

TORSIONAL AND ANGULAR DEFORMITIES

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Intoeing, outtoeing, bowlegs, and knock-knees occur frequently in infancy and childhood. For most cases, these conditions are normal in physiologic development, and spontaneous resolution occurs without treatment. Torsional and angular malalignment, however, are the most common musculoskeletal complaints encountered by pediatricians and are a common cause for referral to orthopedic surgeons. Parents, family members, and friends often express great concern with the child's appearance and gait. Many have preconceived opinions about appropriate management of the problem because they or other family members were treated as children for similar conditions with corrective shoes or braces.

Because spontaneous resolution of these conditions is normal, the primary care provider can, in most cases, appropriately manage these patients with careful observation, referring only those persons in whom the deformity is severe and persistent.^{9, 10, 14} It is important, however, to understand the cause and severity of the deformity and to differentiate between physiologic and pathologic deformity. It is also important to understand the natural history of the deformity and the effect of treatment on natural history. One can then avoid costly and often frustrating unnecessary treatment as well as orthopedic referrals except when indicated and necessary.

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TORSION

Much of the credit for the following discussion should be given to Lynn T. Staheli, MD.^{4, 7, 11-16} Staheli was the guest editor of the *Symposium on Common Orthopaedic Problems* and author of the article "Torsional Deformity."¹³ Much of the material presented in that article was elucidated by Staheli through several interlocking studies in which he strived to establish the natural history of torsional deformities and to evaluate objectively the efficacy of various treatment modalities.

Natural History

During gestation, soon after limb bud formation, the lower extremity rotates medially, bringing the great toe to the midline. Lateral rotation then occurs in the femur and tibia throughout the remainder of development to skeletal maturity.¹³

Version describes the normal rotation of a limb segment. The normal femur is anteverted, that is, the femoral head and neck are rotated anteriorly with respect to the femoral condyles. Femoral anteversion (medial rotation) decreases from an average of 40° at birth to approximately 15° at skeletal maturity, which reflects a change of 25°. The normal tibia is externally rotated 5° at birth and 15° at skeletal maturity, reflecting a change of 10°.^{2, 14, 15} Therefore, one can expect an average remodeling into external rotation of 35° between birth and maturity.

Torsional abnormalities frequently demonstrate a familial tendency as illustrated in Figure 1. Therefore, one should question and even examine family members of patients in whom torsional malalignment is of concern. Examination of family members may actually predict the natural history of the child and illustrate the infrequency of functional problems related to mild torsional malalignment. Intrauterine positioning also may affect rotational alignment and is believed to be responsible for some cases of medial tibial torsion and metatarsus adductus. Uterine positioning also is responsible for the typical hip flexion and lateral rotation contracture seen in newborns.

In general, torsional complaints follow a predictable course. Metatarsus adductus usually presents at birth or shortly thereafter and resolves by the first birthday. Infants out-toe secondary to the newborn lateral rotation contracture of the hips. As this contracture begins to resolve, intoeing secondary to tibial torsion generally presents from 1 to 2 years of age and resolves by age 3 to 4 years. Medial femoral torsion usually presents at age 3 to 6 years, by which time the newborn lateral rotation contracture has resolved completely. Femoral torsion resolves more slowly and plateaus at age 8 or 9 years.^{2, 12, 14, 15}



Figure 1. Children with medial femoral torsion choose the classic “W” sitting position because lateral rotation at the hips is restricted and uncomfortable. Retained medial femoral torsion often demonstrates a familial tendency and helps to predict the expected natural history of the child.

Torsion describes rotational malalignment more than two standard deviations from normal and is rarely persistent into adulthood. Ninety percent to 95% of all torsional deformities resolve spontaneously by maturity. Most children and adults walk with their feet externally rotated a mean of 10° . Consistent intoeing of more than 10° or outtoeing of more than 30° (plus or minus three standard deviations) is considered abnormal but is rarely a functional problem in adolescence and adulthood.^{4, 16}

Evaluation

Evaluation should begin with a complete medical history, including pregnancy, birth, and development, to rule out a pathologic cause for the deformity. The history should also include the type of deformity, onset, progression, and prior treatment; history of the deformity; the parents' perception of the child's deformity; and future concerns regarding gait, function, and cosmesis. Torsional malalignment frequently becomes more apparent with fatigue, which should be acknowledged as an important part of the history.

To determine the level and magnitude of the malalignment, one should proceed systematically, first observing gait and walking. The entire lower extremity should be visible, allowing isolated observation

of the foot, leg, knee, and thigh. Intoeing or outtoeing is reflected by the foot progression angle (FPA), which is the angle subtended by the foot and the line of progression (Fig. 2). The knee and thigh should be evaluated for medial rotation (Fig. 3A). The foot also should be evaluated for dynamic (atavistic great toe) or static (metatarsus adductus, "flat feet") contributions to rotational malalignment. Running gait also should be examined because rotational malalignment often is exacerbated during running, and neurologic dysfunction is more readily apparent during running.

The physical examination should include a general screening and a careful spine and neurologic examination to rule out the possibility of a neuromuscular disorder. Most torsional deformities in children are static and present at rest, with the exception of the "searching" or atavistic great toe, which is dynamic.¹⁴ Dynamic deformities are more commonly found in patients with neuromuscular disorders. A careful examination of the hips also should be performed to rule out hip dysplasia.

Rotational malalignment can occur at any point between the hips and feet and may represent a combination of deformities. To determine the level of deformity, a rotational profile can be established (Fig. 4).¹³ The FPA has been recorded during ambulation.

Hip rotation is best measured with the child prone and the knees flexed to 90°. The legs are then allowed to maximally medially and

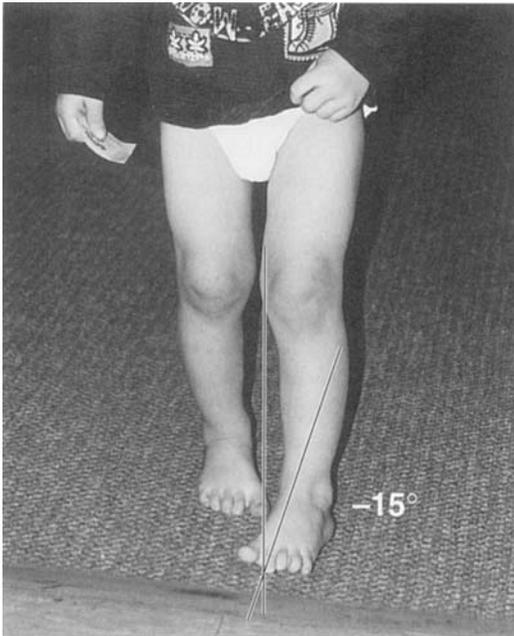


Figure 2. Foot progression angle (FPA). The FPA is the angle subtended by the foot and the line of progression. Medial rotation is signified by a negative number as in this 3-year-old boy whose FPA is -15° .



Figure 3. Medial femoral torsion. *A*, Medial femoral torsion is indicated by excessive medial rotation of the thigh in stance. Note the medial orientation of the patellae with respect to the line of progression. *B*, Medial hip rotation is recorded as demonstrated and best measured with the child prone, hip extended, and pelvis level. *C*, Corresponding lateral rotation. *D*, Femoral version (anteversion) is estimated by rotating the leg until the greater trochanter is palpated to be most prominent laterally. (Courtesy of Tom F. Novacheck, MD, St. Paul, MN.)

laterally rotate, keeping the pelvis at leg level (see Fig. 3*B* and *C*). Femoral anteversion also may be estimated by medially rotating the leg until the greater trochanter is palpated to be most prominent laterally (see Fig. 3*D*).

Tibial rotation is reflected by the thigh-foot angle (TFA), which is measured with the child prone and the knees flexed to 90° (Fig. 5). The TFA is the angle subtended by the axis of the foot and thigh. Because foot position can significantly affect this measurement, care should be taken to place the foot and ankle in a neutral position.

The foot should then be examined. Metatarsus adductus contributes to intoeing. Pes planus ("flat foot") has the appearance of external rotation during stance (outtoeing).

A combination of deformities may exist when evaluating the rotational profile. The deformities may be asymmetric. They may be compen-

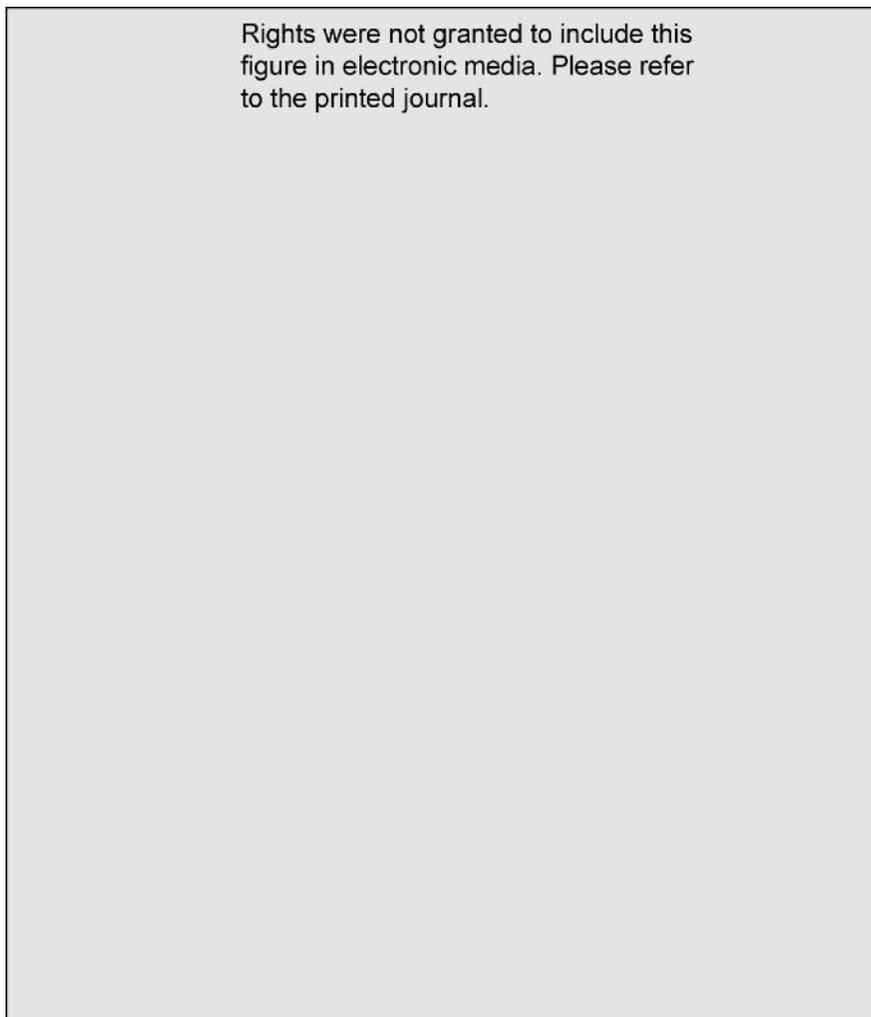


Figure 4. The rotational profile. *A*, By completing this chart, one can establish a diagnosis and document the severity of the malalignment for future comparison. *B–F*, Normative values for the profile \pm two standard deviations. (From Staheli LT: Torsional deformity. *Pediatr Clin North Am* 33:1373, 1986.)

satory, offsetting each other, as in medial femoral torsion and lateral tibial torsion. They may be additive, thereby exacerbating intoeing or outtoeing. Developmental remodeling occurs at a different rate in the femur, tibia, and foot, and this affects the rate at which improvement occurs.

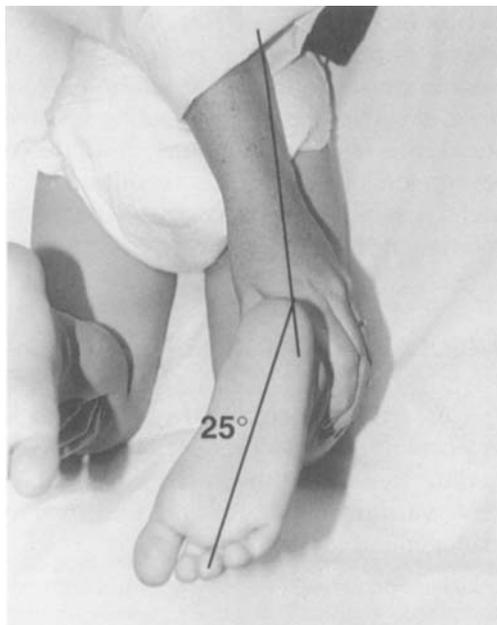


Figure 5. Thigh foot angle (TFA). The TFA is the angle subtended by the long axis of the foot and thigh. This is best measured with the child prone and the knees flexed to 90°.

Management

With the exception of treatment for foot deformities, corrective shoes, braces, and casts have not been shown to affect the natural history of lower extremity rotational alignment.^{3, 7, 12, 14, 15}

Medial tibial torsion occurs most commonly during the second year of life as the child begins to ambulate. If this torsion is asymmetric, one should look for associated metatarsus adductus. Night splinting is still occasionally instituted; however, it has no proven efficacy and is often frustrating for the parents and child.³ Observational management results in spontaneous resolution of malalignment in more than 95% of cases.¹⁴ If the deformity persists into skeletal maturity and results in a severe and functional deformity, tibial derotation osteotomy is necessary on rare occasions to improve alignment.

Medial femoral torsion most commonly occurs in children between 3 and 7 years of age. Medial femoral torsion most often is bilateral and symmetric and occurs more frequently in girls. This condition is frequently familial (see Fig. 1). These children prefer the characteristic "W" sitting position and are not able to sit cross-legged, or are not comfortable sitting cross-legged until the deformity begins to remodel and lateral rotation at the hip improves. If associated with medial tibial torsion, a severe intoeing gait may be present. Spontaneous resolution

occurs in 95% of cases. Residual deformity often is compensated in later life by improved lateral rotation at the hip or lateral tibial torsion and seldom causes functional disability. Femoral derotation osteotomy is the only effective means of treating retained medial femoral torsion. It should be reserved for older children (more than 8 to 10 years) with severe torsional deformity resulting in significant functional and cosmetic disability. In most cases, the primary problem is limited lateral rotation at the hip (0–10°) or associated medial tibial torsion.¹³

ANGULAR MALALIGNMENT

As with torsion, bowlegs and knock-knees most often are normal in physiologic development and resolve with time; however, it is important to exclude the variety of pathologic conditions that may cause genu varum or valgum and that may require special evaluation and management (Table 1).^{1, 5, 6, 9, 10, 17, 18}

Natural History

At birth and through the first year of life, alignment at the knee is pronounced varus (bowlegs). By 18 to 24 months of age, the knees begin to straighten. During the second and third years, significant valgus alignment develops in the knees (knock-knees). Development then progresses back to the normal adult alignment of slight valgus by 7 to 8 years of age (Fig. 6).¹¹ Some deformities may have a familial tendency, and specific deformities may show a racial predilection, as demonstrated by the high incidence of genu varum in the Japanese population.

Table 1. DIFFERENTIAL DIAGNOSIS FOR PATHOLOGIC GENU VARUM OR VALGUM

Metabolic	Post-traumatic
Rickets	Physeal bar
Renal disease	Angular overgrowth
Inflammatory	Congenital deformity
Infection	Congenital pseudarthrosis—tibia
Rheumatoid arthritis	Congenital posteromedial bow
Tumor	Congenitally short femur
Fibrous dysplasia	Fibular hemimelia
Multiple hereditary osteochondromata	Blount's disease
Enchondroma	Osteogenesis imperfecta
Osteochondrodysplasia	
Chondrometaphyseal dysplasia	
Multiple epiphyseal dysplasia	



Figure 6. Development of the tibiofemoral angle during growth. This graph demonstrates the normal physiologic progression of bowlegs to knock-knees and then to normal during the early years of growth. (*Adapted from Salenius P, Vankka E: BD of the tibiofemoral angle in children. J Bone Joint Surg Am vol. 57, 1975; with permission.*)

Evaluation

The initial objective should be to exclude a pathologic cause for angular deformity (Table 1). A complete medical history, including specific information regarding family history, growth, and development, should be obtained. The nature, age of onset, progression, and prior treatment of the deformity should be elucidated. One also should clearly define the parents' perception of the child's deformity and future concerns regarding gait, cosmesis, and function.

The screening evaluation should include height and weight measurement for percentile calculations and a careful physical examination. When observing gait, consideration should be given to rotational malalignment because it may contribute to the appearance of genu varum or valgum. Medial or lateral thrust at the knee, indicating joint instability or ligamentous laxity, should be noted because these characteristics are not associated with physiologic bowing. Foot position in stance also should be noted.

The static examination should include a rotational profile (see Fig. 4), joint laxity assessment, and evaluation for associated deformities. Deformities such as absent or hypoplastic lateral rays of the foot and skin dimpling may suggest fibular hemimelia. Café-au-lait spots and neurofibromata may indicate neurofibromatosis. Joint swelling and syn-

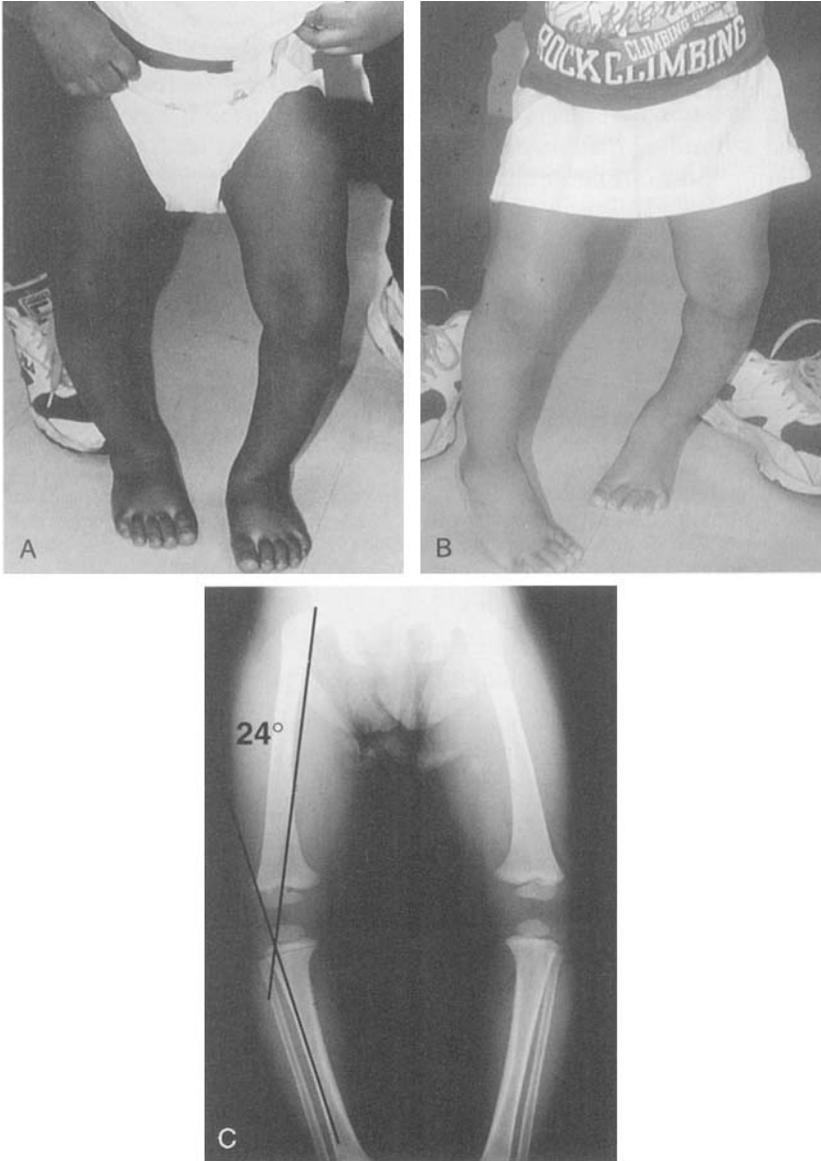


Figure 7. A–C, Physiologic bowlegs. (Mechanical axis, 24°). This 15-month-old child demonstrates the characteristic appearance of physiologic bowing (genu varum) in that both the femur and tibia contribute to the varus alignment. Note the associated medial tibial rotation, which contributes to the varus appearance as the feet are rotated straight ahead (see also Fig. 3C).

ovitis may indicate rheumatoid arthritis. The angular deformity should be measured using a goniometer, as should the intercondylar distance in genu varum and intermalleolar distance in genu valgum.

Imaging Studies

Radiographs are indicated in instances in which a pathologic condition is suspected, as in cases that have one or more of the following: (1) stature below 5th percentile, (2) significant asymmetry, (3) severe deformity, (4) failure to follow a normal developmental sequence, (5) rapid progression of the deformity, (6) family history of pathologic conditions, or (7) associated clinical abnormalities. A single anteroposterior radiograph of the entire lower extremity is adequate. Care should be taken to maintain neutral rotation of the leg with the patellae directly forward. The mechanical axis of the knee should be measured (Fig. 7) and the deformity localized. Does the deformity involve the femur, tibia, or both? Is there a radiographic abnormality of the bony diaphysis, as in osteogenesis imperfecta or trauma; metaphysis, as in bone dysplasia; physeal plate, as in rickets or bone dysplasias; or epiphysis, as in Blount's disease or bone dysplasias (Fig. 8)? Finally, any additional



Figure 8. Blount's disease. Note the acute varus angulation and characteristic and often quite severe growth abnormality at the medial tibial epiphysis and metaphysis. If left untreated, as the deformity progresses, growth of the medial tibial physis will cease and a physeal bar will develop, resulting in acceleration of the deformity and limited treatment options.

special measurements, such as the metaphyseal-diaphyseal (MD) angle should be taken (Fig. 9).⁸

Management

Physiologic bowlegs usually, but not always, resolve, and although education and observational management are the mainstay of treatment, dogmatic predictions should be avoided and follow-up offered. Unproven intervention, such as shoe wedges or corrective shoes, should be avoided, and bracing is only appropriate for certain cases of Blount's disease.

If physiologic genu varum or valgum fails to resolve and persists beyond 7 or 8 years of age, orthopedic referral may then be appropriate. As in rotational malalignment, minor deviations from normal are well tolerated and seldom of functional significance. More significant deformities may be treated with hemiepiphysiodesis (arrest of the growth plate on the apical side of the deformity), realignment osteotomy, or callous distraction (Ilizarov method).

Pathologic conditions should be managed appropriately or referred for appropriate management. Metabolic conditions, such as hypophos-

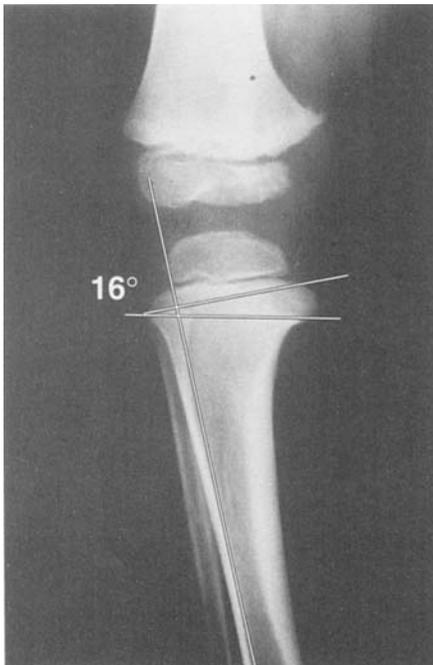


Figure 9. Early Blount's disease. Early Blount's disease is characterized by progressive varus angulation (bowlegs) that fails to follow the normal developmental pattern of resolution during the second and third year. Radiographic examination reveals early medial metaphyseal and epiphyseal changes. Measurement of the metaphyseal-diaphyseal (MD) angle is demonstrated. A line is drawn traversing the proximal tibial metaphysis, and another is drawn perpendicular to the axis of the lateral tibial cortex. Values greater than 11° are consistent with early Blount's disease and signify the need for close observation and, in some cases, treatment.

phatemic rickets, often respond to appropriate medical management and certainly recur or worsen without it. Blount's disease may be treated in the early stages with observation or possibly bracing. In the later stages, osteotomy or realignment by the Ilizarov method is required as a true physal growth abnormality develops (see Fig. 8).^{1, 18} Post-traumatic angular deformities may develop as a result of partial physal closure or physal bar formation. Genu valgum is a specific and peculiar deformity that frequently develops after proximal metaphyseal fractures of the tibia. The deformity develops independently of any appreciable physal abnormality, and the natural history is progression during the first year after injury and subsequent spontaneous resolution in most cases.⁵

Congenital posteromedial bowing of the tibia presents in infancy and initially reflects a severe angular deformity (apex posterior and medial). The natural history is that of spontaneous resolution but with residual shortening of the affected limb an average of 5 cm.¹⁰ Anterolateral bowing of the tibia also presents in infancy and can be severe (Fig. 10). This deformity is associated with congenital pseudarthrosis of the

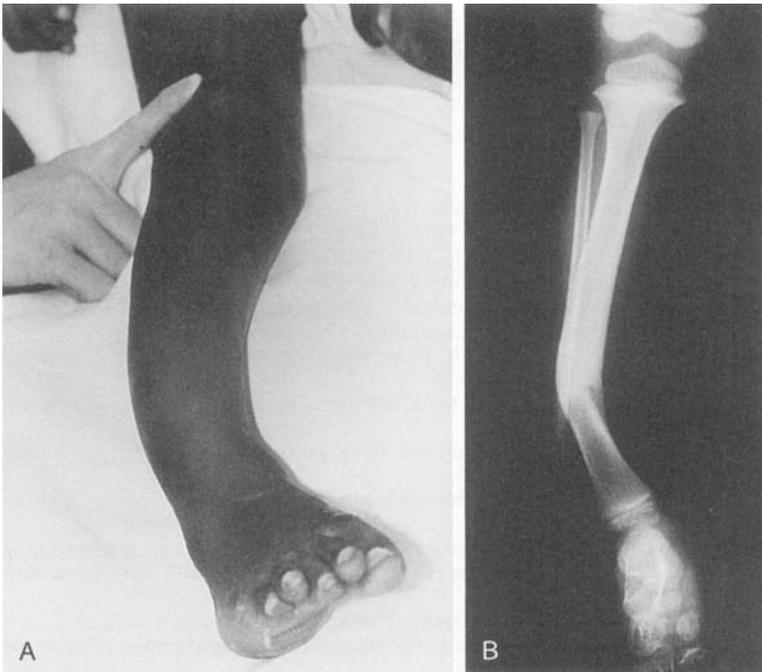


Figure 10. Congenital pseudarthrosis (CPT). The photograph (A) and radiograph (B) show the anterolateral bowing deformity of CPT. Protective orthotic management must be instituted early. Despite management, many children progress to fracture and persistent nonunion (pseudarthrosis).

tibia, 50% of which occurs in children with neurofibromatosis. This deformity must be identified early and protective orthotic management instituted to avoid early fracture, which is often extremely resistant to healing. Despite aggressive protection of legs and treatment of fractures, the natural history is that of refracture or persistent pseudarthrosis (nonunion), not infrequently resulting in amputation.

SUMMARY

A general understanding of the cause and natural history of rotational and angular malalignment of the lower extremity allows accurate differentiation between pathologic and physiologic conditions. One can then educate the involved and often concerned family and proceed with observational management of physiologic conditions as spontaneous improvement of alignment can be expected. Aside from treatment for resistant metatarsus adductus, other forms of treatment, such as special shoes, casts, or braces, are rarely beneficial and have no proven efficacy. Persistent deformity beyond skeletal maturity is unusual and rarely causes significant functional disability. In rare cases of severe residual deformity, operative correction is the only effective treatment.

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