Normal Lower Limb Alignment and Joint Orientation

To understand deformities of the lower extremity, it is important to first understand and establish the parameters and limits of normal alignment. The exact anatomy of the femur, tibia, hip, knee, and ankle is of great importance to the clinician when examining the lower limb and to the surgeon when operating on the bones and joints. To better understand alignment and joint orientation, the complex three-dimensional shapes of bones and joints can be simplified to basic line drawings, similar to the stick figures a child uses to represent a person (Fig. 1-1).

Furthermore, for purposes of reference, these line drawings should refer to either the frontal, sagittal, or transverse anatomic planes. The two ways to generate a line in space are to connect two points and to draw a line through one point at a specific angle to another line. All the lines that we use for planning and for drawing schematics of the bones and joints are generated using one of these two methods (Fig. 1-2).

Mechanical and Anatomic Bone Axes

Each long bone has a mechanical and an anatomic axis (Fig. 1-3). The mechanical axis of a bone is defined as the straight line connecting the joint center points of the proximal and distal joints. The anatomic axis of a bone is the mid-diaphyseal line. The mechanical axis is always a straight line connecting two joint center points, whether in the frontal or sagittal plane. The anatomic axis line may be straight in the frontal plane but curved in the sagittal plane, as in the femur. Intramedullary nails (IMN) designed for the femur have a sagittal plane arc to reflect this. In the tibia, the anatomic axis is straight in
Mechanical and anatomic axes of bones. The mechanical axis is the line from the center of the proximal joint to the center of the distal joint. The mechanical axis is always a straight line because it is always defined from joint center to joint center. Therefore, the mechanical axis line is straight in both the frontal and sagittal planes of the femur and tibia. The anatomic axis of a long bone is the mid-diaphyseal line of that bone. In straight bones (a,c), the anatomic axis follows the straight mid-diaphyseal path. In curved bones (b,d), it follows a curved mid-diaphyseal path. The anatomic axis can be extended into the metaphyseal and juxta-articular portions of a bone by extending its mid-diaphyseal line in either direction.

Both frontal and sagittal planes (Fig. 1-3). Axis lines are applicable to any longitudinal projection of a bone. For practical purposes, we refer only to the two anatomic planes, frontal and sagittal. The corresponding radiographic projections are the anteroposterior (AP) and lateral (LAT) views, respectively.

In the tibia, the frontal plane mechanical and anatomic axes are parallel and only a few millimeters apart. Therefore, the tibial anatomic-mechanical angle (AMA) is 0° (Fig. 1-4a). In the femur, the mechanical and anatomic axes are different and converge distally (Fig. 1-4b). The normal femoral AMA is 7±2°.

The tibial mechanical and anatomic axes are parallel but not the same. The anatomic axis is slightly medial to the mechanical axis. Therefore, the mechanical axis of the tibia is actually slightly lateral to the midline of the tibial shaft. Conversely, the anatomic axis does not pass through the center of the knee joint. It intersects the knee joint line at the medial tibial spine.

The femoral mechanical and anatomic axes are not parallel. The femoral anatomic axis intersects the knee joint line generally 1 cm medial to the knee joint center, in the vicinity of the medial tibial spine. When extended proximally, it usually passes through the piriformis fossa just medial to the greater trochanter medial cortex. The angle between the femoral mechanical and anatomic axes (AMA) is 7±2°.
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a.

Mechanical axis
Anatomic axis
Mechanical axis
Anatomic axis

b.

Mechanical axis
Anatomic axis
Mechanical axis
Anatomic axis
As noted above, the mechanical axis passes through the joint center points. Because the mechanical axis is considered mostly in the frontal plane, we need to define only the frontal plane joint center points of the hip, knee, and ankle (Fig. 1-5). Moreland et al. (1987) studied the joint center points of the hip, knee, and ankle.

For the hip, the joint center point is the center of the circular femoral head. The center of the femoral head can best be identified using Mose circles. Practically, we can use the circular part of a goniometer to define this point (Fig. 1-5a).

Moreland et al. (1987) evaluated different geometric methods to define the center of the knee joint. They demonstrated that the center of the knee joint is approximatively the same using a point at the top of the femoral notch, the midpoint of the femoral condyles, the center of the tibial spines, the midpoint of the soft tissue around the knee, or the midpoint of the tubular plateaus (Fig. 1-5b). Using the top of the femoral notch or tibial spines is the quickest way to mark the knee joint center point without measuring the width of the bones or soft tissues.

Similarly, the ankle joint center point is the same whether measured at the mid-width of the talus, the mid-width of the tibia and fibula at the level of the plafond, or the mid-width of the soft tissue outline (Fig. 1-5c). The mid-width of the talus or the plafond is the easiest to use.

A line can also represent the orientation of a joint in a particular plane or projection. This is called the joint orientation line (Fig. 1-6).

**Ankle**

At the ankle, the joint orientation line in the frontal plane is drawn across the flat subchondral line of the tibial plafond in either the distal tibial subchondral line or for the subchondral line of the dome of the talus (Fig. 1-6a). In the sagittal plane, the ankle joint orientation line is drawn from the distal tip of the posterior lip to the distal tip of the anterior lip of the tibia (Fig. 1-6b).

**Knee**

The frontal plane knee joint line of the proximal tibia is drawn across the flat or concave aspect of the subchondral line of the two tibial plateaus (Fig. 1-6c). The frontal plane knee joint orientation line of the distal femur is drawn as a line tangential to the most distal points on the convexity of the two femoral condyles (Fig. 1-6d). In the sagittal plane, the proximal joint line of the tibia is drawn along the flat subchondral line of the plateaus (Fig. 1-6e). In the sagittal plane, the distal femoral articular shape is circular. The distal femoral

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**Fig. 1-5 a–c**

- a. The midpoint of the femoral head is best identified using Mose circles (Fig. 1-5a). If these are unavailable, measure the longitudinal diameter of the femoral head and divide it in two. Use this distance to measure from the medial edge of the femoral head. The center of the femoral head is located where the distance to the medial border of the femoral head is the same as half of the longitudinal diameter (Fig. 1-5b).
- b. The midpoint of the knee joint line corresponds to the midpoint between the tibial spines on the tibial plateau line and the apex of the intercondylar notch on the femoral articular surface. These points are not significantly different from the mid condylar point of the distal femur and the mid plateau point of the proximal tibia (modified from Moreland et al. 1987).
- c. The midpoint of the ankle joint line corresponds to the midpoint of the tibial plafond measured between the medial articular aspect of the lateral malleolus and the lateral articular aspect of the medial malleolus. The mid-width of the talus and the mid-width of the ankle measured clinically yield the same point (modified from Moreland et al. 1987).

**Fig. 1-6 a–h**

- a. Ankle joint orientation line, frontal plane. Connect two points at either end of the ankle plafond line.
- b. Ankle joint orientation line, sagittal plane. Connect two points from anterior to posterior lip of joint.
- c. Proximal tibial knee joint orientation line, frontal plane. Connect two points on the concave aspect of the tibial plateau subchondral line.
- d. Distal femoral knee joint orientation line, frontal plane. Draw a line tangent to the two most convex points on the femoral condyles.
- e. Proximal tibial knee joint orientation line, sagittal plane. Draw a line along the flat portion of the subchondral bone.
- f. Distal femoral joint orientation line, sagittal plane. Connect the two anterior and posterior points where the condyle meets the metaphysis. For children, this is drawn where the growth plate exits anteriorly and posteriorly.
- g. Neck of femur line, frontal plane. Draw a line from the center of the femoral head through the mid-diaphyseal point of the narrowest part of the femoral neck.
- h. Hip joint orientation line, frontal plane. Draw a line from the proximal tip of the greater trochanter to the center of the femoral head.
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e. Growth plate open

f. Growth plate closed

g. h. Fig. 1-6 a–h

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Joint orientation can be drawn as a straight line connecting the two points where the femoral condyles meet the metaphysis of the femur. For children, this can be drawn where the growth plate exits anteriorly and posteriorly (Fig. 1-6f). Alternatively, Blumensaat’s line, which can be seen as a flat line representing the intercondylar notch, can be used as the joint orientation line of the distal femur in the sagittal plane. This is particularly useful for evaluating sagittal plane deformities secondary to growth arrest problems.

Hip

Because the femoral head is round, it is necessary to use the femoral neck or the greater trochanter to draw a joint line for hip orientation in the frontal plane (Fig. 1-6g). The level of the tip of the greater trochanter has a functional and development relationship to the center of the femoral head. Similarly, the femoral neck maintains a development relationship to the femoral diaphysis and femoral head. A line from the proximal tip of the greater trochanter to the center of the femoral head represents the hip joint orientation line of the hip joint in the frontal plane. Alternatively, the mid-diaphyseal line of the femoral neck can represent the orientation of the hip joint (Fig. 1-6h). This is drawn using the center of the femoral head as one point and the mid-diaphyseal width of the neck as the second point.

Joint Orientation Angles and Nomenclature

The joint lines in the frontal and sagittal planes have a characteristic orientation to the mechanical and anatomic axes. For purposes of communication, it is important to name these angles. These joint orientation angles have been given various names by different authors in different publications (Chao et al. 1994; Cooke et al. 1987, 1994; Krackow 1983; Moreland et al. 1987). There is no standardization of the nomenclature used in the literature. This makes communication and comparison difficult. We think that the names used by different authors are confusing, difficult to remember, and not user friendly. The nomenclature used in this text was developed so that the names could be easily remembered or even derived without memorization (Paley et al. 1994).

In the frontal and sagittal planes, a joint line can be drawn for the hip, knee, and ankle. The angle formed between the joint line and either the mechanical or anatomic axis is called the joint orientation angle. The name of each angle specifies whether it is measured relative to a mechanical (m) or an anatomic (a) axis. The angle may be measured medial (M), lateral (L), anterior (A), or posterior (P) to the axis line. The angle may refer to the proximal (P) or distal (D) joint orientation angle of a bone (femur [F] or tibia [T]). Therefore, the mechanical lateral distal femoral angle (mLDFA) is the lateral angle formed between the mechanical axis line of the femur and the knee joint line of the femur in the frontal plane. Similarly, the anatomic LDFA (aLDFA) is the lateral angle formed between the anatomic axis of the femur and the knee joint line of the femur in the frontal plane. Sagittal plane angles can just as easily be named. For example, the anatomic posterior proximal tibial angle (aPPTA) is the posterior angle between the anatomic axis of the tibia and the joint line of the tibia in the sagittal plane.

Schematic drawings of the nomenclature of the mechanical and anatomic frontal (Fig. 1-7a and b) and
b. Anatomic

- MNSA = 130° (124–136°)
- MPFA = 84° (80–89°)
- aLDFA = 81° (79–83°)
- JLCA (0–2°)
- MPTA = 87° (85–90°)
- LDTA = 89° (86–92°)

MNSA = 130°
MPFA = 84°
aLDFA = 81°
JLCA (0–2°)
MPTA = 87°
LDTA = 89°

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c. Sagittal

- PPFA = 90° (165–175°)
- ANSA = 170°
- PDFA = 83° (79–87°)
- PPTA = 81° (77–84°)
- ADTA = 80° (78–82°)

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d. aJCD = piriformis fossa
- aJCD = medial tibial spine
- aJCD = 10 ± 5 mm
- aJCD = 4 ± 4 mm

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e. a-JER = ¼
- a-JER = ¼
- a-JER = ¼
- a-JER = ¼
sagittal (Fig. 1-7c) plane joint orientation angles are shown. Each axis line and joint orientation line intersection forms two angles. Either angle could be named with this nomenclature. For example, the mechanical medial distal femoral angle (mMDFA) and the mLDFA are complementary to each other (they add up to 180°). Although either angle could be used to name the joint orientation angle of the knee to the mechanical axis of the femur, the mLDFA is the one used in this text (Fig. 1-7a). The angles chosen in this text are those that are normally less than 90° (normal value of the mLDFA = 87° and normal value of the mMDFA = 93°). If the normal joint orientation was 90°, such as for the mechanical lateral proximal femoral angle (mLPFA) and mechanical medial proximal femoral angle (mMPFA), the lateral angle was chosen as the standard angle in this text. When it is obvious that the joint orientation angle refers to the mechanical or anatomic axis, the m or a prefix can be omitted. For example, sagittal plane orientation angles usually refer to the anatomic axis because mechanical axis lines are rarely used in the sagittal plane. The prefix m or a is omitted because anatomic axis is implied. Because the mechanical and anatomic axes of the tibia are parallel, the medial proximal tibial angle (MPTA) and lateral distal tibial angle (LDTA) have the same value whether they refer to the mechanical or anatomic axis. It therefore does not matter whether the prefix m or a is used. Finally, because LPFA is used by convention to describe joint orientation of the hip relative to the mechanical axis and MPFA is used relative to the anatomic axis, the m and a prefixes can be omitted. Therefore, the only time the m or a prefix must be used is with reference to the LDFA. The mLDFA and the aLDFA are both normally less than 90° and are different from each other. Therefore, the prefix should always be used to define which LDFA is being referenced.

The angle formed between joint orientation lines on opposite sides of the same joint is called the joint line convergence angle (JLCA) (Fig. 1-7a and b). In the knee and ankle joints, these lines are normally parallel.

Two mid-diaphyseal points define anatomic axis lines. The intersection of the anatomic axis with the joint line is fairly constant and is important in understanding normal alignment and in planning for deformity correction. The distance from the intersection point of anatomic axis lines with the joint line can be described relative to the center of the joint line or to one of its edges. In the frontal plane, the distance on the joint line between the intersection with the anatomic axis line and the joint center point is called the anatomic axis to joint center distance (aJCD) (Fig. 1-7d). In the sagittal plane, the distance between the point of intersection of the anatomic axis line with the joint line and the anterior edge of the joint is called the anatomic axis to joint edge distance (aJED). The anatomic axis:joint edge ratio (aJER) is the ratio between the aJED and the total width of the joint. Similarly, the anatomic axis: joint center ratio (aJCR) is the ratio of the aJCD and the total width of the joint. The normal values and range are illustrated (Fig. 1-7e).

The normal relationship of the joints of the lower extremity has been the focus of several recent studies (Chao et al. 1994; Cooke et al. 1987, 1994; Hsu et al. 1990; Moreland et al. 1987; Paley et al. 1994). There are two considerations when evaluating the frontal plane of the lower extremity: joint alignment and joint orientation (Paley and Tetsworth 1992; Paley et al. 1990). Alignment refers to the collinearity of the hip, knee, and ankle (Fig. 1-8a). Orientation refers to the position of each articular surface relative to the axes of the individual limb segments (tibia and femur) (Fig. 1-8b). Alignment and orientation are best judged using long stand-
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a MAD is the perpendicular distance from the mechanical axis line to the center of the knee joint line. The frontal plane mechanical axis of the lower limb is the line from the center of the femoral head to the center of the ankle plafond. The normal mechanical axis line passes 8 ± 7 mm medial to the center of the knee joint line.

b Knee joint malorientation is present when the angle between the femoral and tibial mechanical axis lines and their respective knee joint lines (LDFA and/or MPTA) falls outside of normal limits (normal = 87.5 ± 2°).

c Tibiofemoral mechanical alignment refers to the relation between the mechanical axes of the femur and tibia (normal = 1.3° varus).

d Tibiofemoral anatomic alignment refers to the relation between the anatomic axes of the femur and tibia.
In the frontal plane, the line passing from the center of the femoral head to the center of the ankle plafond is called the mechanical axis of the lower limb (Fig. 1-8a). By definition, malalignment occurs when the center of the knee does not lie close to this line. Although normal alignment is often depicted with the mechanical axis passing through the center of the knee, a line drawn from the center of the femoral head to the center of the ankle typically passes immediately medial to the center of the knee. Moreland et al. (1987) reviewed long standing AP radiographs of both lower extremities in 25 normal male volunteers and documented that the center points of the hip, knee, and ankle are nearly collinear. The angle between the mechanical axis of the tibia and femur (tibiofemoral angle) was 1.3 ± 2° varus (Fig. 1-8c). A commonly measured value is the anatomic tibiofemoral angle. This is usually approximately 6° valgus (Fig. 1-8d). Hsu et al. (1990) reviewed long standing AP radiographs of the lower extremity of 120 normal volunteers of various ages and reported that the mechanical axis generally passes immediately medial to the center of the knee. In their population, the mechanical tibiofemoral angle measured 1.2 ± 2.2° varus. In a study of 50 asymptomatic French women older than 65 years (Glimet et al. 1979), the mechanical tibiofemoral angle measured 0°. Most recently, Bhave et al. (unpublished results) studied a group of 30 adults older than 60 years, all of whom had no history or evidence of injury, surgery, arthrosis, or pain in their lower extremities. The mechanical tibiofemoral angle measured 1.3 ± 1.3°.

The distance between the mechanical axis line and the center of the knee in the frontal plane is the MAD. The MAD is described as either medial or lateral. Medial and lateral MADs are also referred to as varus or valgus malalignments, respectively. In a retrospective study of 25 knees in adult patients of different ages, the normal MAD was 9.7 ± 6.8 mm medial (Paley et al. 1994) (Fig. 1-8a). In a recent prospective study of normal lower limbs in people older than 60 years without any evidence of pathological abnormality of the knee, the MAD was 4.1 ± 4 mm (Bhave et al., unpublished results).

**Hip Joint Orientation**

Previously, hip joint orientation was evaluated using the neck shaft angle (NSA). The normal NSA is 125°–131°. In an anatomic study of isolated cadaver femora, Yoshioka et al. (1987) determined that the NSA in adult men normally measures 129° (Fig. 1-9). A line from the tip of the greater trochanter to the center of the femoral head was described by Paley and Tetsworth (1992) to define the orientation of the hip in the frontal plane. Chao et al., unpublished results 89.4 ± 4.8°
Paley et al., 1994 94.6 ± 5.5°
Paley et al., 1994 89.9 ± 5.2°

**Fig. 1-9**
Hip joint orientation in the frontal plane. MNSA according to different authors (mean ± 1 standard deviation [SD]).
et al. (1994) also measured the LPFA, which they called the horizontal orientation angle for the proximal femur, from long standing radiographs in 127 normal volunteers and stratified the study group according to age and gender. There was no significant change noted with age in women, and the relationship of this line to the mechanical axis of the femur measured 91.5±4.6° in younger women and 92.7±4.9° in older women. In men, the relationship of this line relative to the mechanical axis of the femur demonstrated an age-related tendency toward increasing varus, measuring 89.2±5.0° in younger men and 94.6±5.5° in older men. Data from our institution (Paley et al. 1994), based on a smaller group of 25 asymptomatic adults, revealed that this proximal femoral joint orientation line measures 89.9±5.2°. Another study from our institution (Bhave et al., unpublished results) of asymptomatic older adults (>60 years) without gonarthrosis revealed an LPFA of 89.4±4.8°. Based on these observations, we consider 89.9±5.2° to be the normal LPFA (Paley and Tetsworth 1992; Paley et al. 1990, 1994) (Fig. 1-10).

Regarding knee joint orientation, Chao et al. (1994) determined that the distal femoral articular surface is normally in slight valgus relative to the femoral mechanical axis, measuring 88.1±3.2°. These results were confirmed by our data (Paley et al. 1994), with the distal femur in slight valgus relative to the mechanical axis of the femur (mLDFA=87.8±1.6°). Cooke et al. (1987, 1994) obtained radiographs of the knee and hip after positioning the patient in a QUESTAR frame to improve reproducibility of the radiographic technique. In 79 asymptomatic young adults, the distal femoral orientation line measured valgus of 86±2.1°. In one study of older asymptomatic adults (Bhave et al., unpublished results), the LDFA was 88.1±1.5°. Based on all these studies, we consider the normal mLDFA to be 87.5±2.5° (Paley et al. 1994) (Fig. 1-11).

To consider the proximal tibial joint orientation, Chao et al. (1994) again stratified their data by age and gender.
gender and found a significant difference when comparing older with younger men. In all groups, the proximal tibial joint orientation line measured slight varus relative to the mechanical axis of the tibia (87.2 ± 2.1°). In women, there was no age differential. In asymptomatic young men, there was slightly more varus (MPTA = 85.5 ± 2.9°) compared with asymptomatic older men (87.5 ± 2.6°). These data suggest that some young men with more varus later develop symptomatic degenerative arthritis and “drop out” of the asymptomatic group of older men. This hypothesis is supported by data regarding alignment of elderly normal lower limbs with no previous history of injury or surgery and with no evidence of knee arthritis or pain. One study (Glimet et al. 1979) of 50 elderly asymptomatic French women documented that the mechanical tibiofemoral angle in this select group measures 0° instead of slight varus as is seen in the normal population. The second study, from our institution (Bhave et al., unpublished results), demonstrated an MPTA of 88.3 ± 2° in patients older than 60 years. Cooke et al. (1994) reviewed standardized radiographs obtained using a positioning frame and found that the MPTA is 86.7 ± 2.3°. These results were confirmed by our data (Paley et al. 1994), with an MPTA of 87.2° varus ± 1.5°, and by the data presented by Moreland et al. (1987), with an MPTA of 87.2° varus ± 1.5°. Based on these observations, we consider the normal MPTA to be 87 ± 2.5° (Paley et al. 1994) (Fig. 1-12).

The knee joint orientation measures approximately 3° off the perpendicular, such that the distal femoral joint line is in slight valgus and the tibia is in slight varus to the proximal tibial joint line (by convention, we always refer to the distal segment relative to the proximal segment when describing deformity of the lower extremity) (Krackow 1983; Moreland et al. 1987; Paley et al. 1990, 1994). When walking, the feet progress one in front of the other along the same line, with the leg inclined (adducted) to the vertical approximately 3° (Saunders et al. 1953) (Fig. 1-13). Krackow (1983) reports that this 3° varus position of the lower limb allows the knee to maintain an optimal parallel orientation to the ground during gait (Fig. 1-13a). In bipedal stance, with the feet as wide as the pelvis and the tibia perpendicular to level ground, the knee joint line would be oriented in 3° valgus relative to the vertical (Fig. 1-13b).

Several authors have presented reports on proximal tibial sagittal plane orientation. Meister et al. (1998) reported that the posterior slope of the proximal tibia in the sagittal plane is 10.7 ± 1.8°. (PPTA = 79.7 ± 1.8°.) Chiu et al. (2000) reported a PPTA of 78.5° in a radiographic study of 25 pairs of Chinese cadaveric tibiae. Matsuda et al. (1999), using magnetic resonance imaging, reported separate PPTAs measured from the medial and lateral tibial plateaus relative to the anatomic axis of the tibia. They reported a PPTA of 79.3 ± 5° when measured from the medial tibial plateau and a PPTA of 82 ± 4° when
a. During walking, the limb is in the "at attention" posture, 3° inclined to the ground. Therefore, the knee joint lines are parallel to the ground during walking (modified from Krakow 1983).

b. The standing alignment of the lower limbs to the ground changes with the feet apart at a distance equal to the width of the pelvis ("at ease" standing position) and the feet together ("at attention" standing position). When the feet are apart, the knee joint line is 3° inclined to the ground and the mechanical axis is perpendicular to the ground. When the feet are together, the knee joint line is parallel to the ground and the mechanical axis is oriented 3° to the ground (modified from Krakow 1983).

Fig. 1-14
Proximal tibial knee joint orientation in the sagittal plane. PPTA according to different authors (mean ± 1 SD).
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Fig. 1-15
Distal femoral knee joint orientation in the sagittal plane. PDFA according to different authors (mean ± 1 SD).

measured from the lateral plateau. In our series (Bhave et al., unpublished data) of normal volunteers, the PPTA was 80.4 ± 1.6° (Fig. 1-14).

The distal femoral knee joint orientation line in the sagittal plane has never been studied using the joint line of the distal femur that we describe. The normal posterior distal femoral angle (PDFA) in our series of normal volunteers was 83.1 ± 3.6° (Fig. 1-15).

The orientation of Blumensaat’s line was studied by Bhave et al. (unpublished results). The Blumensaat’s line angle measured 32 ± 2.6° (Fig. 1-16).

Fig. 1-16
Distal femur sagittal plane orientation. The angle formed by the distal femoral anatomic axis and Blumensaat’s line is shown.

Ankle Joint Orientation

Moreland et al. (1987) reported that the ankle is in slight valgus (89.8 ± 2.7°). Data from our institution (Paley et al. 1994) also demonstrated slight valgus (LDTA = 88.6 ± 3.8°), as did the data presented by Chao et al. (1994) (87.1 ± 3.3°). This relationship is variable, and up to 8° of valgus can be seen (Moreland et al. 1987). Part of this variation may be projectional because, in most studies, this angle was measured from radiographs obtained centered on the knee with the patella forward and without consideration for foot rotation. Inman (1976) measured 107 cadaver specimens and reported that the average ankle joint orientation equated to an LDTA of 86.7 ± 3.2°, with a range of 80°–92°. Based on these measurements, we consider the normal LDTA to be 89 ± 3° (Paley and Tetsworth 1992; Paley et al. 1994) (Fig. 1-17). In practice, it is convenient to use the line perpendicular to the tibial diaphysis as the joint orientation line for the ankle.
Finally, the normal sagittal plane joint line orientation of the ankle has been described as the anterior tilt of the distal tibia (Fig. 1-18). In our studies, the values were 79.8±1.6° (Paley et al. 1994) and 83.1±2.1° (Bhave et al., unpublished results).

References


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