Introduction

- Varus is the commonest manifestation of the arthritic process resulting from the weight-bearing axis passing through the medial compartment of the knee joint.¹²
- Varus is mostly described as a standalone deformity but our data suggests that it seldom presents as a uniplanar deformity.
- In about 85% of cases, varus is associated with some FFD and in 15% cases with hyperextension deformity.
- This chapter not only deals with correction of varus deformity but also its association, interplay and correction of sagittal plane deformity (fixed flexion deformity [FFD]/hyperextension).
- As the varus deformity progresses, it achieves a biplanar dimension, manifesting as a varus-flexion or varus-recurvatum deformity.³⁴
- Computer navigation assists in the correct estimation of the varus deformity in the coronal plane and the associated flexion/recurvatum deformity in the sagittal plane.⁵
- Navigation also demonstrates the overall fixed and dynamic deformity throughout the range of motion (ROM) of the knee.
- In the majority of the cases, varus deformity gradually corrects itself as the knee flexes, thus requiring less soft tissue release of anteromedial structures to obtain ligament balance.⁶
- However, in patients with resistant varus deformity, a greater extent of soft tissue release or a reduction osteotomy may be required to achieve optimal alignment and balance.⁷

- Based on the severity of varus, the sequence of soft tissue release followed by the authors is:⁸
  - Subperiosteal elevation of deep medial collateral ligament (MCL).
  - Posteromedial (PM) capsule.
  - Semimembranosus.
  - Reductional osteotomy of tibia.
  - Pie crusting of superficial MCL.
  - Sliding medial epicondylar osteotomy.

- Based on its association of sagittal component, varus deformity can be divided as:
  - Varus with FFD.
    - Varus = FFD.
    - Varus < FFD.
    - Varus > FFD.
  - Varus with a recurvatum deformity:
    - Varus = Recurvatum.
    - Varus < Recurvatum.
    - Varus > Recurvatum.

Principle for Biplanar Deformity Correction

- The authors have observed that in the knees with a biplanar deformity, the correction of a coronal plane deformity also results in the correction of the concomitant sagittal plane deformity in equal measure. Thus a 10-degree varus correction will also correct about 10 degree of associated flexion deformity.
The release of tight PM structures relaxes the posterior capsule, leading to an increase in the extension gap.

The surgeon should be aware of this possible gain in the extension gap while planning the distal femur resection.

**Algorithm for Planning Distal Femur Cut in Varus Knee with FFD**

- A varus-flexion deformity is caused by the contracture of the PM structures and the joint capsule, leading to the progression of the flexion deformity as the arthritic process increases in severity.
- In a biplanar deformity with equal angulation in both the planes (flexion = varus), PM soft tissue release for varus correction corrects the flexion deformity, thus obviating the need for additional distal femur cut (Table 3.1).
- In a biplanar deformity with flexion > varus, the distal femur resection needs to be increased to compensate for the tight extension gap. This should not be done in the presence of large osteophytes in the posterior recess, as their removal also increases the extension space and corrects flexion deformity.
- In knees with varus > flexion deformity, the distal femur resection needs to be decreased by 1 to 2 mm to compensate for the potential overcorrection in the sagittal plane following the releases for varus correction.

Table 3.1  Distal femur cut in biplanar deformity

<table>
<thead>
<tr>
<th>Varus (degrees)</th>
<th>FFD (degrees)</th>
<th>Distal femur cut (for S&amp;N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>9.5 mm (regular)</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>8.5–9 mm (less)</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>10.5–11 mm (more)</td>
</tr>
</tbody>
</table>

Abbreviation: FFD, fixed flexion deformity.

**Pearls**

Such seemingly minor adjustments in the distal femur cut are quite significant to achieve the correct sagittal plane alignment and to balance the knee in both planes.

**Varus with Fixed Flexion Deformity**

- Varus = FFD.
- Varus > FFD.
- Varus < FFD.

**Varus ≈ FFD (10 degrees)**

- The full-length radiographs of the lower limb with anteroposterior (AP) and lateral views of the left knee joint (Fig. 3.1).
- X-rays shows tricompartmental osteoarthritis with mild varus deformity.
- The kinematic analysis of this patient demonstrates a varus deformity of 10 degrees with 9.5 degrees of flexion in the sagittal plane (Fig. 3.2).
- The kinematic graph shows uncorrectable varus during the entire arc of movement. (Purple dotted line in Fig. 3.2.)
- This suggests that the medial gap is consistently tight which may need PM soft tissue release and downsizing of the tibial tray.
- The intraoperative navigation values show normal distal femur cut (Fig. 3.3).
- In such cases, the femoral component can be externally rotated to 5 to 6 degrees with respect to posterior condylar axis to balance the tight medial gap in flexion (Fig. 3.4).

![Fig. 3.1 Preoperative radiographs.](image1)

![Fig. 3.2 Initial limb alignment and kinematics.](image2)
The femoral component rotation should be individualized in each case.

Aligning the component in 3-degree external rotation as a routine in all the cases might lead to a tight medial gap and loose lateral gap, requiring unnecessary soft tissue releases and tibial downsizing for balancing the knee (Fig. 3.5).

The femoral component rotation depends upon the following factors:
- Knee kinematics.
- Lateral joint space opening.
- Bone loss due to arthritis.
- Femoral component size.
- Ligamentous laxity.

The navigation values show the verification of the proximal tibial cut (Fig. 3.6).

In a varus deformity, the medial tibial condyle gets worn off. Hence the lateral tibial resection is more than that of the medial tibial condyle.

Navigation predicts the ideal thickness of the tibial bony cut by considering the posterior slope required to balance the knee.

### Pearls
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- In a varus deformity, the medial tibial condyle gets worn off. Hence the lateral tibial resection is more than that of the medial tibial condyle.
- Navigation predicts the ideal thickness of the tibial bony cut by considering the posterior slope required to balance the knee.

### Pitfalls
- Occasionally, navigation doesn’t predict the true thickness of the proximal tibial cut as required.
- The authors recommend manual verification of the thickness of the tibial resection both before and after executing the tibial cut.
- Verification of the thickness of the tibial bone resected with a Vernier caliper (Fig. 3.7).
• The PM soft tissue release required for the residual varus correction.
  – Clinical pictures depicting the tibial tray kept in external rotation (Fig. 3.8).
  – The AP axis of the tibial tray should be in line with the tibial tuberosity.
  – The postoperative navigation graph showing the correction of deformity in both the sagittal and coronal planes (Fig. 3.9).
  – There was a residual flexion of 4.5 degrees, with a gap difference of <2 mm throughout the ROM of the knee.
  – The postoperative AP and lateral X-ray views of the knee joint showing well-placed femoral and tibial prosthesis components with corrected limb alignment (Fig. 3.10).
Varus ≈ FFD (20 degrees)

- The preoperative radiographs and clinical images reveal a severe varus and flexion deformity with laterally subluxed tibia (Fig. 3.11 and Fig. 3.12).
- The patient had a history of bipolar hemiarthroplasty 8 years back, which further emphasizes the need for using navigation to perform total knee replacement (TKR).
- The preoperative kinematic analysis suggesting a severe varus and flexion deformity (Fig. 3.13).
- The extent of varus deformity was nearly as much as the flexion deformity.
- Laterally subluxed tibia can be appreciated in 3D reconstructed image.
- As varus equals FFD, normal resection of the distal femur was required to balance the extension gap with the flexion gap (Fig. 3.14).
- It is important to maintain the standard external rotation of the femoral prosthesis, as the loss of the cartilage over the posterior medial femoral condyle in severe varus knees may lead to increased external rotation (Fig. 3.15).
- The Whiteside line along with TEA is used to reconfirm femoral component rotation (Fig. 3.16).
- Under-resection of the proximal tibia was performed to balance the flexion and extension gaps with a 9-mm insert (Fig. 3.17 and Fig. 3.18).
- Authors advise that the flexion and extension gaps should be reassessed after the PM soft tissue release, before proceeding with the proximal tibial cut (Fig. 3.19).
- The postoperative kinematic image showing complete correction of the biplanar deformity with balanced gaps throughout the knee ROM (Fig. 3.20).
- The postoperative radiograph demonstrates a well-aligned femoral and tibial component with corrected limb alignment (Fig. 3.21).
- A tibial stem was used to facilitate load shearing and to reduce stress on the tibial baseplate.

![Fig. 3.11 Preoperative radiographs.](image1)

![Fig. 3.12 Image of the patient.](image2)

![Fig. 3.13 Initial limb alignment and kinematics.](image3)

![Fig. 3.14 Distal femur cut verification.](image4)
Chapter 3

Fig. 3.15  Femoral external rotation verification.

Fig. 3.16  Whiteside side marked over distal femur.

Fig. 3.17  Proximal tibia cut verification.

Fig. 3.18  Proximal tibia cut.

Fig. 3.19  Posteromedial soft tissue release.

Fig. 3.20  Postoperative limb alignment and kinematics.

Fig. 3.21  Postoperative radiographs.
Varus < FFD

- The preoperative radiographs suggest a moderate varus deformity with the opening of the lateral joint space (Fig. 3.22 and Fig. 3.23).
- The preoperative kinematics graph shows partial correction of the varus deformity with knee flexion (Fig. 3.24).
- FFD (20 degrees) is more than the varus deformity (13 degrees).
- An additional distal femur resection was performed to gain the extension gap (Fig. 3.25).
- If there are large osteophytes tightening the posterior capsule, then they should be removed first, extension gap should be reassessed before proceeding for extra distal femur cut.

- A measured proximal tibial resection with a normal posterior slope was planned to balance the flexion gap (Fig. 3.26).
  - A 20-gauge needle was used for MCL pie crusting in this patient (Fig. 3.27).
  - Authors reserve MCL pie crusting only for cases where the varus deformity is not correctable in flexion.
  - 10 to 12 needle pricks were given in anterior fibers of MCL to facilitate easy insertion of the insert.
  - This step should be guarded to prevent over release and instability.
- The postoperative kinematics demonstrate complete correction of the biplanar deformity (Fig. 3.28).
- The postoperative radiographs show well-aligned prosthesis components (Fig. 3.29).
Varus > FFD (10 degrees)

- The preoperative radiographs showing a moderate varus deformity with subluxed joint (Fig. 3.30 and Fig. 3.31).
- The preoperative kinematic analysis showing 11.5-degree varus associated with almost neutral sagittal alignment (Fig. 3.32).
- Under resection of distal femur was performed considering varus correction will increase extension gap (Fig. 3.33).
- Measured tibial resection was done to create adequate gap for insert (Fig. 3.34).
- Kinematic analysis showing residual varus flexion deformity with tight medial gap (Fig. 3.35).
- At this stage, there is no need for additional distal femur resection as the correction of residual varus would correct the remaining FFD.
- Tight medial gap causing lateral opening and FFD (Fig. 3.36).

- Tibial baseplate is downsized and PM bone is marked (Fig. 3.37).
- Tibial baseplate should not be downsized so much so that it sinks in soft cancellous bone of lateral condyle.
- Tibial baseplate should sit on lateral tibial cortex and shouldn’t overhang medially.
- PM bone resection with help of saw to relax the PM soft tissue structures (Fig. 3.38).

Pearls

Whenever a saw is used for reduction osteotomy, MCL should be carefully protected.

- Gap balanced with 1 to 2 mm lateral opening and smooth reduction in flexion (Fig. 3.39).
- Postoperative kinematic analysis showing complete correction of biplanar deformity without additional bone resection (Fig. 3.40).
**Fig. 3.30** Preoperative radiographs.

**Fig. 3.31** Image of the patient.

**Fig. 3.32** Initial limb alignment and kinematics.

**Fig. 3.33** Distal femur cut verification.

**Fig. 3.34** Proximal tibia cut verification.

**Fig. 3.35** Postoperative limb alignment and kinematics.
Fig. 3.36  Tight medial gap with lateral laxity.

Fig. 3.37  Posteromedial reduction osteotomy of tibia.

Fig. 3.38  Removal of posteromedial bone.

Fig. 3.39  Correction of mediolateral gap imbalance.

Fig. 3.40  (a, b) Postoperative kinematics and radiographs showing balanced knee with well-fixed component.
Varus >> FFD

- The preoperative radiographs and clinical images of the left knee demonstrate subluxed knee with profound varus deformity (Fig. 3.41 and Fig. 3.42).
- A constrained prosthesis should be available as a backup for such cases.
- The preoperative kinematic analysis demonstrated a subluxed knee with more than 20-degree varus associated with minimal flexion deformity (Fig. 3.43).
- The navigation values depict conservative distal femur resection. This is because extension gap opens up after correction of varus deformity (Fig. 3.44).
- A conservative proximal tibial cut was planned to manage the gaps (Fig. 3.45).
- Intraoperatively, despite downsizing the tibial component and performing an extensive PM soft tissue release, there was lateral joint space opening with a tight medial gap (Fig. 3.46).
- The navigation screen demonstrated a residual 8.5-degree varus alignment despite performing the soft tissue releases (Fig. 3.47).
- A sliding medial epicondylar osteotomy was performed under navigation guidance to correct the residual varus deformity (Fig. 3.48).
- The medial epicondyle was fixed in a position where the knee was stable and mechanically aligned in the coronal and sagittal planes, with the help of computer navigation.9
- The navigation graph shows complete correction of varus deformity (Fig. 3.49).
- The postoperative radiographs show correction of varus deformity with well-fixed medial epicondylar osteotomy (Fig. 3.50).
- The authors prefer to utilize a tibial stem in such cases to provide extra stability and to distribute stress on weight-bearing.

![Fig. 3.41 Preoperative radiographs.](image1)

![Fig. 3.42 Clinical image of the patient.](image2)

![Fig. 3.43 Initial limb alignment and kinematics.](image3)

![Fig. 3.44 Distal femur cut verification.](image4)
**Fig. 3.45** Proximal tibia cut verification.

**Fig. 3.46** Severe lateral laxity despite medial release.

**Fig. 3.47** Severe mediolateral gap imbalance on navigation screen.

**Fig. 3.48** Medial epicondyle osteotomy.

**Fig. 3.49** Correction of mediolateral gaps and deformity.

**Fig. 3.50** Postoperative radiographs.
Varus with Hyperextension (Recurvatum) Deformity

- A varus deformity along with recurvatum can be subtle and occult finding. Careful gait examination is required to identify it preoperatively.
- Hyperextension associated with varus deformity can be due to cartilage loss or soft tissue laxity.
- Hyperextension is prone to recurrence and subsequent failure. Thus, it is important to identify it preoperatively.
- Authors recommend to keep these knees in 5 to 7 degrees of flexion to prevent recurrence of recurvatum.

Varus with Recurvatum Deformity

- Varus ≈ Recurvatum.
- Varus > Recurvatum.
- Varus < Recurvatum.

Algorithm for Planning Distal Femur Cut in Varus Knee with Hyperextension

- When varus is associated with recurvatum, distal femur and tibial cut need to be conservative.
- If recurvatum > varus deformity, the distal femur resection needs to be decreased by a 1 to 2 mm to tighten the extension gap. The authors’ aim to achieve a 5 to 7 degrees of flexion postoperatively in patients presenting with a recurvatum deformity as the lax posterior capsule stretches over time on weight-bearing.
- In knees with varus > recurvatum deformity, correction of varus deformity will increase the extension gap; hence, distal femur cut should be decreased by 2 mm or more.
- The full-length radiographs of the lower limb with AP and lateral views of the right knee (Fig. 3.51).
- X-rays demonstrate tricompartmental osteoarthritis with varus deformity.
- The navigation kinematic analysis of this patient elicits an equal measure of varus and recurvatum deformity (Fig. 3.52).
- There is gradual correction of the varus deformity beyond 60 degrees of knee flexion.
- The dynamic nature of the coronal plane deformity suggests that the medial soft tissues are lax in knee flexion. Hence, minimal soft tissue release is required to balance the knee.
- Undersection of distal femur was performed considering hyperextension and eroded cartilage (Fig. 3.53).
- An image depicting the resected distal femur with eroded articular cartilage over the medial femoral condyle (Fig. 3.54).
- The navigation values demonstrate under-resection of the tibial cut (Fig. 3.55).
- An image showing the resected proximal tibia with eroded articular cartilage and minimal bone resected from the medial tibial plateau (Fig. 3.56).
- A medial osteophyte may be hidden beneath the MCL (Fig. 3.57).
- A small osteotome can be used to excise it.
- This decreases the tenting of the MCL fibers and relaxes the medial joint space without requiring any further soft tissue release.
- There is complete correction of deformity, both in sagittal and coronal planes, with the residual flexion of 5 degrees (Fig. 3.58).
- The postoperative AP and lateral X-ray views of the knee showing well-placed femoral and tibial components (Fig. 3.59).

Fig. 3.51 Preoperative radiographs.

Fig. 3.52 Initial limb alignment and kinematics.
Fig. 3.53  Conservative distal femur resection.

Fig. 3.54  Distal femur cut.

Fig. 3.55  Proximal tibia cut verification.

Fig. 3.56  Proximal tibia cut.

Fig. 3.57  Medial osteophyte hidden under MCL origin on medial femoral condyle is removed.

Fig. 3.58  Postoperative limb alignment and kinematics.

Fig. 3.59  Postoperative radiographs.
Varus < Recurvatum

- The preoperative long-leg radiographs and clinical images depict subluxed tibia along with varus and recurvatum deformity of the left knee (Fig. 3.60 and Fig. 3.61).
- Preoperative kinematics suggest severe varus and hyperextension deformities of left knee with recurvatum (17.5 degrees) > varus (12 degrees) (Fig. 3.62 and Fig. 3.63).
- A 3- to 4-mm under-resection of the distal femur was planned to manage the loose extension gap (Fig. 3.64).
- Minimal distal femur cut to balance loose extension gap (Fig. 3.65).
- To correct residual varus deformity, tibial tray was down sized from size 3 to 2 (Fig. 3.66 to Fig. 3.68).
- Residual PM bone was marked and removed.
- Tibial baseplate should be at lateral edge of tibia and in external rotation with respect to tibial tuberosity.
- To correct the varus deformity (tight medial gap) PM tibial reduction osteotomy was performed (Fig. 3.69).
- The tibial tray was appropriately sized and excess PM bone was marked.
- A saw can be used to remove residual medial bone to open up the tight medial space and correct residual varus.
- The final kinematic analysis showing correction of the varus and hyperextension deformities (Fig. 3.70).
- The postoperative radiographs showing well-aligned femoral and tibial prosthetic components with a 3 to 5 degrees of residual flexion, which is desirable in patients with recurvatum deformity (Fig. 3.71).
Fig. 3.64 Distal femur cut verification.

Fig. 3.65 Conservative distal femur and proximal tibia cut.

Fig. 3.66 Proximal tibia cut verification.

Fig. 3.67 Under resection of tibia by 2 mm.

Fig. 3.68 Downsizing of tibial baseplate.

Fig. 3.69 Reduction osteotomy of tibia.
Varus > Recurvatum

- The preoperative radiographs show a subluxed tibia with severe varus deformity (Fig. 3.72).
- There is 15-degree uncorrectable varus deformity with 5-degree recurvatum (Fig. 3.73).
- The navigation values reveal an under-resection of the distal femur (1-2 mm) to compensate for the loose extension gap following varus correction (Fig. 3.74).
- The navigation values demonstrate less than normal proximal tibial cut (Fig. 3.75).
- This was done as the patient had a loose extension gap along with an equally lax flexion space.
- Severe varus was corrected by tibia reduction osteotomy and posteromedial soft tissue release.
- A screw was used for the residual medial tibial condyle bone defect (Fig. 3.76).

Pearls

The authors prefer the following for managing tibial condyle bone defects:
- 0- to 5-mm defect—cement only.
- 5 to 10 mm—augmentation with screw.
- >10 mm—bone graft and tibial extension rod.

- It is advisable to leave these patients in 5 to 7 degrees of residual flexion to prevent recurrence of recurvatum postoperatively (Fig. 3.77).
- The postoperative radiographs suggesting well-aligned femoral and tibial components with a screw in the medial tibial condyle to compensate for the residual bone defect (Fig. 3.78).
Fig. 3.72 Preoperative radiographs.

Fig. 3.73 Initial limb alignment and kinematics.

Fig. 3.74 Distal femur cut verification.

Fig. 3.75 Proximal tibia cut verification.

Fig. 3.76 Screw fixation for bone defect.
**Points to Remember**

- Varus is often associated with flexion deformity. If varus is near equal to flexion deformity, correction of varus corrects FFD roughly in a 1:1 ratio. In such cases soft tissue releases are done to correct varus which also results in correction of FFD.
- If FFD > varus, then additional distal femur bone cut may be required along with soft tissue releases to correct FFD so as to achieve neutral alignment in coronal and sagittal planes.
- If varus is more than FFD, then correction of varus may lead to increase in extension gap and extension laxity; hence, distal femur cut can be conservative especially in severe varus deformity.
- Similarly, varus is sometimes associated with recurvatum deformity. These represent a variety of lax knees with loose gaps. Both distal femur and tibia cut need to be conservative when varus is near equal to recurvatum.
- When varus is more than recurvatum, correction of varus deformity will increase the extension space and hence distal femur cut needs to be conservative to prevent recurrence of recurvatum.
- When recurvatum is more than varus, extreme caution needs to be exercised as these knees are most prone to recurrence of hyperextension deformity. Along with conservative cuts and minimal handling of soft tissues, a constrained poly can be used to attain stability.

**References**
