What is a Malunion?

- Definition: a fracture that has healed in a nonanatomic (i.e. deformed) position
- Must know normal parameters for limb alignment to determine if deformity exists
- Thorough clinical & radiographic evaluation is paramount
What is a malunion?

• Limits of deformity vary by bone and plane
  - Somewhat arbitrary
  - Merchant and Dietz, JBJS 1989
    - No long term effects on knee or ankle function at 29 years with deformity >10 degrees after tibia fx
    - Proximal vs distal

RADIOGRAPHIC ASSESSMENT
Malunion: Radiographic Evaluation

Objective radiographic analysis answers the following questions:

1) Is there a deformity?
2) Where is the deformity?
3) What are the characteristics of the deformity?

Recommended X-rays: Bilateral full length standing AP & lateral views

- AP view taken with patella aimed forward, lateral view is 90° to AP
- Knees are fully extended
- May Use blocks to equalize limb lengths if necessary
  - Feet should be plantigrade if possible
- Center x-ray beam at knee level for initial films, use magnification marker if possible
  - Deformities near hip or ankle are often best assessed with repeat films with XR beam centered at that level
How to Determine Frontal Plane Alignment

1. Draw mechanical axis of lower extremity (LE)
   - line from center of femoral head to center of ankle

2. Measure the mechanical axis deviation (MAD)
   - distance from the knee joint center to the mechanical axis
     * center of knee joint is ½ way between tibial spines
   - If MAD is abnormal, a deformity is present
     * Varus malalignment = medial MAD > 15mm
     * Valgus malalignment = lateral MAD >3mm

Steps to Identify & characterize deformity
1. Obtain X-rays
2. Analyze limb alignment
3. Evaluate joint orientation
4. Find deformity apex (aka CORA)
5. Identify deformity type
6. Determine plane of deformity
7. Quantify magnitude of deformity

(varus malalignment)

How To determine Sagittal plane Alignment -

1. Draw mechanical axis of lower extremity (LE)
   - line from center of femoral head to center of ankle
   - Should pass anterior to hinge point of knee

2. Measure anterior cortical lines of femur & tibia
   - Lines are collinear in normal limb
   - If mechanical axis of anterior cortical lines abnormal, then flexion or hyperextension deformity present

Steps to Identity & characterize deformity
1. Obtain X-rays
2. Analyze limb alignment
3. Evaluate joint orientation
4. Find deformity apex (aka CORA)
5. Identify deformity type
6. Determine plane of deformity
7. Quantify magnitude of deformity

Anterior cortical lines are abnormal & demonstrate a flexion deformity
**Determine Joint Line Orientation**

Draw Either Mechanical or Anatomic Axes

1. Obtain X-rays
2. Analyze limb alignment
3. Evaluate joint orientation – frontal plane
4. Find deformity apex (aka CORA)
5. Identify deformity type
6. Determine plane of deformity
7. Quantify magnitude of deformity

- **Mechanical axis of femur and tibia**
- **Anatomic axis of the femur and tibia**

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**Joint Orientation Lines (JOL)**

**Frontal Plane JOL**

1. **Proximal femur JOL**: line connecting center of femoral head to tip of the greater trochanter
2. **Distal femur JOL**: line connecting most convex points of medial & lateral femoral condyles
3. **Proximal tibia JOL**: line connecting most concave points of medial & lateral tibial plateau
4. **Distal tibia**: line connecting medial and lateral margins of tibial plafond
Joint Orientation Angles

1. Proximal femoral angle
   Lateral proximal femoral angle (mLPFA) if mechanical axis used
   Medial proximal femoral angle if anatomic axis used (aMPFA)
2. Lateral distal femoral angle (LDFA)
3. Medial proximal tibial angle (MPTA)
4. Lateral distal tibial angle (LDTA)

Joint Orientation Angles (Mechanical Axis)

3 Frontal Plane Joint Orientation Angles
1. Posterior distal femoral angle (PDFA)
2. Posterior proximal tibial angle (PPTA)
3. Anterior distal tibial angle (ADTA)
Identify Apex Of The Deformity
CORA
(center of rotation and angulation)

- Location of a deformity within a deformed bone
- Located at the intersection of the proximal & distal axis lines
- Mechanical or anatomic axis can be used
  - Anatomic axis best used in diaphyseal malunions
  - Juxta-articular malunion: Use intersection of femoral mechanical axis and intersection of tibial mechanical axis (same as anatomic axis)
- Simple deformities have 1 apex, complex deformities can have multiple apices
Identify Apex Of The Deformity
CORA
(center of rotation and angulation)

In this case, the intersection of the mechanical and anatomic axis are at the SAME location

THUS...If you rotate around the CORA you will correct the angular deformity and restore the correct anatomic and mechanical axis

Steps to Identify & characterize deformity
1. Obtain X-rays
2. Analyze limb alignment
3. Evaluate joint orientation – sagittal plane
4. Find deformity apex (aka CORA)
5. Identify deformity type
6. Determine plane of deformity
7. Quantify magnitude of deformity

In this case, the intersection of the mechanical and anatomic axis are at the SAME location

CORA

But......they are NOT located at the apex of the deformity.....thus you have a translational deformity as well

HOWEVER>>>>>

Apex of deformity
HOWEVER...If you rotate around the CORA you will correct the angular deformity and restore the correct anatomic and mechanical axis

Without having to disturb the original malunion....

FRONTAL PLANE ALIGNMENT
ANGULATION ASSESSMENT

• Asses degree of translation (if any)
• If the intersection of the anatomic axis does NOT correspond to the actual location of the deformity......
  □ A compensatory *translation* is present
  □ Translation may represent unrecognized mal rotation...
FRONTAL PLANE ALIGNMENT
ANGULATION ASSESSMENT

• Any time you see a translational deformity……on plain x-ray…..
  □ There has to be some degree of MAL ROTATIONAL component
  □ Determined with clinical exam or CT

Types of Deformities

• ANGULATION
• MALROTATION
  □ CT EVALUATION
  □ CLINICAL DETERMINATION
• LEG LENGTH DESCREPANCY
  □ CT / SCANOGRAM
• TRANSLATION
  □ RELATIVE ALIGNMENT
  □ MEDULLARY CANALS
Relationship Of Translation To Mal-rotation

• With any translational deformity ........
  there almost ALWAYS is a
  COMPENSATORY mal rotation

Especially in the tibia!!...perform a thorough
clinical exam to include evaluation of rotation

Deformity Evaluation

• Rotation
  - Exam (rotational profile)
  - CT
Remember All Deformities Are “Oblique Plane Deformities”

• We think in terms of A/P and lateral deformities
• In reality all deformities are “out of plane” with respect to the x-ray views.
• Value of oblique radiographs.
  ☑ Best visualized by determining plane of true deformity and magnitude of the deformity using the graphic method.

Oblique Plane Deformity
Lateral View

![Oblique Plane Deformity Diagram]
Oblique Plane Deformity
A/P View

A/P ANGULATION
LATERAL ANGULATION

A/P view
33° apex lateral

33°
GRAPHIC METHOD

1. Plot the A/P and lateral degrees of angulation.
2. Draw resultant line and measure...gives true magnitude of deformity in degrees.
3. Measure angle in degrees...gives orientation of oblique plane deformity.

20° apex anterior

33° apex lat

35° oblique orientation

20° apex ant

40°

Magnitude of true deformity
If you angle the x-ray beam 90° to the true plane of the deformity, you will see that the x-ray gives you the plane of maximal deformity i.e. will measure the 40° angle deformity.

You will see the deformity with its true magnitude measuring 40°.
If you angle the x-ray beam 35° off the horizontal, you will see that the x-ray demonstrates the true plane of the deformity. i.e. you will see a straight bone.

35° From the horizontal is the true plane of the deformity. An x-ray taken in line will demonstrate a “straight” tibia... except for any translation present.

X-ray beam is parallel to the true plane of the deformity. Thus, you will see that the x-ray gives you a straight tibia... except for the residual translation. Any osteotomy will need to be carried out in this plane in order to correct all deformities.
You can use this technique clinically to demonstrate the plane of maximal deformity and observe the true plane of the deformity.

45° varus

15° apex posterior
15° apex posterior

18° external rotation, plane of maximal deformity

GRAPHIC METHOD

20° oblique orientation

48° magnitude true deformity

45° apex lateral

INT ROTATE 18° will reveal leg with maximal deformity
INT ROTATE 18° will reveal leg with maximal deformity. INT ROTATE 20° will reveal leg with no deformity, you are looking parallel to the true plane of the deformity.

Length Descrepancy
- Acute or gradual correction possible
  - Acute correction
    - Bone ends acutely distracted or compressed to desired length
    - Osteotomy stabilized with intramedullary nail or plate
    - Bone graft utilized in acute distraction
  - Gradual correction
    - Distraction thru corticotomy or nonunion
    - Bone formed by distraction osteogenesis
    - Ex fix can correct all deformities simultaneously

Malunion: Treatment by deformity type
Malunion: Treatment by deformity type

Angulation
• Acute or gradual correction possible
• Acute correction
  □ Dome osteotomies well suited for juxta-articular deformities
  □ Wedge osteotomies work well in diaphyseal region
  □ Osteotomy typically stabilized with intramedullary nail or plate
• Gradual correction

Single Apex, Correction: Closing wedge
• Single site to heal
• Biomechanically sound
• Soft tissue friendly
• Corrects angulation
• May shorten
• No graft required
Correction:
Closing wedge

Correction:
Closing wedge
Complex Deformity, Acute Correction

• Determine apex and plane of deformity
  - Graphic method
  - Mathematical methods

• Osteotomy apex with or without “slide” to achieve length and translation

• Plate or nail for fixation

COMPLEX DEFORMITY

Note that the CORA does NOT correspond to the apex location of the deformity... thus there is a translational deformity as well... AND MAL ROTATION........
Mathematically Directed Single-Cut Osteotomy for Correction of Tibial Malunion

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CORA DETERMINATION

INTERSECTION OF MECHANICAL AXIS OF FEMUR AND TIBIA GIVES LOCATION OF DEFORMITY (CORA)

Note that the CORA does NOT correspond to the apex location of the deformity... thus there is a translational deformity as well.

RELATIONSHIP OF ANGULATION TO TRANSLATION

• Intersection of anatomic axis does NOT correspond to the apex of the actual deformity
• A compensatory translation is present.
• Intersection of mechanical axis of femur and tibia
• Intersection of anatomic axis of femur (apex of the deformity)
• Note ... not at the same level...... thus a translational deformity also exists!!!
• Along with angular correction a translational correction must also occur

Surgical correction

• Plane of deformity
• Degree of translation
  - Perform oblique cut
  - Slide for angular correction
  - Distract for length
  - De-Rotate
• Cora IS *not* at apex of deformity......THUS a translational and malrotational deformity is present
• Oblique multiplanar osteotomy slide to correct all deformities.
Common places to get into trouble

- Distal femur
- Proximal tibia
  - Medial condylar component...
- Proximal femur
- Lack of fibular length restoration
  - Pilon fractures

Reduction at length with temp spanning ex fix