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The evaluation and management of rotational deformity in cerebral palsy

Beyin felcinde rotasyonel deformitenin değerlendirilmesi ve tedavisi

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Rotational deformities are common lower extremity abnormalities in children with cerebral palsy, which include intoeing and outtoeing. Intoeing is caused by one of the three types of deformity: increased femoral anteversion, internal tibial torsion, and metatarsus varus, while outtoeing, the less common form, is caused by femoral retroversion and external tibial torsion. An accurate diagnosis should be made with careful physical and radiographic examination.

Key words: Cerebral palsy; child; femur/surgery; foot; gait/physiology; osteotomy/methods; tibia; torsion abnormality/surgery.

Rotasyonel deformiteler beyin felçli çocuklarda yaygın olarak görülen, içe dönük ve dışa dönük yürümeyi içeren alt ekstremite anormallikleridir. İçe dönük yürüme üç tür deformitenin birinden kaynaklanır: artmış femoral anteversiyon, internal tibial torsiyon ve metatarsus varus; daha nadir görülen dışa dönük yürüme ise femoral retroversiyon ve eksternal tibial torsiyondan kaynaklanır. Dikkatli fizik ve radyografik inceleme ile doğru tanı konmalıdır.

Anahtar sözcükler: Beyin felci; çocuk; femur/cerrahi; ayak; yürüme/fizyoloji; osteotomi/yöntem; tibia; torsiyon anormalliği/cerrahi.

Rotational deformities lead to an ineffective gait pattern since they affect the lever arm of the foot during gait (Fig. 1). Treatment usually starts as conservative. Special shoes, cast, or braces are rarely beneficial and have no proven efficacy. Surgery is reserved if deformity cause gait abnormality. Surgical treatment consists of soft tissue release[1] or osteotomies of the femur and tibia. The choice of treatment in children with fixed bony deformities is frequently osteotomy to improve the gait pattern.[1-3]

Intoeing rotational deformities

Increased femoral anteversion

Femoral anteversion is a normal position of the femur in infants. It begins with 40° to 60° at birth and then slowly resolves with growth until the normal 10° to 20° of anteversion is reached by the age eight years.[4] In children with cerebral palsy (CP), the spasticity and poor motor control do not provide a mechanical environment in which the femur derotates itself. Consequently, the normal resolution of this anteversion does not occur.

Femoral anteversion is described as the angular difference between the axis of the femoral neck and transcondylar axis of the femur or simply torsion of the femur (Fig. 2). This torsion can be located anywhere along the femur in children with CP. Anteversion can also be defined as the anterior projection of the femoral head and neck relative to a plane in the femur in line with the femoral knee joint axis.

There are several methods for measuring femoral anteversion, each having slight advantages and disadvantages. Physical examination, radiographic measurement, computed tomography (CT), ultrasound, fluoroscopy, and magnetic resonance imaging can be used. Measurement of anteversion by physical exami-

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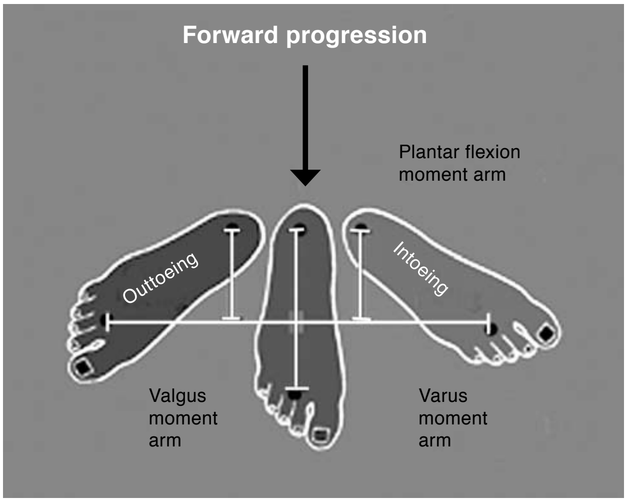


Fig. 1. Drawing shows lever arms of foot with foot progression.

nation is done with the child in the prone position, measuring internal and external rotation of the hip, and making sure there is no rotation of the pelvis. This method, however, has the difficulty to differentiate internal rotation contracture of the muscles from bony femoral anteversion. The degree of internal rotation is measured as the angle subtended by the tibia to the vertical line (Fig. 3). Femoral anteversion can also be assessed with the child lying supine, allowing the legs to drop off the end of the table with the knees flexed. This method is very easy and simple; however, it is limited to patients who are very slender and to those who have not had hip surgery, which would obliterate the palpable landmarks.

Radiographic measurement is mainly of historical interest because it was the first technique used to make a quantitative measurement of femoral anteversion, although it is seldom used today.[4] Diagnosis with this particular correlation requires extra attention, because coxa valga can cover up the anterior projection of the femoral neck. This method should be used only when there is a normal or relatively low degree of coxa valga, primarily being less than 120°.

The accuracy of CT scanning relies on the femoral neck shaft angle which should be normal. The anterior projection of the femoral neck in relation to the knee joint axis, as defined by the posterior condyle is measured (Fig. 4). The angle between these two planes on the image is measured as the anteversion.[5-8] Currently, CT is the most appropriate method to measure anteversion in individuals who have had hip surgery and have femoral neck shaft angles that are relatively normal.

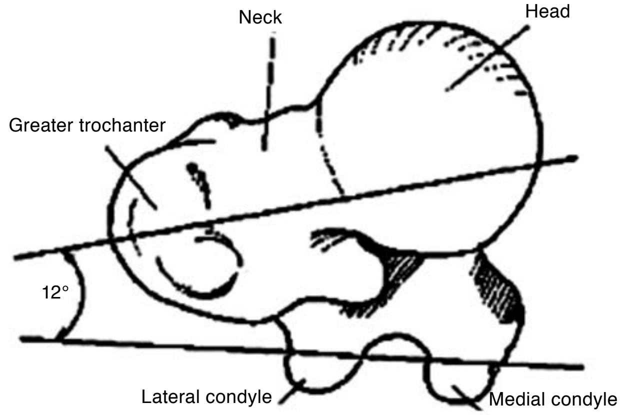


Fig. 2. Femoral anteversion is described as the angular difference between the axis of the femoral neck and transcondylar axis of the femur.

Femoral anteversion can also be measured with the use of ultrasound. This technique requires positioning the limbs so that the tibias are vertical; this defines the posterior femoral condyle. The ultrasound is used and the anterior flat plane of the extracapsular femoral neck is defined. An inclinometer is attached to the ultrasound head and when the flat plane is horizontal on the monitor, the angle can be read.[6,9-11] Ultrasound can be done quickly and cheaply, but it requires a technician who is trained and familiar with this technique as well as some positioning devices for accurate readings. In some children with severe contractures and severe spasticity, it is impossible to position the child accurately. Ultrasound measurement is also not appropriate in children who have had previous femoral osteotomies or surgery of the proximal femur, because irregularities left from the surgery make determining the proper plane by ultrasound impossible.

Fluoroscope may also be used to measure femoral anteversion. The patient's position is the same as the

Fig. 3. Demonstration of the degree of internal rotation measured as the angle subtended by the tibia to the vertical line.

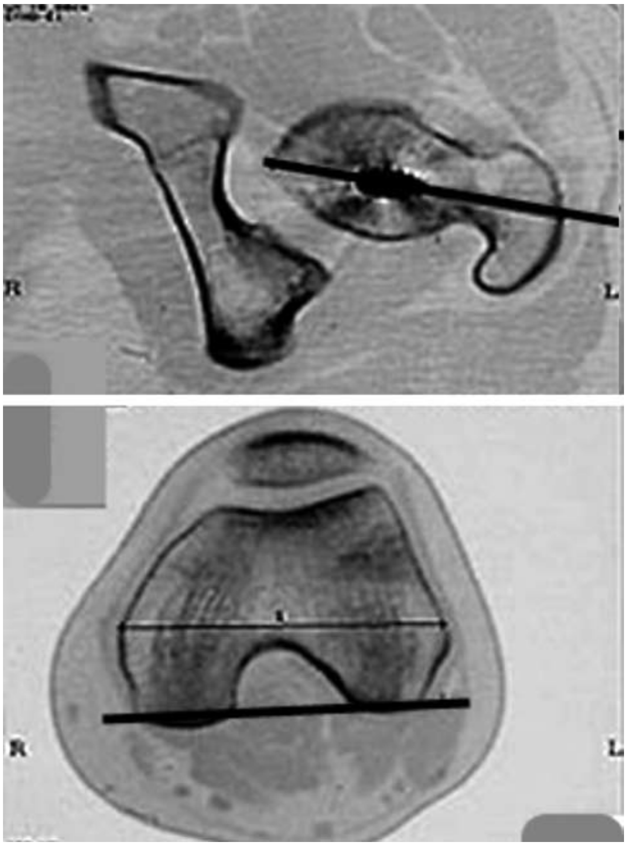


Fig. 4. The anterior projection of the femoral neck in relation to the knee joint axis, as defined by the posterior condyle, is measured on CT sections. The angle between these two planes shows anteversion.

ultrasound position, the feet are dropped off the table so that the knees are flexed and the tibia is completely vertical. In this position, the degree of internal rotation is measured with the knee flexed, demonstrating the degree of femoral anteversion.[8] Fluoroscopy has no extra advantages and, in addition, it requires a technician or radiologist who knows the technique and requires the availability of a fluoroscopy suite, which often has to be scheduled. Fluoroscopy is the ideal mechanism for measuring anteversion in the operating room when hip reconstruction is contemplated. The fluoroscope is available in the standard operating procedure and checking the degree of anteversion and getting an accurate assessment of proximal femoral coxa valga adds no additional time.[4]

Magnetic resonance imaging (MRI) has no major benefits known, but it can be used if a CT scanner is not available or if a child is having an MRI scan for another reason and there is a desire to measure femoral anteversion at the same time.[12]

Treatment of spastic internal rotation, caused by spastic internal rotator muscles or contracted internal rotator muscles, is best done by lengthening of the offending muscles (the hip internal rotators and adductors as well as the medial hamstrings) if radiographic measurements have documented that increased femoral anteversion is not a problem.[4] Soft tissue release surgery is beneficial especially in non-ambulatory children in whom all the anterior abductors are tight and causing internal rotation.[4] The best time for surgery is between the ages 5 to 7 years in ambulatory children, at which time the risk for recurrence of bony anteversion is low.[4] Recently, Rethlefsen et al.[13] advocated that intoeing was almost commonly associated with osseous deformity rather than with simple muscle overactivity; therefore, they did not recommend soft-tissue surgery on the hamstrings, hip adductors, or internal rotators to correct internal rotation gait.

Osteotomies for correcting anteversion can be performed in three regions of the femur: intertrochanteric, subtrochanteric, or supracondylar femur. Intertrochanteric or subtrochanteric derotational osteotomy is preferred if there is hip subluxation requiring varisation of the proximal femur in addition to derotation. According to Cooke et al.[14] supracondylar femoral osteotomy is a simple procedure; easier to perform than subtrochanteric osteotomy; allows the use of a tourniquet; and allows early mobilization. Kay et al.[15] compared proximal and distal femoral osteotomies and suggested that the choice between proximal and distal osteotomies might be left to the discretion of the treating surgeon.

The stabilization of osteotomy may be done by using Kirschner (K) wires, angulated plate, intramedullary nail, or external fixator.[16] Before growth plate closure, angulated plate has been preferred due to some advantages.[17-19] Intramedullary nailing has become the procedure of choice for most long bone fractures in skeletally mature individuals. The advantage of this procedure in this age group is that it provides adequate stability with a less invasive approach, allowing earlier rehabilitation when casting is not required after surgery. Ferri-de-Barros et al.[20] published the results of 20 rotational percutaneous osteotomies with intramedullary nail fixation performed in 15 skeletally mature patients with CP. They concluded that percutaneous osteotomy with intramedullary nail fixation was a safe alternative pro-

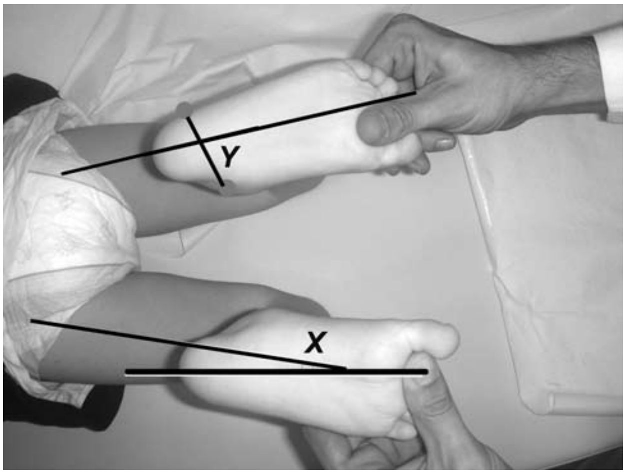


Fig. 5. Clinically, the leg rotational profile is assessed with the child in the prone position and the knee flexed 90°. The thigh-foot alignment (X) gives a measurement of the overall alignment of the leg and foot . The transmalleolar axis (Y) is also used to define the tibial torsion. The relation of the ankle joint axis to the thigh longitudinal axis gives us the degree of the tibial torsion.

cedure to correct rotational deformities of the lower limbs in adolescents.[20] In this technique, a mid-diaphyseal osteotomy is performed and the nail is driven across the osteotomy toward the distal metaphysis and locked proximally and distally. Casting is not required to maintain stability and the goal of femoral deformity correction is to obtain equal external and internal rotation when the hip is extended.

Internal tibial rotation

Internal tibial rotation is a part of embryonic development and it continues thereafter,[21] representing the harmless rotational variation of the lower limb in normal children that resolves spontaneously during growth.[22-26] However, in children with abnormal motor control, this abnormal torsion can progress with age (8 to 10 years of age). These children may be clumsy, but function well. Children with CP do not appear to have a higher incidence of tibial torsion than normal children. However, there is a major difference in children with CP in that tibial torsional deformities do not resolve spontaneously with growth and there is often substantial disability from the tibial torsion requiring surgical correction.[4]

Physical examination and CT can be used to measure the angle. Clinically, the leg rotational profile is assessed with the child in the prone position and the knee flexed 90°. The thigh-foot alignment (X) gives a measurement of the overall alignment of the leg and foot (Fig. 5). In like manner, the transmalleolar axis (Y) is used to define the tibial torsion. The relation of the ankle joint axis to the knee joint axis gives us the degree of the tibial torsion.[27]

Measuring tibial torsion using CT scan can be incorporated in the torsional assessment of the whole limb. Proximal and distal transverse cuts are performed in the tibia on the CT scan. The reference lines are the posterior femoral condyles, posterior border of the tibial plateau, and the centre of the fibula and distal tibia (Fig. 6). These cuts provide measurements

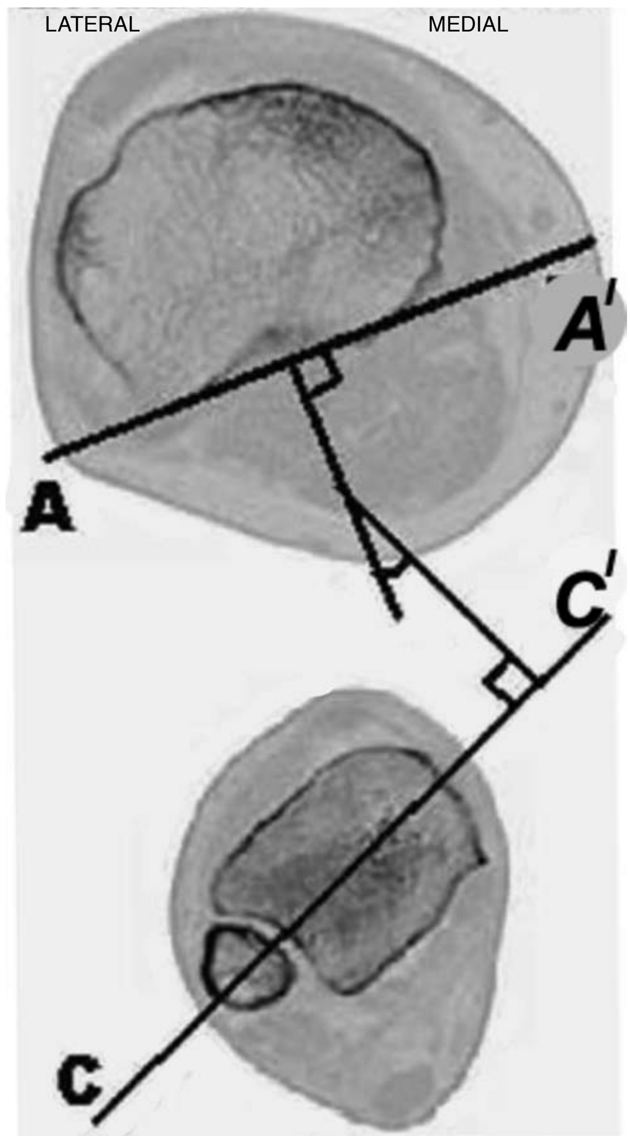
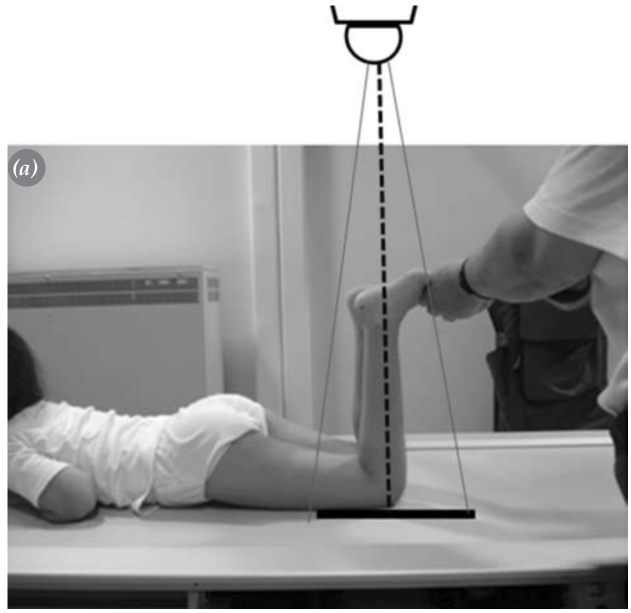


Fig. 6. Proximal and distal transverse cuts are performed in tibia on the CT scan. The reference lines are the posterior border of the tibial plateau, and the center of the fibula, and distal tibia are measured as the tibial torsion.

of knee joint rotation and tibial torsion, in addition to the femoral anteversion.[28]

We have recently developed a radiographic measurement technique. In this technique, radiographs are obtained in two positions. In the first position, the child lies down prone with the knee 90° flexed (Fig. 7a). The foot and ankle are then held in neutral position so that the plantar surface is parallel to the ceiling. The radiograph is taken with the X-ray beam centered to the knee. In the second position, the child sits on a chair, with the knee and ankle held at 90° in relation to the leg (Fig. 7b). The radiograph is taken with the X-ray beam centered to the heel and parallel to the long axis of the tibia (Fig. 7c). We believe measurement of tibial anteversion using this technique is easier and cost-effective.

There are well-established surgical techniques used to correct tibial rotational deformities. These techniques differ depending on the level of the osteotomy,[29-31] the method of fixation using a cast with or without a K-wire,[32] Steinmann pin,[29] staple,[33] plating,[34] intramedullary nail,[35] or external fixation,[16] and whether osteotomy of the fibula is performed.[36,37] All of them are successful and each has different complications and minimal surgical trauma.[38,39] İnan et al.[40] advocated percutaneous supramalleolar osteotomy as the ideal method for correction of rotational



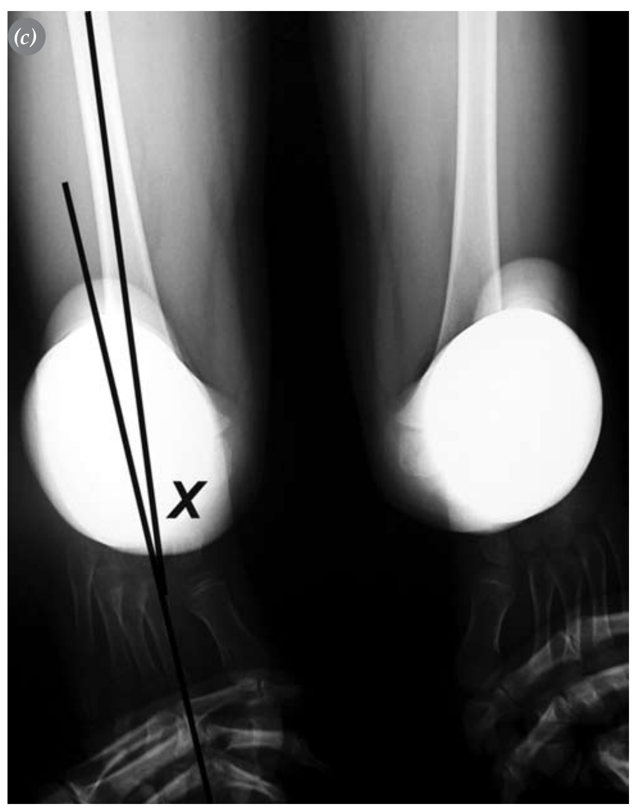


Fig. 7. **(a)** The child lies down prone with the knee 90° flexed. The radiograph is taken with the X-ray beam centered to the knee. **(b)** The child sits on a chair, with the knee and ankle held at 90° in relation to the leg. **(c)** The radiograph is taken with the X-ray beam centered to the heel and parallel to the long axis of the tibia.

deformity of the tibia in CP. They performed a skin incision 0.5 to 1 cm in length on the medial side of the tibia. The osteotomy was then performed by making multiple drill holes, typically six to ten, using a 3.2-mm drill bit, followed by angular bending of the bone in the anteroposterior direction. Rotational bending was not performed in order to prevent the formation of an oblique osteotomy. Derotation was performed by rotating the foot until a thigh-foot angle of 0° was achieved. A short-leg cast was then applied with the proximal tibial K-wire incorporated in the cast to maintain correction. The authors concluded that percutaneous supramalleolar osteotomy with multiple drill holes was a safe and simple surgical procedure.

Metatarsus varus

Metatarsus varus is most common in infants and children under two years of age. It is associated with the intrauterine position, is flexible, and resolves spontaneously in more than 90% of children. If the forefoot is passively correctable and if the hindfoot is normal, radiographs are usually not necessary. Metatarsus is a condition in which medial displacement of the metatarsals on the cuneiform occurs. Forefoot is adducted at the tarsal metatarsal joint. On radiographs, the mid-tarsal axis corresponds to the base of the first metatarsal or is lateral to it. Physical examination is adequate to diagnose.

The prevalence of metatarsus varus (26%) in such children suggests that tendon transfers about the foot and ankle alone may not fully correct the intoeing.[41] Studies have demonstrated a higher prevalence of posterior tibialis dysfunction than anterior tibialis dysfunction in association with varus foot positioning. Besides the flexor hallucis longus, flexor digitorum longus, gastrocnemius, and soleus also can contribute to such a foot posture.[42]

Split or total transfer of the tibialis anterior or posterior tendon may be used to correct dynamic varus deformities. Releases of the abductor hallucis, capsulotomy, and/or metatarsal osteotomy are surgical options for fixed varus deformity.

Outtoeing rotational deformities

Femoral retroversion

In femoral retroversion, the femoral neck axis is oriented posterior to the transcondylar axis, thus positioning the femoral neck and head posterior to the coronal plane of the femur. Femoral anteversion of 10°-20°, along with acetabular anteversion, provides inherent stability to the hip joint.[43] External torsion typically resolves spontaneously, especially after children begin to stand and walk, but orthopedic referral is needed when excessive torsion persists after 8 years of age.[43]

External tibial torsion

External tibial torsion is usually seen to contribute to increased femoral anteversion. It is often bilateral. To justify operative correction, the deformity should be severe enough with a thigh-foot angle of more than 40 degrees.[44] Disability from lateral tibial torsion is usually caused by lever arm dysfunction, patellofemoral instability, and pain. The surgical techniques are the same as those outlined for internal tibial torsion.[40]

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