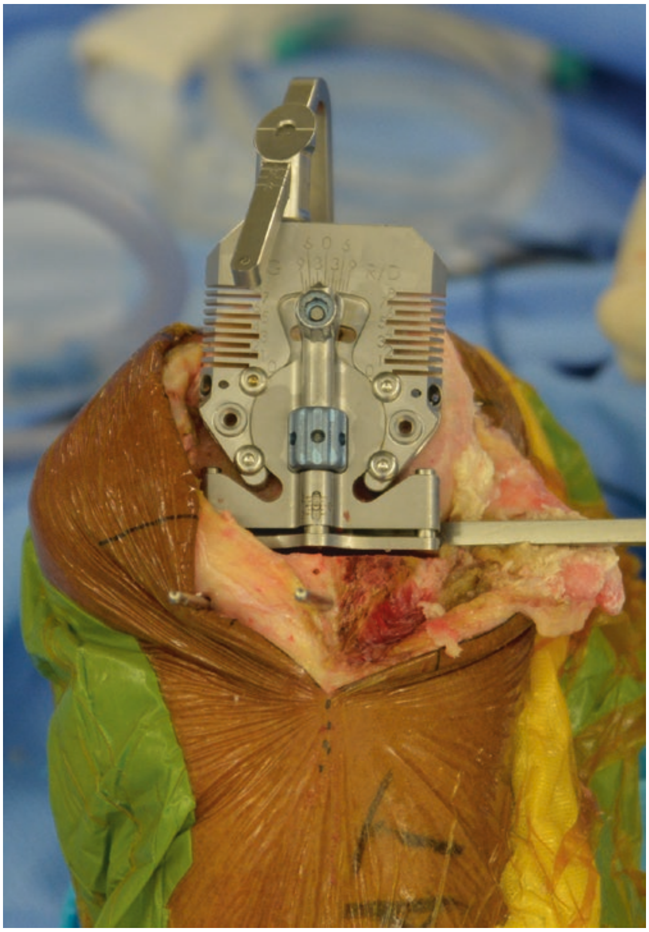


Fig. 25.113 Case 4. The external rotation has been produced by build-up, but also some central rotation to allow the use of a smaller femoral component without notching

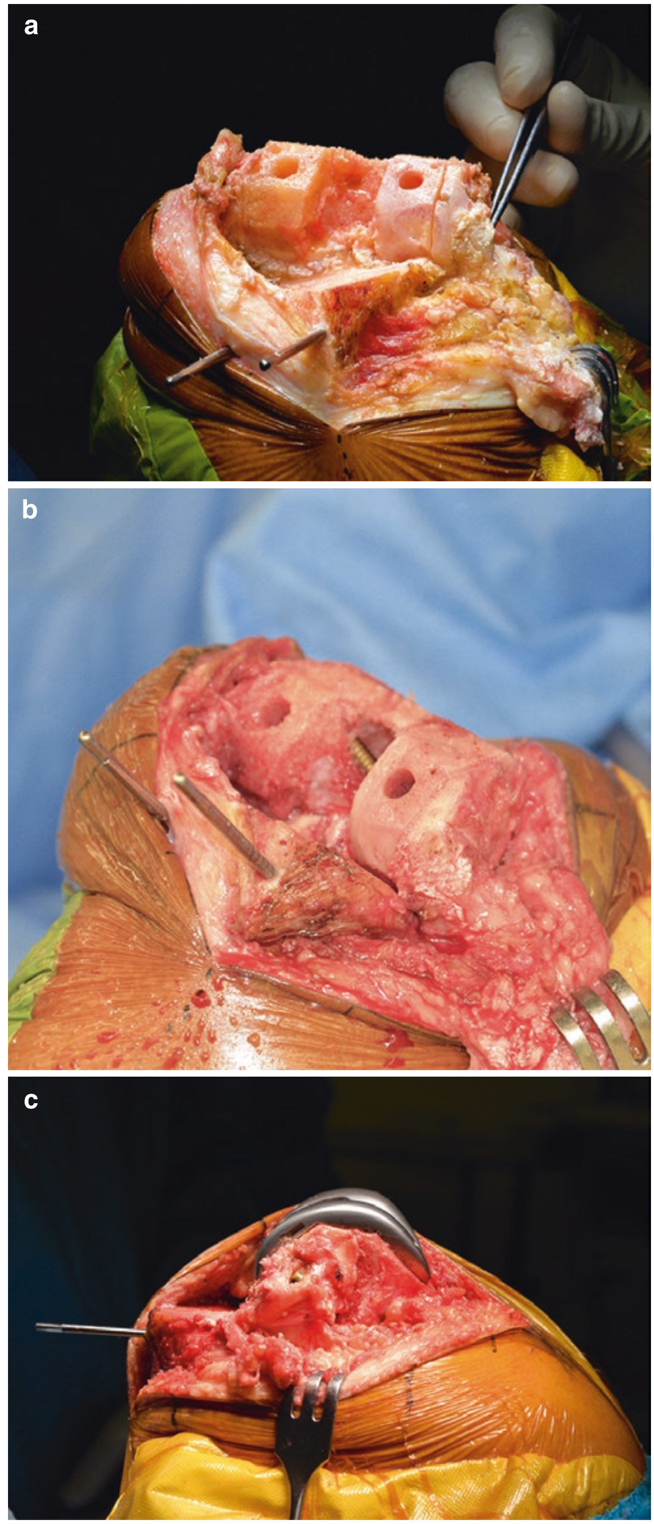


Fig. 25.114 (**a**–**c**): Case 4. Sliding lateral femoral condyle osteotomy. (**a**) Cut completed, prior to mobilisation. (**b**) Fragment fixed with a single screw. (**c**) Fragment moved more distally than posteriorly to improve the gap balancing, as well as the gap symmetry

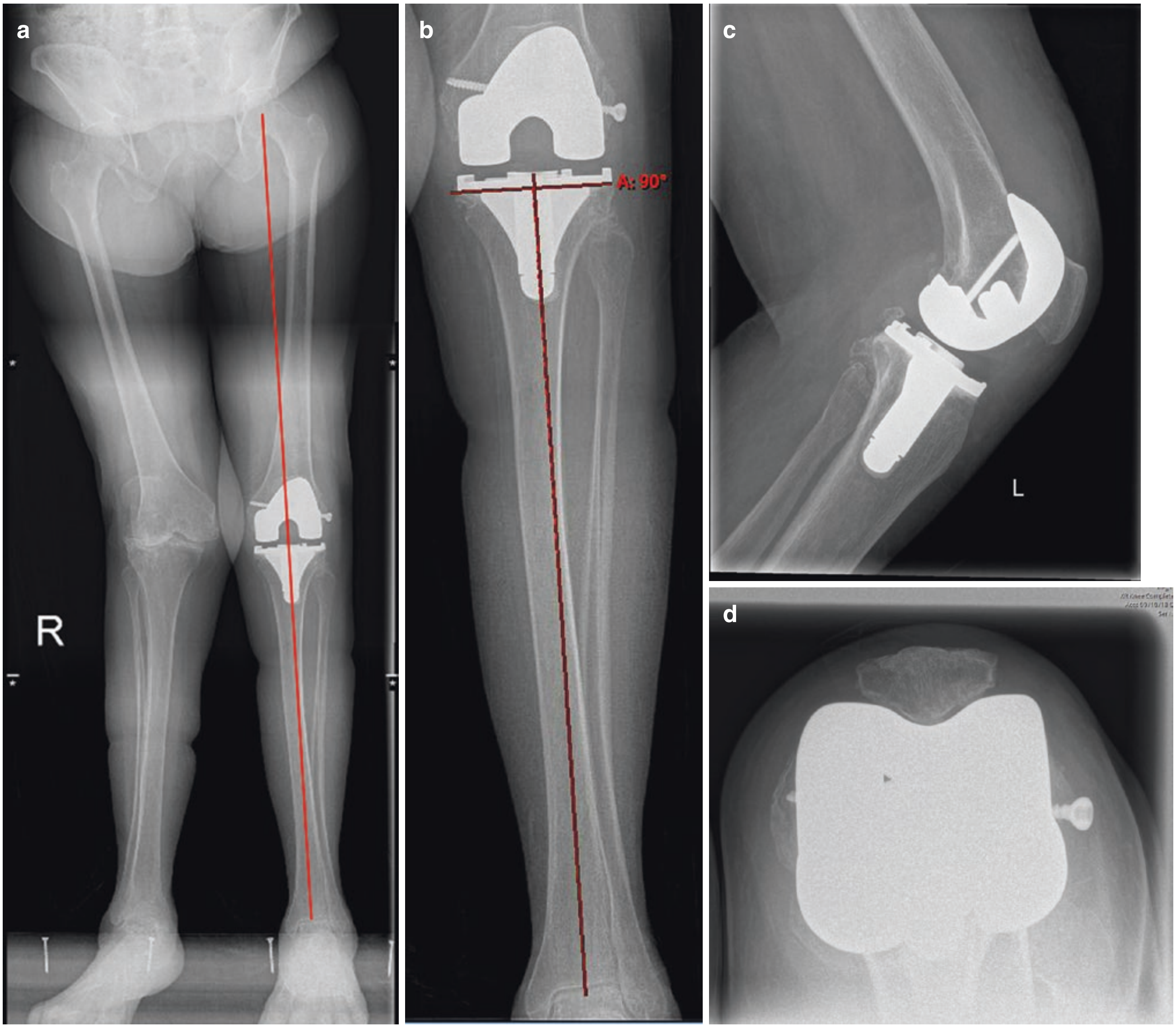


Fig. 25.115 (**a**–**d**): Case 4. (**a**) Alignment is mechanical. (**b**) Extra-medullary guidance was necessary. Distalisation of the lateral condylar fragment is apparent. (**c**) Lateral view (**d**) A lateral facetectomy has been performed

Summary

The technical goal of TKA is to produce a balanced knee without malalignment. What constitutes good alignment is controversial, but for technological reasons we still aim for an overall mechanical coronal alignment, although our approach on the femoral side is more kinematic. We have used this strategy for many years and it has yielded good results in terms of longevity, patient reported outcomes and patellar femoral function.

During conventional TKA, the multitude of interrelated steps, and the linear process of the operation, can make it difficult to achieve a predictable result in every patient. Success relies on producing specifically sized and orientated flexion and extension gaps, by a combination of bone cuts and soft tissue releases. A understanding of the relationships between these steps, their order and priority is required whether in conventional or navigated TKA. Not only is this understanding necessary to use navigation safely, but conventional TKA techniques will be the mainstay in many regions of the world for the foreseeable future.

In attempting to simplify the algorithm of TKA, we consider the femoral and tibial contributions to the gaps separately. This simple concept of tibial and femoral spaces and segments helps comprehend the interchangeable relationship between bone resection and soft tissue release and provides a rationale for patient-specific femoral rotation.

As materials and methods evolve, the constraints of unnatural alignment and balance may also be removed, allowing us to move towards a process of recreating each patient’s anatomy. The algorithm may become simpler with time.