Arch Orthop Trauma Surg (2014) 134:1381–1386
DOI 10.1007/s00402-014-2052-2

TRAUMA SURGERY

Findings related to rotational malalignment in tibial fractures treated with reamed intramedullary nailing

Ferhat Say · Murat Bülbül

Received: 24 January 2013 / Published online: 7 August 2014

Abstract

Introduction Rotational malalignment following closed intramedullary nailing of tibial fractures does not attract attention but is a complication which may lead to serious results. This study aimed to present findings related to rotational malalignment from rotational alignment measurements made clinically and with computerised tomography (CT) in patients who had undergone locked intramedullary nailing for tibial fracture.

Materials and methods A total of 26 patients (male/female: 23/3) were evaluated after application of reamed locking intramedullary nailing to a diagnosed tibial shaft fracture. The mean age was determined as 37.5 ± 15.6 years. Rotational alignment was measured in both lower extremities clinically as thigh-foot angle (TFA) and radiologically with CT. Rotational malalignment was accepted as a more than 10° difference between the two lower extremities.

Results Malrotation was determined at more than 10° from TFA in two (7 %) of 26 patients and from CT in five (19 %) of 26 patients. In three of them, the malrotation was >15°. Of the patients determined with malrotation with CT, it was determined from clinical measurements in 40 %. The mean rotational difference was determined as greater with CT measurement (4.7° ± 9.5) compared to the TFA (1.1° ± 5.6) ($p < 0.001$). No statistically significant relationship was determined between a rotational difference over 10° and the AO fracture type, fracture location and fibula fixation.

Conclusions A significant number of patients treated with intramedullary nailing for a tibial fracture may result in rotational malalignment. To determine rotational malalignment, a thorough clinical evaluation must be made and different kinds of clinical measurements taken and, when suspicions remain, determination should be made by CT.

Keywords Tibia · Intramedullary nail · Malrotation · Computerised tomography

Introduction

Closed tibial shaft fractures are common injuries. As a surgical treatment option, intramedullary nails have the advantages of minimal dissection, excellent fracture healing and functional recovery. Nowadays, reamed intramedullary nailing is the best choice for most tibial shaft fractures surgical treatment.

Axial rotational malalignment of the lower extremity can be defined as impairment of the axial alignment between thigh and foot. Tibial torsion is defined as the turning of the proximal and distal of the leg in the same axis and rotation as turning in a different axis [1]. Rotational malalignment following closed intramedullary nailing of tibial fractures does not attract attention but is a complication which may lead to serious results. Clementz reported [21] greater outward rotation of the right tibia and difference in torsion between the right and left tibia ranged −11° to 15° in normal adults. Because of the variable value of tibial torsion in normal adults, evaluating rotational alignment could be difficult for a tibial fracture after

F. Say (✉)
Department of Orthopaedics and Traumatology, Faculty of Medicine, Ondokuz Mayıs University, Kurupelit, Samsun 55139, Turkey
e-mail: ferhatsay@gmail.com

M. Bülbül
Department of Orthopaedics and Traumatology, Faculty of Medicine, Medipol University, Istanbul, Turkey

treated with intramedullary nailing. There is limited information on the real incidence of rotational malalignment following tibial fractures, where torsional degree is important or indications for correction [2].

Rotational malalignment of the lower extremity causes changes in the knee and ankle joint biomechanics; thus in the early stages, arthrosis may be seen associated with changes in joint cartilage and weight-bearing on the joint [3–7]. Rotational malalignment is also a cosmetic problem. Both clinical and radiological methods can be used to determine tibial rotation. Defined clinical methods of measuring tibial rotation are the thigh-foot angle (TFA) and thigh-transmalleolar angle. TFA is easier to measure than thigh-transmalleolar angle and is the most practical way to understand the rotational deformity [8]. As a radiological method, computerised tomography (CT) is a more reliable and reproducible method to determine rotational malalignment [10–12].

This study aimed to present findings related to rotational malalignment from rotational alignment measurements made clinically of the TFA, and with CT, in patients who had undergone locked intramedullary nailing for tibial fracture.

Methods

Between January 2011 and October 2011, 26 patients (23 male, 3 female) aged mean 37.5 ± 15.6 years were treated at our clinic with reamed intramedullary nailing for tibial shaft fractures. Ethical approval for the study was granted by the local ethics committee. Informed consent for CT scanning was obtained from all patients. The study group comprised patients with tibial fractures who had been treated with reamed intramedullary nailing. The fractures were sixteen right side and ten left side. Patients with a pelvic fracture, femoral fracture or contra lateral tibia fracture were excluded from the study.

According to AO fracture classification, the fractures were fourteen Type A, nine Type B and three Type C. Of the fractures, sixteen were in the mid-third of the tibia, six in the distal third and four in the proximal third. In 22 patients, the fractures were closed, and in four patients open fractures; according to Gustilo-Anderson classification, Type 1 in two patients and Type 2 in two patients. In all 26 tibial fractures, there was also fibula fracture, which was fixated in six cases and not fixated in 20 cases.

All the tibial shaft fractures were treated with the same intramedullary nailing system (TRIGEN META-NAIL tibial nail, Smith&Nephew, USA) and the same operative protocol. We have used supine position for nailing; traction table did not use in any patients. Standard intramedullary nailing approach was used and all fractures reduced closed. We did not use a standard technique to evaluate rotational alignment intraoperatively, and to obtain this only the healthy side was compared. We have used the same postoperative protocol for the patients. All patients were mobilised with partial weight-bearing until clinical and radiological union and then mobilised with full weight-bearing. All patients were operated on within 1-week of the injury. Patient routine follow-up was made with physical examination and standard plain X-rays.

The clinical measurement of TFA was taken by goniometry [8, 9]. With the patient in a prone position, the ankle was put into a neutral position with the knee in 90° flexion. The foot axis and thigh axis of both lower extremities were measured by goniometry (Fig. 1). The difference between the two was determined as the rotational difference.

For all patients, a CT scan of both tibia was taken to determine any rotational malalignment. A standard

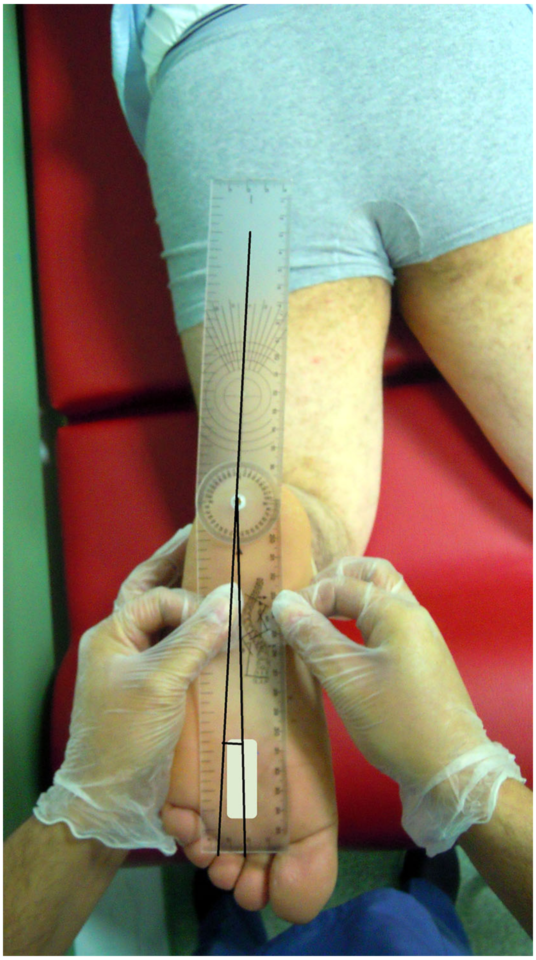

Fig. 1 The clinical measurement of thigh–foot angle. With the patient in a prone position, the ankle was put into a neutral position with the knee in 90° flexion. The foot axis and thigh axis of both lower extremities were measured by goniometry

technique, similar to those previously described in literature, was used [10–14]. The patient was placed in a supine position with both lower limbs in full extension with a support to minimise movement during scanning. The proximal and distal transverse axes were determined by CT scanning. The CT images included axial cuts just above the proximal tibiofibular joint [11] and immediately proximal to the tibiotalar articulation [10] of both limbs.

Rotation measurements were made from the CT slices taken. The proximal measurement was defined as the angle between the tibia posterior cortex immediately above the fibula head and the transverse axis [11]. In the distal, the measurement was taken as the angle between the line passing from the fibula and tibia centre on the slice taken immediately over the tibiotalar joint and the transverse axis [10] (Fig. 2). By comparing with the healthy side, the rotational difference between the two sides was defined. Positive values were evaluated as external malrotation and negative values as internal malrotation. As has been accepted in previous studies on malrotation in literature, more than 10° between the two extremities was accepted as a rotational difference [2, 16, 24, 30].

Data were analysed with SPSS program (Windows version 16.0). Mean values between groups were evaluated with Wilcoxon paired sample test, Fisher's exact test and Chi square test. A value of $p < 0.05$ was accepted as statistically significant.

Results

The clinical TFA measurements of the healthy side determined mean rotation as 10.1° ± 3.5. The rotational difference was between 7° internal rotation and 12° external rotation. The mean rotational difference was determined as 1.1° ± 5.6. Rotation was internal in 12 patients and external in fourteen patients (Table 1). Rotational difference of more than 10° was determined in two (7 %) of 26 patients.

In the CT measurements, the mean rotation of the healthy tibia was determined as 27.9° ± 6.3. The rotational difference was between 19° external rotation and 14° internal rotation. The mean rotational difference was determined as 4.7° ± 9.5. Rotation was internal in eight patients and external in eighteen patients (Table 1). A rotational difference of more than 10° was determined in five (19 %) of 26 patients and of more than 15° in three patients.

The difference between the mean clinical TFA measurement (1.1° ± 5.6) and the mean CT measurement (4.7° ± 9.5) was statistically significant ($p < 0.001$, Wilcoxon paired sample test). No statistically significant relationship was determined between a rotational difference over 10° and the AO fracture type, fracture location and fibula fixation (Table 2). The details of patients determined with rotational difference of more than 10° are given in Table 3.

Discussion

Malalignment in the sagittal, coronal and axial planes may be seen in tibial fractures. Generally, more than 1 cm shortness and more than 5° rotational or angular deformity are accepted as malunion [29]. In most of the studies malrotation was defined to be greater than 10° [2, 16, 24, 30]. Tibial malrotation findings are minimal and usually patients have no clinical sign of tibial malrotation. By the

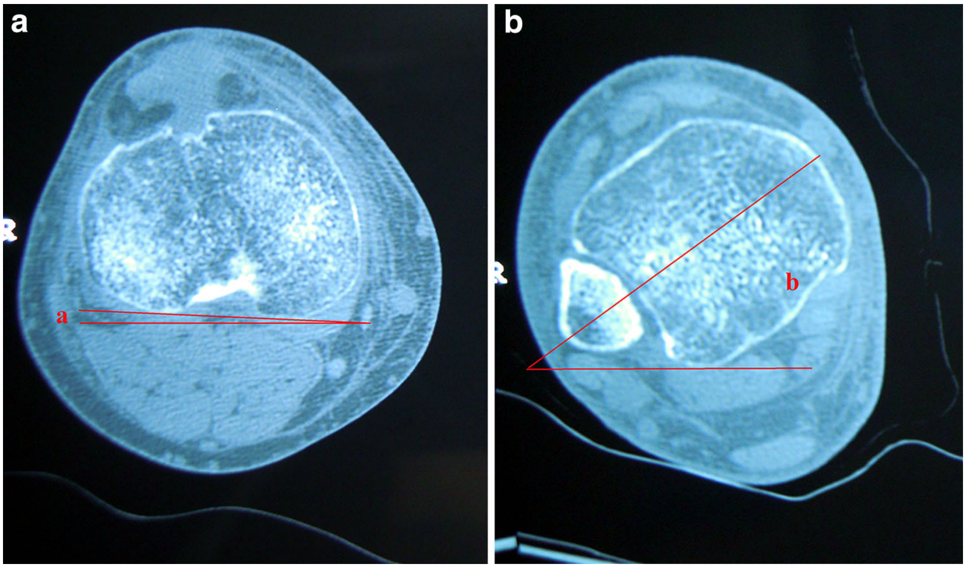

Fig. 2 Measurement of tibial rotation with CT slices. **a** The angle *a* between posterior cortex of tibia and transverse axes on the proximal slice. **b** The angle *b* between the line passing from the fibula and tibia centre and the transverse axis on the distal slice. a:−3.6° b:34° measured. The rotation of leg measured $a + b$: 30.4° and by comparing with the healthy side, the rotational difference was defined

Table 1 The rotational differences of patients measured by thigh–foot angle (TFA) and computerised tomography (CT)

Malrotation	0–10° TFA/CT	10–20° TFA/CT	Total TFA/CT
Internal rotation	12/6	0/2	12/8
External rotation	12/15	2/3	14/18
Total	24/21	2/5	26

Table 2 Relationship between rotational difference and the AO fracture type, fracture location and fibula fixation

	Rotational difference TFA			Rotational difference CT		
	<10°	>10°	*p* value	<10°	>10°	*p* value
AO fracture type			1*			1*
Simple	13	1		11	3	
Complex	11	1		10	2	
Fracture location			0.588**			0.079**
Proximal	4	0		4	0	
Middle	15	1		14	2	
Distal	5	1		3	3	
Fibula			1*			0.298*
Fixated	6	2		15	5	
Not fixated	18	0		6	0	

* Fisher's Exact test

** Chi-square test

Table 3 The details of patients determined with rotational difference of more than 10°

Malrotation TFA degree direction		Malrotation CT degree direction		AO fracture type	Fracture location	Fibular fixation
4	Internal	14	Internal	A2.3	Distal	Not fixated
6	Internal	14	Internal	A3.2	Middle	Not fixated
10	External	19	External	A2.3	Middle	Not fixated
12	External	18	External	B3.2	Distal	Not fixated
5	External	18	External	C3	Distal	Not fixated

patient noticing a difference in the cosmetic appearance of the foot, or asymmetry between legs, tibial malrotation may be determined [2, 16]. Bonnevialle et al. [31] reported no clinical sign of tibial malrotation though the values were 22° external and 31° internal malrotation. The reasons for the good functional outcome may be related to intrinsic compensation mechanisms [30].

The most accurate measurement technique of tibial rotation is anthropometric measurements made on autopsy samples. However, this technique is not possible in clinics [10]. The indirect measurement of tibial rotation can be determined in the clinic by measuring the TFA and the thigh-transmalleolar angle [8]. The transmalleolar angle can be measured using a gravity goniometer [32]. Tibial rotation can also be estimated with the patient supine. The patient is supine with the knees extended the ankles at neutral flexion. The legs are then rotated until the patellar surface is parallel to the floor. Measurement consists of determining the angle subtended by the foot from the table [16]. Milner et al. [18] compared four in vivo clinic methods and reported that none of the indirect techniques appears to measure true tibial torsion. They also stated that as these clinical measurements, depend on the patient's position, they are not sufficient to reveal real tibial rotation.

The measurement of tibial rotation by radiological techniques can be obtained by direct radiographs [19], ultrasonography [20], fluoroscopically [21, 22] and by CT [2, 10–15]. The use of CT in radiological measurements was first described by Jacob et al. [10]. Several studies in literature have used CT for the measurement of tibial torsion [2, 10–15]. Studies have shown no differences in measurement between observers using CT [2, 12]. Negative aspects of the method are the costs involved and radiation exposure. In the current study, the measurement of tibial malrotation was determined clinically with the TFA and radiologically with CT.

Malalignment of the tibia is related to patellofemoral instability [3], pes planus and impaired gait [23]. In the long-term, weight-bearing increases on the knee and ankle joint cartilage and degenerative changes may be seen [1, 3–7]. As the hip and knee joints compensate for the tibial malrotation, this leads to changes in both joints [7]. Puno et al. [26] reported that malunions of tibia tend to affect the foot and ankle more than the knee. Malalignment in the lower extremities may affect functions such as running, playing sport, and climbing stairs and may lead to limping [17]. However, Theriault et al. [30] reported that patients who have ≥10° of tibial malrotation following locked intramedullary nailing for the treatment of a tibial fracture have similar intermediate-term functional outcomes.

In addition to functional impairment and long-term degenerative changes, tibial malalignment may also lead to cosmetic problems [2]. In a study by Jaarsma et al. [17], it was reported that there were more functional problems in patients determined with external malrotation of the lower extremity. Theriault et al. [30] did not found functional and walking test differences between patients with internal or external malrotation. In the current study, posterior tibialis tendon insufficiency was determined in the short-term in two of the patients with 18° external rotation. No symptoms were determined in the early stages in the other three patients in malrotation ≥10° or patients with malrotation

<10°, although it is unknown as yet what will develop in the long-term in these patients.

Court-Brown et al. [25] reported malrotation in three of 125 patients in a study where malrotation was measured clinically in patients who had undergone intramedullary nailing for a tibial fracture. Malrotation was reported in one patient of a series of 51 by Puno et al. [26]. These two studies used unlocked intramedullary nailing. In studies conducted on locked intramedullary nailing, Williams et al. [27] determined malrotation in one of 102 patients and Freedman and Johnson [28] determined no malrotation in 133 patients. In the current study, a rotational difference of more than 10° was determined in two (7 %) of 26 patients with the clinical measurement of TFA.

In contrast to the low rates of malrotation determined by clinical measurements, in studies which measured radiologically with CT, Prasad et al. [15] determined malrotation at a rate of 36 % in 22 patients, Puloski et al. [2] at 22 % in 22 patients, Jafarinejad et al. [24] at 30 % in 60 patients, and Theriault et al. [30] at 41 % in 70 patients. In the current study, malrotation was determined in five (19 %) of 26 patients with CT. A rotational difference of more than 10° was determined in two of these five patients with the clinical measurement of TFA. Thus, in the current study, only 40 % of the patients with malrotation were determined by the clinical method. In a study of 22 patients by Prasad et al. [15] using CT, rotational difference of more than 8° was determined in eight patients of which two (25 %) were determined by clinical measurements. Theriault et al. [30] reported that sensitivity of the clinical method (TFA) as compared with the CT scanning was (16 of 29 patients) 55 % and its specificity was 73 %.

The mean value of TFA measurement has been reported as 10° (−5°/30°) [8]. In the current study, the mean TFA of the healthy extremity was determined as 10.1° (3°/16°) and the mean torsion of the healthy tibia determined with CT was 27.9° (18°/42°). These values were close to those in previous studies in literature [13, 14].

In a study by Puloski et al. [2] of high-energy displaced and distal tibia fractures, a tendency to malreduction was reported. In the current study, five of the patients determined with malrotation were classified as AO A3-B3-C3 type complex fractures. In three of the five patients, the fracture localisation was distal. Even though no statistically significant relationship was determined from the results of the current study between fracture type and localisation, greater care is recommended in lower extremity alignment during surgery while applying intramedullary nailing to these types of fractures. To achieve this, differences in physiological torsion [8–12] should be obtained by comparison with the healthy side rather than alignment of the patella with the second toe [15]. Preoperative planning is recommended for the comparison of the healthy extremity [16]. Intraoperatively rotation measurement can be evaluated by fluoroscopy with the method described by Clementz et al. [21, 22]. To obtain this method, first the examined leg was rotated in such a way that the posterior contours of the femoral condyles were observed to coincide in horizontal plane. The leg was allowed to rest in this basic position. After the fluoroscope was moved to the level of ankle joint, the new line of reference equal to the tangent of the inner surface of the medial malleolus was found. The tibial torsion value was read on the protractor on the C-arm. By comparing with the healthy side, the rotational difference could be defined.

Limitations of the current study may be that the measurements were made by a single observer, the number of patients was low, there was no evaluation of the relationship between rotational malalignment and limping, impaired gait or functional outcomes and there was no long-term follow-up of the patients.

In conclusion, a significant number of patients treated with intramedullary nailing for tibial fracture result in rotational malalignment. To determine rotational malalignment, a thorough clinical evaluation must be made and different kinds of clinical measurements taken and, when suspicions remain, determination should be made by computerised tomography. It should be always kept in mind that it is much easier to reoperate and correct the malalignment early than to carry out a late osteotomy.

Conflict of interest None.

References

1. Rosen H, Sandick H (1955) The measurement of tibiofibular torsion. J Bone Joint Surg Am 37-A(4):847–855
2. Puloski S, Romano C, Buckley R, Powell J (2004) Rotational malalignment of the tibia following reamed intramedullary nail fixation. J Orthop Trauma 18(7):397–402
3. Turner MS, Smillie IS (1981) The effect of tibial torsion of the pathology of the knee. J Bone Joint Surg Br 63-B(3):396–398
4. Turner MS (1994) The association between tibial torsion and knee joint pathology. Clin Orthop Relat Res 302:47–51
5. van der Schoot DK, Den Outer AJ, Bode PJ, Obermann WR, van Vugt AB (1996) Degenerative changes at the knee and ankle related to malunion of tibial fractures. 15-year follow-up of 88 patients. J Bone Joint Surg Br 78(5):722–725
6. Svoboda SJ, McHale K, Belkoff SM, Cohen KS, Klemme WR (2002) The effects of tibial malrotation on the biomechanics of the tibiotalar joint. Foot Ankle Int 23(2):102–106
7. Kenawey M, Liodakis E, Krettek C, Ostermeier S, Horn T, Hankemeier S (2011) Effect of the lower limb rotational alignment on tibiofemoral contact pressure. Knee Surg Sports Traumatol Arthrosc 19(11):1851–1859
8. Staheli LT, Corbett M, Wyss C, King H (1985) Lower-extremity rotational problems in children. Normal values to guide management. J Bone Joint Surg Am 67(1):39–47
9. Stuberg W, Temme J, Kaplan P, Clarke A, Fuchs R (1991) Measurement of tibial torsion and thigh-foot angle using

goniometry and computed tomography. Clin Orthop Relat Res 272:208–212

10. Jakob RP, Haertel M, Stussi E (1980) Tibial torsion calculated by computerised tomography and compared to other methods of measurement. J Bone Joint Surg Br 62B:238–242
11. Jend H, Heller M, Dallek M, Schoettle H (1981) Measurement of tibial torsion by computer tomography. Acta Radiol 22:271–275
12. Laasonen EM, Jokio P, Lindholm TS (1984) Tibial torsion measured by computed tomography. Acta Radiol 25:325–329
13. Reikerås O, Høiseth A (1989) Torsion of the leg determined by computed tomography. Acta Orthop Scand 60(3):330–333
14. Sayli U, Bölükbasi S, Atik OS, Gündogdu S (1994) Determination of tibial torsion by computed tomography. J Foot Ankle Surg 33(2):144–147
15. Prasad CV, Khalid M, McCarthy P, O'Sullivan ME (1999) CT assessment of torsion following locked intramedullary nailing of tibial fractures. Injury 30(7):467–470
16. Kahn KM, Beals RK (2002) Malrotation after locked intramedullary tibial nailing: three case reports and review of the literature. J Trauma 53(3):549–552
17. Jaarsma RL, Pakvis DF, Verdonschot N, Biert J, van Kampen A (2004) Rotational malalignment after intramedullary nailing of femoral fractures. J Orthop Trauma 18(7):403–409
18. Milner CE, Soames RW (1998) A comparison of four in vivo methods of measuring tibial torsion. J Anat 193:139–144
19. Güven M, Akman B, Unay K, Ozturan EK, Cakici H, Eren A (2009) A new radiographic measurement method for evaluation of tibial torsion: a pilot study in adults. Clin Orthop Relat Res 467(7):1807–1812
20. Joseph B, Carver RA, Bell MJ, Sharrard WJ, Levick RK, Aithal V, Chacko V, Murthy SV (1987) Measurement of tibial torsion by ultrasound. J Pediatr Orthop 7(3):317–323
21. Clementz BG (1988) Tibial torsion measured in normal adults. Acta Orthop Scand 59(4):441–442
22. Clementz BG, Magnusson A (1989) Fluoroscopic measurement of tibial torsion in adults. A comparison of three methods. Arch Orthop Trauma Surg 108:150–153
23. van der Werken C, Marti RK (1983) Post-traumatic rotational deformity of the lower leg. Injury 15(1):38–40
24. Jafarinejad AE, Bakhshi H, Haghnegahdar M, Ghomeishi N (2012) Malrotation following reamed intramedullary nailing of closed tibial fractures. Indian J Orthop 46(3):312–316
25. Court-Brown CM, Christie J, McQueen MM (1990) Closed intramedullary tibial nailing: its use in closed and open type I fractures. J Bone Joint Surg Br 72:605–611
26. Puno RM, Vaughan JJ, Stetten ML, Johnson JR (1991) Long-term effects of tibial angular malunion on the knee and ankle joints. J Orthop Trauma 5:247–254
27. Williams J, Gibbons M, Trundle H, Murray D, Worlock P (1995) Complications of nailing in closed tibial fractures. J Orthop Trauma 9:476–481
28. Freedman EL, Johnson EE (1995) Radiographic analysis of tibial fracture malalignment following intramedullary nailing. Clin Orthop 315:25–33
29. Court-Brown CM (2006) Fractures of the tibia and fibula. In: Rockwood and Green's fractures in adults, 6th edn. Lippincott Williams & Wilkins, Philadelphia, p 2129
30. Theriault B, Turgeon AF, Pelet S (2012) Functional impact of tibial malrotation following intramedullary nailing of tibial shaft fractures. J Bone Joint Surg Am 94:2033–2039
31. Bonnevialle P, Andrieu S, Bellumore Y, Challé JJ, Rongières M, Mansat M (1998) Torsional abnormalities and length discrepancies after intramedullary nailing for femoral and tibial diaphyseal fracture. Computerized tomography evaluation of 189 fractures. Rev Chir Orthop Reparatrice Appar Mot 84(5):397–410
32. Kim HD, Lee DS, Eom MJ, Hwang JS, Han NM, Jo GY (2011) Relationship between physical examinations and two-dimensional computed tomographic findings in children with intoeing gait. Ann Rehabil Med 35(4):491–498