Idiopathic Rotational Abnormalities of the Lower Extremities in Children and Adults

Abstract

- Rotational malalignment of the lower extremity is a potential cause of hip, knee, and ankle pain.
- Physical examination must include observation of gait and an assessment of femoral rotation and the thigh-foot axis with the patient prone.
- Advanced imaging helps to quantify the degree of deformity, improving the accuracy of the preoperative plan.
- Surgical correction of rotational malalignment of the femur and tibia is reserved for severe, symptomatic deformity.
- Future software that allows for 3-dimensional assessment of alignment and preoperative planning will further aid in the correction of the complex deformities.

Idiopathic rotational abnormalities of the lower extremity have been studied for decades, yet there remains no consensus regarding the etiology of these conditions and at what degree of deformity a normal variant crosses the threshold into malalignment (known as “torsion”). In-toeing or out-toeing, the most conspicuous sign of torsional deformity, is first noticed in young children as an alteration of the foot progression angle. It is generally believed that most rotational deformities in children resolve over time, making the treatment of childhood deformity controversial. Meanwhile, deformity due to metabolic and neurological conditions must be considered during the initial work-up. Pathological rotational abnormality can cause difficulty with walking, patellofemoral pain, and instability and has been implicated in femoroacetabular impingement (FAI), patellofemoral arthritis, and knee and hip osteoarthritis in adults.

Natural History

An appreciation of the childhood rotational development pathway helps us to better understand associated deformity in adolescents and adults. Limb rotation starts in utero and is part of normal development. At 5 months, the normal fetus has about 20° of internal tibial torsion. At birth, many infants have internal rotation (2° to 4°), increased femoral anteversion (~40°), and external contractures at the hip. Postrumatic malunion is a separate but important etiology of rotational deformity.

Disclosure: No external funds were received in support of this study. On the Disclosure of Potential Conflicts of Interest forms, which are provided with the online version of the article, one or more of the authors checked “yes” to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work.
resolve spontaneously, after which abnormal rotation is revealed\(^5\). Rotational change continues until the age of 8 to 10 years, with the tibia externally rotating nearly 15° to 20° and the femur externally rotating 25° (thereby decreasing anteversion)\(^5,18,19\). There is certainly a packaging component to pathological limb rotation, as excess femoral anteversion that is present at birth often persists into skeletal maturity\(^20,21\). Meanwhile, rotation has been shown to vary based on laterality, indicating that torsion may develop or adapt over time\(^5,22,23\). Further evidence of the progressive development of torsion is seen in patients with concurrent deformity of the tibia and femur\(^5\), such as compensatory external rotation of the tibia after the age of 8 years in patients with in-toeing gait secondary to femoral anteversion\(^4,21\).

**Clinical Evaluation**

Evaluation begins with a thorough history and physical examination. Many benign rotational variations are seen in children and adults, and it is important to differentiate normal variability from pathological deformity. The clinical history should include an assessment of issues during pregnancy or birth and the meeting of developmental milestones. A family history of musculoskeletal disorders or hereditary conditions that may predispose to rotational malalignment (e.g., vitamin D-resistant rickets, mucopolysaccharidoses, achondroplasia, epiphyseal or metaphyseal dysplasia) should be included\(^24\). The extent of functional impairment experienced by the patient must be elicited.

Next, a detailed musculoskeletal examination is performed. The patient wears shorts in order to allow for improved visualization of alignment and function. The initial focus is on general appearance, including stature, posture, and signs of limb or spine asymmetry that may indicate a syndromic condition. The crux of the physical examination is the assessment of the rotational profile. Hip rotation can be assessed with the patient in either the supine or prone position. With the patient in the prone position, the hip is extended and the knee is flexed to 90°. The prone position is preferred as the pelvis can be better stabilized, goniometer measurement is easier, the extended hip more closely resembles the walking position, and comparison with the contralateral leg is easier\(^25,26\). In 1985, Staheli et al. evaluated 1,000 limbs in patients of all ages and determined normal values for rotational positioning and passive range of motion of the lower extremities that are still used today\(^1\). The measurements that they described (internal and external hip rotation, thigh-foot axis, transmalleolar axis, and foot progression angle during gait), combined with the heel-bisector angle, which assesses concurrent foot deformity, allow for determination of the existence and location of deformity prior to imaging. Increased levels of hip internal rotation are suggestive of femoral anteversion\(^27\), whereas limited internal rotation may indicate decreased anteversion, retroversion, or femoracetabular dysplasia\(^16\). However, range-of-motion values do not necessarily correlate with the degree of anteversion\(^27\). Increased femoral anteversion also may be diagnosed on the basis of medially-facing patellar alignment during gait or during standing with the feet pointed straight ahead (“winking patella sign”). The “W” sitting position is another characteristic sign of anteversion (Fig. 1). The “eggbeater” running pattern also may be seen during the gait examination secondary to internal rotation of the thighs during swing phase\(^28\). Although not a component of the rotational profile as described by Staheli et al., femoral anteversion can be assessed by determining the relative positions of the greater trochanter and the transverse axis of the femoral condyles\(^23,28\), or it can be estimated as the midpoint of the passive rotation arc of the hip, but physical examination correlates poorly with computed tomography (CT) measurements\(^29,30\).

Classically, the thigh-foot axis is used to assess tibial rotation. In reality, it is a composite measurement of a combination of tibial and hindfoot rotation in relation to the longitudinal axis of the thigh. Assessment is performed with the patient in the prone position, with the knee flexed to 90° and the ankle in a neutral position. A goniometer is used to measure the angular difference between the axis of the foot and the axis of the thigh. Infants have 5° of internal rotation on average. The thigh-foot axis externally rotates to about 10° by the age of 8 years, and there is little change from this point through adulthood\(^3,31\). External tibial rotation in infancy is less common and often worsens during growth, necessitating that these patients be closely followed as they may need surgery to prevent future patellofemoral issues\(^31\). Concurrent foot deformity can alter the measurement of the thigh-foot axis\(^3\) and is evaluated with the heel-bisector line, which is drawn through the midline axis of the hindfoot. This line should pass through the second web space in a neutral foot, and medial or lateral deviation is a sign of forefoot adduction or abduction\(^32\). Metatarsus adductus, cavus, or clubfoot are potential causes of in-toeing, whereas pes planovalgus is a potential cause of out-toeing.

Finally, functional assessment of the extremity during gait is performed. The foot progression angle is defined as the angular difference between the axis of the foot and the line of progression (an imaginary straight line along which the patient walks). The foot progression angle is determined by the combination of femoral and tibial rotation, foot shape, and muscular forces and represents the global alignment of the lower extremity. By convention, in-toeing is considered a negative angle whereas out-toeing is positive. A typical in-office assessment is performed with the patient walking a straight line directly toward the examiner. The foot progression angle remains mildly positive (average, 6° to 10°) throughout growth, with relative out-toeing in young children (due to increased lateral rotation of the hip) and in elderly adults (due to progressive loss of hip internal rotation)\(^3,33,34\).
It is important to be aware that the foot progression angle can be normal even in the setting of severe deformity. Several reports have described coupling of femoral anteversion and external tibial torsion, a compensatory adaptation that helps to normalize the foot progression angle. Tibial torsion is intimately related to the foot progression angle and usually twists in the same direction, whereas the femur often rotates in the opposite direction. Offsetting rotation can occur in >50% of patients, evidence that supports a full examination even for patients with an apparently normal gait and foot progression angle. Gait analysis (mandatory for neurogenic patients) provides an objective overview of trunk, pelvis, hip and extremity rotation throughout the gait cycle and can assist in unmasking relationships between static osseous abnormalities and dynamic mechanisms of compensation at the hip and the knee.

With the advent of advanced imaging technologies, the value of a detailed physical examination has been questioned. Although correlation between examination and imaging findings is often noted, there can be noteworthy and unpredictable differences in absolute value of degrees of rotation. Tamari et al. reported measurement errors of ~5° but noted overall good correlation between clinical and magnetic resonance imaging (MRI) findings, indicating the usefulness of physical examination in screening for disease. Several investigators have compared goniometric and CT measurements and have concluded that the 3° to 5° measurement error was acceptable in clinical practice. Meanwhile, others have noted significant differences between clinical and CT assessment of femoral anteversion and tibial torsion, and this discordance between radiographic and examination measurement increases as rotational deformity worsens. Theoretically, these unpredictable results may be secondary to soft-tissue or acetabular restraints that are not accounted for in many imaging studies.

Ultimately, a provider who can perform a thorough assessment of the rotational profile and has good understanding of expected normal values for each site at each age should be able to accurately diagnose torsional deformity even without the assistance of radiographic studies.

**Radiographic Evaluation**

For patients with abnormal findings on physical examination, radiographs are made to assess the affected joints. Hip and pelvic radiographs can identify...
acetabular or femoral dysplasia and early osteoarthritis. Anteroposterior, lateral, and Merchant radiographs of the knee can identify patellofemoral alignment issues and arthritis. Rotational deformity about the knee or ankle may present with increased tibia-fibula overlap (Fig. 2). For patients with severe in-toeing or out-toeing, radiographs of the foot can also be useful for identifying metatarsus adductus and quantifying pes planus. Finally, a standing lower extremity radiograph or EOS imaging (a biplanar low-dose imaging system) should be used to assess concurrent coronal plane deformity and limb-length discrepancy, but surgeons must be aware that coexisting tibial torsion deformity may confound the assessment of knee malalignment. Patients with external tibial torsion and genu varum often will appear to have more varus when the feet are pointing forward. Patients with femoral anteversion will appear to have a high femoral neck-shaft angle that will decrease after correction.

Unfortunately, rotational alignment is difficult to assess on radiographs. Several authors have described methods for determining femoral anteversion with use of axial or biplanar radiography, with questionable accuracy and reproducibility. Meanwhile, radiographic methods for determining tibial torsion provide values that are similar to physical examination measurements but not CT comparisons. Currently, we use radiographs to assess coronal and sagittal alignment as well as joint integrity. Other imaging modalities that allow for more quantitative assessment, such as ultrasound, fluoroscopy, and MRI, have been described.

Rotational profiling with use of 3-dimensional (3D) imaging such as MRI and CT is the definitive method for the diagnosis of lower extremity abnormality. Measurements are taken from 2D axial slices through the femoral neck, distal part of the femur, proximal part of the tibia, and ankle mortise to determine rotation. Axial imaging theoretically provides highly accurate and repeatable measurements, but it is not without limitations. The orientation of the axial cut can change planes, which has been shown to alter measurement results. The most widely used femoral measurements rely on CT-derived axial slices through the femoral neck and distal femoral condyles. With all techniques, the distal

![Fig. 2](image-url)  
**Figs. 2-A and 2-B** Photographs showing the lower limbs of a patient with severe rotational deformity about the tibia. **Fig. 2-C** Anteroposterior long-cassette standing radiograph showing classic lateral tibia-fibula overlap.
<table>
<thead>
<tr>
<th>Author</th>
<th>No.</th>
<th>Age* (yr)</th>
<th>Femoral Anteversion†</th>
<th>Tibial Torsion‡</th>
<th>Measurement Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botser et al.²⁷</td>
<td>129</td>
<td>36 (14-74)</td>
<td>15.9°</td>
<td>—</td>
<td>Femoral neck axis on oblique slice to tangent of the posterior aspect of femoral condyles</td>
<td>Statistically significant discrepancies found in anteverision angle measurements between MRI and CT scan</td>
</tr>
<tr>
<td>Decker et al.⁶⁸</td>
<td>211</td>
<td>34 (0-105)</td>
<td>18.2° ± 9.9°</td>
<td>—</td>
<td>Femoral neck axis to tangent of the posterior aspect of femoral condyles</td>
<td>Statistically significant discrepancies found in anteverision angle measurements between MRI and CT scan</td>
</tr>
<tr>
<td>Erkocak et al.¹²</td>
<td>40</td>
<td>20-40</td>
<td>11.6° ± 3.5°</td>
<td>26.0° ± 4.2°</td>
<td>Line drawn parallel to femoral neck to line tangent to posterior border of femoral condyles</td>
<td>No correlation of tibial torsion with age. Statistically significant side-to-side torsional differences noted.</td>
</tr>
<tr>
<td>Jakob et al.⁷⁶</td>
<td>45</td>
<td>Cadaveric tibiae</td>
<td>—</td>
<td>30°</td>
<td>Axis through widest transverse condylar diameter to line bisecting anteroposterior diameter of distal part of tibia that passes through anterior part of fibula at level of incisura</td>
<td>Statistically significant differences (up to 9°) between rotation of consecutive proximal tibial axial slices</td>
</tr>
<tr>
<td>Keppler et al.⁵⁷</td>
<td>78</td>
<td>2-18</td>
<td>34° at 5 yr; 19° at 17 yr</td>
<td>32°</td>
<td>—</td>
<td>Trend but no significant differences based on sex or ethnicity. Retroversion common in white (21.4%) versus Hispanic (7.1%)</td>
</tr>
<tr>
<td>Koerner et al.⁷⁰</td>
<td>328</td>
<td>Not reported</td>
<td>8.8° ± 9.7°</td>
<td>—</td>
<td>Axis of femoral neck to the posterior femoral condylar line</td>
<td>Close correlation between anatomical cadaver measurement and CT value</td>
</tr>
<tr>
<td>Kuo et al.⁵²</td>
<td>10</td>
<td>20-64</td>
<td>12.4° ± 3.8°</td>
<td>—</td>
<td>Line connecting center of femoral head with center of neck to line parallel to posterior femoral condylar line, just distal to upper pole of patella (Hernandez method)</td>
<td>No correlation of tibial torsion with age. Statistically significant side-to-side torsional differences noted.</td>
</tr>
<tr>
<td>Reikerås and Høiseth⁷³</td>
<td>50</td>
<td>Adult</td>
<td>—</td>
<td>Female: 32.3° ± 8.3° (R), 30.7° ± 10.4° (L); Male: 35.3° ± 7.6° (R), 34.0° ± 10.3° (L)</td>
<td>Dorsal tangent of tibial condyle to malleolar bisector line at ankle joint</td>
<td>Statistically significant differences (up to 9°) between rotation of consecutive proximal tibial axial slices</td>
</tr>
</tbody>
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### TABLE I (continued)

<table>
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<tr>
<th>Author</th>
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<th>Femur Comments</th>
<th>Tibia Comments</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Seber et al.29</td>
<td>50</td>
<td>Adult males</td>
<td>6.5° ± 7.7° (R); 5.8° ± 8.4° (L)</td>
<td>30.9° ± 7.1° (R); 29.1° ± 6.9° (L)</td>
<td>Line connecting center of femoral head with center of femoral neck to dorsal tangent of femoral condyles (Hernandez method)</td>
<td>Proximally, with the axial cut taken at the level of the fibular head, a line connecting the junction of anterior and lateral fibular margins with the most prominent part of the medial tibia to intermalleolar line distally at level of incisura fibularis</td>
<td>Average foot progression angle of 13.7°</td>
<td></td>
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<tr>
<td>Strecker et al.22</td>
<td>355</td>
<td>Adult</td>
<td>24.1° ± 17.4°</td>
<td>34.9° ± 15.9°</td>
<td>Line connecting center of femoral head with center of greater trochanter to dorsal condylar line</td>
<td>Dorsal tangent of tibial plateau to line connecting center of an ellipse formed from surface of medial malleolus and another ellipse formed by incisura fibularis (Ulm method)</td>
<td>Torsion R &gt; L (p &lt; 0.001)</td>
<td></td>
</tr>
<tr>
<td>Stuberg et al.38</td>
<td>17</td>
<td>12.3 (3.3-24)</td>
<td>—</td>
<td>24.5° ± 8.4°</td>
<td>—</td>
<td>Tibial condyle bisector line to malleolar bisector line at incisura</td>
<td>Statistically significant side-to-side differences (4.3° in femur, 6.1° in tibia)</td>
<td></td>
</tr>
<tr>
<td>Waidelich et al.63</td>
<td>50</td>
<td>31 (13-61)</td>
<td>33.1° ± 8°</td>
<td>20.4° ± 9°</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
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*The values are given as the mean with or without the standard deviation, when available. **The values are given as the mean and/or the range, when available.

 axis of the femur is a line tangent to the posterior aspects of the condyles on the axial image, where the condyles have the largest anterior-to-posterior distance.18,61,62 Measurement of the femoral neck axis is variable and can be performed with use of different 2D slices (axial, oblique, superimposed) and anatomical landmarks (femoral head, femoral neck, greater trochanter).9,22,61,63-65 The use of 3D-CT reconstructions has also been described.66 CT offers the ability to measure acetabular version. If the femoral version that was measured during the physical examination does not correlate with that measured on CT scans, then the acetabular version needs to be evaluated as acetabular retroversion can decrease the measurement of internal rotation during physical examination.63 A wide range of normative CT values for femoral anteversion have been reported (from 6° to 24°) (Table I).22,27,52,63,67-71 Differing measurement techniques are largely responsible, with mean values differing by as much as 11.4° (range, 11° to 22.4°) for the same patients when measured with different techniques.18 Even when the same technique has been used, values have been shown to be highly dependent on the CT slice, leading to intraobserver and interobserver differences of as much as 15°.52,72-74 Age, sex, ethnicity, and laterality may contribute to the variability of reported values.22,63,65,67,70,75

Jakob et al. first described the use of CT scanning for the evaluation of tibial torsion in 1980.76 Other techniques have been described since then. Proximally, the axis may be drawn either (1) parallel to the posterior parts of the tibial condyles, (2) tangential to the posterior rim of the tibial plateau, or (3) as an axis line bisecting the widest anteroposterior diameter of the medial and lateral tibial condyles.28,77 The level of the proximal tibial slice may be hard to define, and, given that the majority of tibial torsion occurs in the proximal 4 cm of the tibia, slices must be chosen as proximal to the tibial plateau as possible.15,71

A number of other measurement techniques have been described to define the distal tibial axis.22,74 The bimalleolar method describes a line drawn from the center of the anteroposterior diameters of the medial malleolus and fibula in an axial slice either just proximal to the ankle mortise with the fibula in the incisura or at the level of the talar dome.12,38,62,73 The posterior intermalleolar line at the level of the talar dome also has been used.59 Variability has been noted with these reference points, with average disagreement of as much as 13° on intermethod comparisons.74

As in the femur, a wide range of normative CT values for tibial torsion (from 24.5° to 38°) have been reported in the literature.12,22,36,38,63,65,69,71,73,76 (Table I). Possible explanations include sex, race (with Asian and African American individuals having lower values), laterality, hip dysplasia, and the
presence of secondary arthritis. Meanwhile, the anatomy of the posterior tibial condyles has been noted to be quite variable, with as much as a 10° difference in angulation depending on the axial slice chosen. For this reason, some have advocated measuring the torsion of the “leg” from the femoral condyle (which has only 1° to 2° of variability) to the distal tibial reference point (Fig. 3).

With the widespread use of CT for the evaluation of the rotational profile, concerns remain regarding the radiation exposure in young patients. In practice, the use of CT also may be limited in younger patients because of incomplete ossification. Physicians regularly using CT should consider developing protocols that reduce risks due to ionizing radiation for their younger patients. Alternatively, EOS (the biplanar low-dose imaging system) has been used for 3D modeling of the lower extremity and measurement of femoral and tibial rotation. EOS imaging requires radiation doses lower than even conventional radiographs, and computer software reconstructions allow for measurements of rotation.

MRI methods are considered relatively accurate and do not subject the patient to any radiation, but tests are time-consuming and costly compared with CT scanning. Koenig et al. described an MRI protocol for assessing rotation within approximately 10 minutes; this protocol may be important when assessing children, for whom sedation may be required for adequate imaging. Additionally, MRI measurements have been found to vary by as much as 5° depending on the imaging protocol, are systematically biased toward lower values (≤10°), and are less accurate than CT measurements. Discrepancies noted throughout multiple imaging studies likely represent the difficulty of creating a 2D measurement projection of what is really a 3D problem. Additionally, deformity can occur at different locations along the femur, such as supratrochanteric deformity, which is measured as the tilt of the femoral neck, and infratrochanteric deformity, which is measured as the rotation of the femoral shaft. Methods to quantify femoral rotation with use of 3 axes for measurement or 3D-CT volumetric reconstructions have been described and are believed to be more accurately localize transverse plane rotation than conventional methods.

Sequelae of Rotational Deformity

Different conditions associated with rotational deformity present at different stages of life and may include abnormal gait, patellar instability and pain, slipped capital femoral epiphysis (SCFE), hip labral tears, FAI, and osteoarthritis of the knee and the hip.

Issues with the extensor mechanism include patellofemoral pain, malalignment, and instability. The term miserable malalignment describes a combination of femoral antever sion, tibial external torsion, and an increased Q angle, which can occur alongside patella alta, squinting patella, genu varum, and genu recurvatum. While coronal plane deformity clearly plays a role in altering the Q angle, axial plane changes also affect tracking biomechanics. Increased femoral antever sion displaces the patella medially, increasing the Q angle and altering the lateral patellar tilt angle, which drastically increases lateral patellofemoral contact pressures. Exter nal tibial torsion displaces the tibial tubercle laterally, also increasing the Q angle. Erkocak et al. demonstrated a close relationship between the Q angle, femoral antever sion, external tibial torsion, and anterior knee pain in adults 20 to 40 years of age.

While obesity is the primary risk factor for SCFE, it has been suggested that anatomical alterations of the proximal part of the femur may also put patients at risk for SCFE. Botser et al. demonstrated that patients with low antever sion are more likely to have pincer...
impingement, whereas patients with high anteversion are more likely to have a cam deformity. The longer-term sequelae of rotational deformity are not well understood. FAI is known to accelerate the progression of hip degeneration. Terjesen et al. and Halpern et al. noted that femoral anteversion is a predisposing factor for hip degeneration.

Fig. 4

Figs. 4-A through 4-F A 14-year-old girl with anteromedial left knee pain with pathological femoral anteversion (42°) and tibial external torsion (41°). The patient was 4 years postmenarchal, and the growth plates were nearly fused on CT imaging. Physical examination findings included 85° of internal rotation of the hip (compared with 65° on the contralateral side) and a 35° thigh-foot axis (compared with 15° on the contralateral side). The patient underwent concurrent left-sided femoral and tibial percutaneous osteotomies and nailing through greater trochanteric and transtibial starting points, respectively. The femur was externally rotated by 25°. The tibia was internally rotated by 20°, and a fibular osteotomy was not needed. Fig. 4-A and 4-B Preoperative anteroposterior and lateral radiographs demonstrating classic radiographic findings of tibial torsion. The top left panel (Fig 4-A) shows an anteroposterior view of the knee joint, with an oblique view at the knee. The top right panel (Fig 4-B) shows a lateral view of the knee, with an oblique view of the ankle. Figs. 4-C through 4-F Radiographs made at 6 weeks postoperatively, showing healing and improvement of radiographic positioning.
osteoarthritis. Tön尼斯 and Heinecke described a relationship between extreme values of anteversion and retroversion and increasing hip pain suggestive of early osteoarthritis. Those authors recommended corrective treatment of excessive femoral version in order to decrease pain and decrease risk of early arthritis. Several other studies involving radiography, CT evaluation, and cadaveric specimens have demonstrated no association.

While investigations of the link between rotational malalignment and knee osteoarthritis have demonstrated inconsistent findings, pathological rotation is thought to increase shear forces across articular cartilage, leading to biomechanical changes in the subchondral bone and deep chondral layers. Femoral anteversion is increased in patients with patellofemoral arthritis, a sign that excessive femoral torsion may contribute to increased wear of the patellofemoral joint. Femoral retroversion is more likely to be associated with tibiofemoral osteoarthritis, and internal tibial torsion has been correlated with medial knee osteoarthritis.

Operative Considerations
Operative correction of torsional deformity remains a controversial topic, and the majority of published data are found in the pediatric literature, with poor application to adult populations. Adults who present with torsion have self-identified problems related to malalignment and may benefit from osteotomy. As there is no absolute value of deformity that requires surgery, asymptomatic children who are brought in by concerned parents require a careful approach and may be best served by observation until symptoms appear.

Spontaneous remodeling of the femur with improvement of gait abnormalities occurs in most children by the age of 8 years, with little change after that point. Unfortunately, nonoperative treatment for symptomatic femoral anteversion is ineffective. Relative indications for surgery include hip, knee, or ankle pain in the presence of excessive anteversion or retroversion and/or functional concerns of persistent in-toeing, impaired gait, and tripping during athletic activity.

A number of osteotomy locations and fixation methods have been described. Percutaneous osteotomies involve minimal periosteal stripping and are thought to improve the speed and success of osseous union. Closed osteotomy with an intramedullary saw also has been described. Plate fixation with either proximal or distal osteotomy is a well-described and effective technique, although serious complications are not uncommon. With the advent of a lateral trochanteric entry nail, intramedullary fixation is the preferred method for the correction of primary rotational deformities in older children. The advantages of intramedullary nails include improved aesthetics, minimal soft-tissue dissection, early weight-bearing, load-sharing (which promotes osseous healing), and a
A 32-year-old man who presented with right knee pain caused by external tibial torsion of 57° (15° greater than that on the contralateral side). The patient underwent right tibial supramalleolar osteotomy and fibular osteotomy with application of a Taylor Spatial Frame. He gradually underwent correction of 15° starting on the third postoperative day, with daily adjustments for 15 days. **Fig. 6-A** Preoperative clinical photograph showing an obvious external foot progression angle. **Figs. 6-B, 6-C, and 6-D** Anteroposterior radiograph (**Fig. 6-B**), clinical photograph (**Fig. 6-C**), and lateral radiograph (**Fig. 6-D**) of the right lower leg, made 6 weeks after Taylor Spatial Frame correction. **Figs. 6-E and 6-F** Clinical photograph and radiograph, made 6 months postoperatively, demonstrating improvement of the foot progression angle and healing of the supramalleolar osteotomy site.
decreased risk of complications. The reported complication rates have been low. For younger patients, the nail can be placed safely through a trochanteric starting point, whereas for older patients, a piriformis starting point can be used. In order to avoid creating a varus deformity, care should be taken to select the correct nail size and starting point. Fat embolism syndrome is a theoretical risk associated with intramedullary fixation, and vent holes drilled at the osteotomy site prior to reaming may reduce the risk of fat embolus. Percutaneous osteotomy and fixation with use of a modified Ilizarov frame has been described with excellent results, although the frame is poorly tolerated in the thigh. The indications for the treatment of idiopathic torsion remain vague and include the presence of severe deformity, but functional pain and disability remain the primary considerations. Osteotomy for the treatment of tibial torsion can restore kinetic and kinematic parameters of knee motion to near-normal values. Osteotomy is performed proximally, distally, or in the midshaft and can be either percutaneous or open. Fixation can be performed with an intramedullary nail, staples, casting, plates, Kirschner wires, or an external fixator. Fibular osteotomy may be performed if the tibia derotation angle is >30°. It is thought that an intact fibula could lead to incongruity of the ankle joint and may contribute to recurrence of deformity, although one study demonstrated that an intact fibula prevented the loss of fixation and angulation at the osteotomy site. With regard to the level of osteotomy, proximal osteotomies are associated with a higher risk of complications, including peroneal nerve injury and compartment syndrome, but they are useful in patients with concurrent coronal knee deformity. Casting in children requires no metal implants but includes the risk of loss of correction. Plate fixation requires larger incisions, requires ultimate removal of the implant, may lead to a decreased rate of union because of the presence of rigid fixation, and is associated with increased rates of complications as compared with percutaneous pin fixation in distal tibial osteotomy. External fixation can be used to safely and reliably correct malalignment as the lower leg tolerates external fixation relatively well. Circular external fixation can be used to correct rotation and angulation of the lower extremities, with gradual correction making neurovascular accommodation possible and compartment syndrome highly unlikely. External tibial torsion exists in as many as 50% of patients with congenital genu varum, whereas internal tibial torsion is often seen in patients with Blount disease. The treatment of complex...
Overview

Rotational malalignment of the lower extremities is an important cause of hip, knee, and ankle pain. Understanding common presentation and physical examination findings is the first step to diagnosis, and advanced 3D imaging can aid in diagnosis and preoperative planning. Surgical intervention is uncommon, but it can be advantageous in the right patients with symptomatic deformity.

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