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Review Article

Tibial Malrotation Following Intramedullary Nailing of Tibial Fractures

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Abstract

Tibial malrotation represents a complication of tibial shaft fractures treated with intramedullary nailing. Tibial malrotation has been described as ≥ 10 degrees and the incidence varies from 0 to 41% in the literature. The effect of tibial malrotation on patient outcome ranges from being asymptomatic and having no complications to issues with cosmesis, gait kinematics, joint contact pressures, and osteoarthritis in adjacent joints. Tibial malrotation can be measured with a physical exam, CT scan, or fluoroscopy. In this review, we discuss the literature with regards to the effect of tibial malrotation on patient outcome as well as review methods to measure tibial rotation.

Keywords: Tibial Malrotation; Tibial Torsion; Tibial Intramedullary Nailing; Tibial Fractures

Abbreviations

LEFS: Lower Extremity Functional Scale; OMS: Olerud-Molander Score; TFA: Thigh Foot Angle; ETRA: External Tibial Rotation Apparatus

Introduction

Malrotation and subsequent malunion are complications of tibial shaft fractures treated with intramedullary nailing. With tibial malrotation defined as ≥ 10 degrees, the incidence of tibial malrotation following intramedullary fixation in the literature originally ranged from 0% to 6% [1-6]. However, more recent studies have reported higher rates between 22 and 41% [5,7-9]. The discrepancy likely lies in that malrotation was likely previously underreported because some degree of malrotation is tolerated and asymptomatic, as well as the fact that advanced imaging techniques to measure malrotation have improved over time [10,11]. Tibial malrotation may result from many factors, which include fracture morphology, patient habitus, available assistive personnel, and surgical error. This article will review the effect of tibial malrotation on patient outcome as well as ways to measure tibial malrotation.

Tibial malrotation on patient outcome

The effect of tibial malrotation on patient outcome varies in the literature. Some studies report that tibial malrotation remains asymptomatic and has little effect on patient outcome. However, other studies report tibial malrotation leading arthrosis of the adjacent knee and ankle joint. In this section, we will first review literature demonstrating the limited effect of tibial malrotation on patient outcome followed by literature revealing reason to believe that tibial malrotation does affect patient outcome.

To assess the effect of tibial malrotation on patient outcome, Theriault et al. studied 70 patients with a tibial shaft fracture that underwent intramedullary nailing with an average follow-up of 58 months. Interestingly, despite high rates of tibial malrotation following intramedullary fixation, there were no significant functional outcome limitations. In their study, they found that 29/70 (41%) of patients had tibial malrotation as defined by ≥ 10 degrees. However, there was no significant difference in the Lower Extremity Functional Scale (LEFS) between patients who had malrotation versus those who did not, as the malrotation patients averaged 70.8 points and the normal rotation patients averaged 72.6 points. Furthermore, the Olerud-Molander Score (OMS) and the 6-minute walk test were also not significantly different between the two groups. Even when Theriault et al. increased the diagnostic threshold of malrotation to be defined as ≥ 15 degrees and ≥ 20 degrees, there was still no statistical difference between the groups for the LEFS, OMS, or the 6-minute walk test. There was also no significant difference when the data was stratified according to sex. Theriault et al. results did not support their hypothesis that tibial malrotation would lead to functional impairment during activities of daily living. The reasons for the good functional outcome among patients with tibial malrotation may be related to intrinsic compensation mechanisms [12]. Van der Shoot et al. assessed 88 patients with tibia shaft fractures in which 20/88 fractures healed with malrotation of ≥ 5 degrees. Of these 20 patients, only 7/20 (35%) developed arthritis in the ipsilateral knee or ankle joint. Of the remaining 68 patients that healed without malrotation, 32/68 (47%) developed arthritis. Their study demonstrated no significant link between malrotation and knee arthritis development [13].

While Theriault et al. and Vandershoot et al. reported minimal consequences of tibial malrotation, other authors have reported how tibial malrotation can cause complications. One complication includes the cosmetic concern, which results from healed tibia with malrotation [14]. The cosmetic appearance of a patient's foot pointing differently as compared to the other foot can lead a patient to present to a healthcare provider. Van der Werken and Marti reported on a patient with 25 degrees of external rotation deformity, who underwent corrective osteotomy due to cosmetic reasons even though she was otherwise asymptomatic [15]. In addition to stationary cosmetic appearance, this malrotation can cause impaired gait. Previous studies have shown that tibial external rotation, especially when > 30 degrees, leads to crouch gait, which disrupts the stability and function of the ankle [16,17]. Authors have also described the foot adopting a pes planus position over time to compensate for the tibial malrotation [18]. Other compensatory mechanisms have been described when there is isolated tibial torsion, which include pelvic rotation, hip abduction and adduction; hip, knee, and ankle transverse rotations, and contralateral limb compensation [19].

Impaired gait mechanics not only causes a cosmetic problem, but also alters the contact pressures in the lower extremity. Svoboda et al. studied the effects of tibial malrotation on the biomechanics of the tibiotalar joint on 23 cadaveric lower extremities using rotational malalignments of 20 degrees internal rotation, 10 degrees internal rotation, neutral rotation, 10 degrees external rotation, and 20 degrees external rotation. They discovered that the internal and external rotational deformities of 20 degrees or more significantly increased the peak pressure in the tibiotalar joint. The authors concluded that tibial malrotation affects the tibiotalar joint biomechanics and tibial malrotation should be minimized if possible [20].

Yazdi., *et al*. also performed a cadaveric study, in which they analyzed the effects of tibial torsion on knee contact pressures. The authors found that the medial compartment contract pressure increased by 17.7% with 15 degrees of internal rotation and by 4.9% with 30 degrees of internal rotation. On the other hand, the medial compartment contact pressure decreased by 10.8% with 15 degrees of external rotation. However, the external rotation of 15 degrees increased the lateral compartment pressure by 22.8% [21]. Regarding the knee joint, Yadzi., *et al*. biomechanical studies are consistent with the numerous observational studies that demonstrated increased rate of medial compartment osteoarthritis in patients lacking external tibial rotation. Yagi et al. reported a correlation between tibial malrotation and the severity of osteoarthritis in which an external rotation of 14.1 degrees correlated with mild arthritis, an external rotation of 11.9 degrees correlated with moderate arthritis, and an external rotation of 7.5 degrees correlated with severe arthritis [22].

Measuring tibial rotation

Measuring tibial rotation both pre- and post-operatively can be accomplished either in the clinic, with a CT scan, or with fluoroscopy. In the clinic, tibial torsion can be measured utilizing the thigh foot angle (TFA). The TFA can be measured with the patient prone with the knee flexed to 90 degrees where angle between the axis of the thigh and foot can then be measured (Figure 1) [14,23]. Tibial torsion can also be measured using the patella with the patient supine. With the patient's knees extended, the leg is rotated until the patellar surface is parallel to the examination table. Then the angle between the axis of the foot and the surface of the examination table is measured [14,23].

Figure 1: The thigh foot angle (TFA), which can be used to measure tibial rotation.

A CT scan represents a more precise method to measure tibial rotation. With a CT scan, the tibial rotation is calculated by measuring the angle between the proximal tibial axis and the distal tibial axis. The proximal tibial axis is determined by a tangent line across the posterior aspect of the tibial plateau. Several techniques have been described to determine the distal tibial axis, which include the Ulm method, the Jend method, and the bimalleolar axis method [24-26]. The Ulm method defines the distal tibial axis as a line which connects the center of two ellipses. The first ellipse is created by the arc of the incisura fibularis, and the second ellipse is created by the arc of the medial malleolus. The Jend method uses the midpoint of a line which is drawn from the anterior to the posterior aspect of the incisura fibularis. A line drawn perpendicular to this line represents the distal tibia axis. Finally, the bimalleolar axis method defines the distal tibial axis as a line that connects the center of the medial and lateral malleoli. These distal tibial axis methods are depicted in figure 2. Of these methods, the bimalleolar axis method has the greatest intraobserver and interobserver reliability [27].

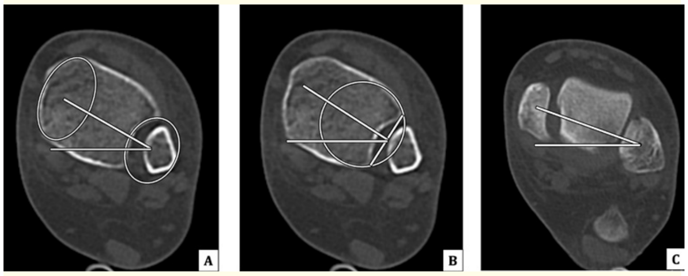

Figure 2: Different methods to measure the distal tibial axis, which include the A) Ulm method, B) Jend method, and C) bimalleolar axis method.

Clementz first reported a fluoroscopic technique for measuring tibial rotation intraoperatively in 1989. Clementz's technique is based on the rotational difference between a lateral view of the knee and a mortise view of the ankle. The technique relies on having a protractor attached to the C-arm so one can measure how many degrees of rotation are needed to obtain the two fluoroscopic images. To begin, the patient lies supine with the knee extended until the posterior contours of the femoral condyles are superimposed to obtain a lateral view. When this superimposition is captured, this marks the first point of degrees on the protractor. Then the C-arm is moved to the ankle and captures a mortise view so that an image of the inner surface of the medial malleolus can be obtained. This marks the second point of degrees on the protractor. The difference in degrees captured by the protractor when the C-arm transitions between these two images represents the rotation. The technique requires a stable knee joint and normal medial malleolar morphology. In 100 normal adults, Clementz performed this technique and discovered the mean torsion was 30.7 degrees. When comparing the tibial rotation to the contralateral tibia rotation in the same patient, Clementz found a mean difference of 2.1 degrees. Thus, in the case of intramedullary nailing for an isolated tibial fracture, one can perform an intraoperative comparison of the uninvolved leg and then use this measurement to restore the anatomic rotation of the injured leg [28].

More recently, Holler and Kandemir described another intraoperative fluoroscopic technique to measure tibial rotation. Like Clementz, they first obtained a perfect lateral image of the knee as defined by having the posterior femoral condyles superimposed on each other. However, in contrast to Clementz, they next moved the C-arm distally to obtain a perfect lateral image of the ankle, which was defined by having the distal fibula superimposed by the posterior aspect of the distal tibia, the talar domes superimposed, and a uniform joint space throughout the tibiotalar joint. Holler and Kandemir claim that obtaining a perfect lateral image of the ankle is easier and more reproducible than Clementz's technique of obtaining a tangential image of the inner surface of the medial malleolus [10].

The cortical step sign represents another intraoperative tool that can help guide obtaining anatomic tibial rotation. The cortical step sign relies on how the cortical width of bone is continuous, and uses this continuity to determine if there is malrotation. For instance, if the cortices between two fracture segments fixed with an intramedullary device have a step-off, then the cortices are likely malrotated as the cortices should be confluent with each other. This sign is particularly useful in transverse fracture patterns, but it is not as applicable in comminuted fractures or fractures with extensive bone loss [11]. Beyond the cortical step sign, Keppler et al. describe the diameter difference sign, which assesses the tibial cortical thickness and diameter in multiple planes to help a surgeon achieve optimal tibial rotation. More specifically, Keppler et al. assessed the medial cortical thickness, lateral cortical thickness, anterior cortical thickness, posterior cortical thickness, tibial diameter, and transverse diameter of the proximal and distal tibial fracture fragments to help guide proper tibial rotation during intramedullary nailing. In their study a tibial malrotation of 15 degrees was most reliably detected by using the anterior cortical thickness and the tibial diameter [29].

Finally, Inci., *et al.* advocate for the use of an external tibial rotation apparatus (ETRA) - the apparatus used during total knee arthroplasty – to control for malrotation during tibial intramedullary nailing. After placing the distal interlocking screws, the alignment is checked using the reference points of the ERTA. If the rotation is not acceptable from a superior view of the ETRA, then internal or external rotation is applied to correct the malrotation. Once acceptable reduction is obtained, the proximal interlocking screws are applied. To assess the efficacy of the ETRA, Inci et al. conducted a randomized control trial on 42 tibial shaft fractures. In 21 cases, the surgeon used an ETRA to control for malrotation, whereas in the other 21 patients the surgeon relied on observation to control for malrotation. The authors found that the ETRA significantly reduced the mean delta rotation, which was 3.8 degrees in the ETRA group versus 8.1 degrees in the control group. In the 42 patients that were enrolled in the study, 8/41 (19%) had malrotation of > 10 degrees. Of these 8 patients, the ETRA group had 1 patient with malrotation versus the control group, which had 7 patients with malrotation. This difference was deemed significant, and the authors concluded that the ETRA serves as a strategy to reduce malrotation that does not require the radiation exposure of the fluoroscopic strategies previously described [30].

Conclusion

With regards to tibial malrotation, the literature is inconclusive on the long-term effects of this complication of tibial intramedullary nailing. Some studies report no deficit in functional outcome, whereas other studies report complications in cosmetic appearance, gait kinematics, joint contact pressures, and correlations with osteoarthritis. More primary research is needed on the long-term effect of tibia malrotation. There are multiple methods to measure tibial rotation, which include physical exam measurements, CT scan measurements, and intraoperative fluoroscopic measurements. Intraoperative fluoroscopic measurements along with fluoroscopic signs, such as the cortical step off sign and diameter difference sign, should be used during intramedullary nailing of tibial shaft fractures to prevent a complication of malrotation.

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