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ORIGINAL STUDY

Intraoperative rotation control in closed intramedullary nailing in tibia diaphyseal fractures: a prospective, randomised study

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The intraoperative determination of rotation in closed intramedullar nailing of tibial fractures is difficult. In this study, a more reliable method was used and it was a more practical means of checking rotation intra-operatively for tibia diaphysis fractures.

42 patients who presented with a unilateral tibia diaphyseal fracture. were randomly divided into two groups. In Group 1, the Intraoperative Rotation Control Method (IRCM) was used and compared with Group 2 as the control group. The Delta Rotation obtained from the MRI measurements were recorded and the Mean Delta Rotation (MDR) was obtained for each group separately.

Malrotation was determined at a statistically significantly lower rate in Group 1. The MDR was statistically significantly lower in Group 1.

This method does not require exposure to radiation like other radiological methods. Thus, the method used can be considered to be effective in the prevention of malrotation.

Keywords : tibia fracture ; malrotation; magnetic resonance imaging ; intramedulary nailing ; intraoperative.

INTRODUCTION

Fractures of the tibial diaphysis are the most common long bone fracture *(10,19)*. Intramedullar Nailing (IMN) is accepted as the gold standard treatment method due to rapid healing and low complication rates *(18)*. The aim of treatment of tibia shaft fractures is to provide longitudinal and rotational alignment while preserving the bone length and to provide rapid healing with early weight-bearing and movement and a return to daily social life *(7)*.

Malalignment in all axes is a commonly seen complication during closed nailing of tibia fractures *(4)*. The most attention is given to angular alignment during fracture reduction. As rotational malreduction is not easily determined under fluoroscopy, it is often underestimated. Increased rate of malrotation has been reported after tibial IMN *(3,21,23)*. In recent studies, the prevalence of malrotation have been reported 23%-36% in ranges due to development of more advanced techniques while the frequency has been reported at low rates of 0%-6% in past studies *(3,8,16,21,23,29)*.

In addition to cosmetic problems resulting from tibial malrotation, there may also be delayed union

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due to the increased fracture gap or impaired gait as a result of patello-femoral problems *(2)*. Osteoarthritis in the adjacent joint can often be seen in the long-term period *(13,21,23,27)*. The cable technique and cortical comparisons are methods frequently used in the prevention of these complications *(15)*. Due to the difficulties of application and the need for additional fluoroscopy, these methods may be insufficient in the determination of malrotation *(20, 26,27)*.

In this study, it was thought that checking rotation intra-operatively for tibial shaft fractures was a more practical and reliable method also did not require additional flouroscopy. The aim of the study was to present better clinical and radiological results in patients by avoiding the complication of malrotation.

PATIENTS AND METHOD

The study included 42 patients who admitted with a unilateral tibia diaphyseal fracture that were to undergo reamed intramedullary nail fixation over a 8 month of period in 2016. 28 males and 14 females were included into the study with a mean age of 38.7 years (range, 17-70 years). The tibial fracture was right-side in 25 patients and left-side in 17 patients. Open fractures were recorded as Type 1 in 3 and as Type 2 in 2 patients according to the Gustilo-Anderson classification *(9)*. Inclusion criteria for the study were adult patients with an open or closed, isolated, unilateral, tibia diaphyseal fractures, 10cm distal from the knee and 7.5 cm proximal from the ankle joint. Patients were excluded from the study if there was a history of previous fracture in the ipsilateral or contralateral lower extremity with any neurological impairment or congenital deformity. Preoperatively, the tibial rotation angle of the healthy leg in all patients was recorded by clinical observation. Patients conforming with the inclusion and exclusion criteria were included in this randomised, prospective study. Approval for the study was granted by the Local Ethics Committee in accordance with the Declaration of Helsinki 1964.

Surgical technique (intraoperative rotation control method: IRCM):

Preoperatively, the tibial rotations of the healthy extremities were evaluated clinically. IMN was applied to all the tibial fractures on a radiolucent operating table and with the use of fluoroscopy.

Closed reduction was applied to the fractures under fluoroscopy guidance, then the reaming process was applied and the nail was placed in the canal while providing appropriate alignment to the fracture. While applying the tibial nailing, the External Tibial Rotation Apparatus (ETRA) that was in the arthroplasty surgery set was used for intraoperative rotation control in Group 1. For the patients in Group 2, rotation control was made by clinical observation.

The ETRA is generally used in knee artroplasty by placing externally on the ankle to provide appropiate tibial cut and allow checking of the tibial component alignment.

In Group 1 patients, the ETRA was placed on the ankle during IMN in the same way as for knee

Fig. 1. — Lateral view of the extremity while controlling the rotation of the fracture line after the reduction

arthroplasty. The end attached to the cutting block of the ETRA was mounted together with the IMN tapping apparatus (Figure 1,2). In the operation theatre when we achieve the reduction we first apply the distal interlocking screws. The alignment of the tibial fracture was checked with the aid of the reference points of this apparatus on the tibia and foot in a position of knee and foot flexion on the operating table according to superior view of the extremity (Figure 3). By looking at the projection on the foot of the rod in the part of the apparatus placed externally on the ankle, internal or external rotation of the distal part was observed. That is we see the alignment of the fracture line whether there is malrotation or not. If it is acceptable we aplly the proximal locking screws. If it is not acceptable we correct the malrotation. To correct the rotation,

Fig. 2. — Anterior view of the extremity with rotation controlling system after the fracture reduction

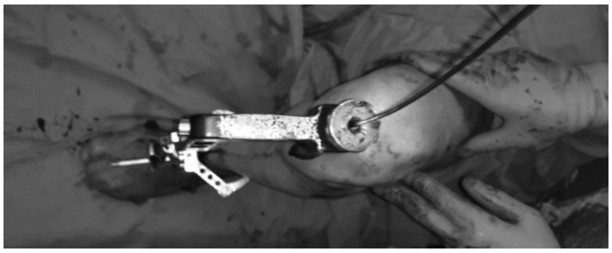

Fig. 3. — Superior view of the extremity to see the alining of second metatars

the fracture fragment was turned in the appropriate direction to the ankle. Following the checking of appropriate alignment and rotation, the proximal screw holes were locked.

For the patients in Group 2, after rotation control according to clinical observation with the knee in flexion and the foot in 90° dorsiflexion, the nail was locked. At the end of the nail inserting overall we also check the rotation after proximal and distal locking screws.

In the radiological evaluation, the MRI method described by Koenig et al was used for the postoperative rotation measurement *(17)*. The proximal reference was the tangential line drawn to the dorsal cortex of the tibia on the MR image taken close to the fibular head. The distal reference line was the line crossing the most distant part of the distal tibial plafond and passing the centre of the fibula in the transverse axis. The rotation angle was the angle between the vertical lines drawn to the 2 reference lines. The difference between this and the degree of rotation of the contralateral healthy limb was recorded for each patient as the Delta Rotation (DR). All the scans were taken by a single radiologist and were examined 2 days later by a second researcher and both of these observers were blinded to the study groups. For each patient, the DR measured according to the contralateral leg was evaluated separately by 2 observers.

The patients were randomly separated into 2 groups. In Group 1, the Intraoperative Rotation Control Method (IRCM) was used and compared with Group 2 as the control group. Evaluation was made of the efficacy of IRCM in respect of the fracture localisation and the AO/OTA fracture pattern (Table 1).

Table 1. — The parameters of group 1 and 2

GROUP 1			GROUP 2		
Delta Rotation	AO classification	Fracture localisation	Delta Rotation	AO classification	Fracture localisation
3.8	A2	m	13	A1	m
5.1	A3	m	6	A2	d
5.3	B2	m	13.7	B1	m
11.1	A1	d	14.9	A1	m
3.6	B2	m	8	A1	d
2.1	A3	d	4.3	B3	m
3.2	B2	d	8.1	A1	m
2.2	B3	d	13.4	B2	m
0.7	A1	d	15.1	B2	d
1.4	A1	d	9.6	A1	d
2.4	A3	d	4.1	A3	d
1.6	A1	d	12.1	B1	m
8.4	A1	d	8.9	A3	m
5	B1	m	3.1	B2	d
5.7	A3	m	3.9	A3	m
3.5	A3	m	6.1	A1	d
2.3	B2	m	13.4	A2	d
7.1	A2	d	7.6	B2	d
6.9	A1	d	6.7	B3	m
4.8	B3	m	5.7	B2	d
6.1	A3	m	8.1	B2	d

(m): middle-third localisation, (d):distal-third localisation

The rotation differences obtained from the MRI measurements were recorded for each patient and the Mean Delta Rotation (MDR) was obtained for each group separately. The MDRs of the groups were analysed according to fracture localisation and the AO fracture pattern using the Mann Whitney U-test.

As the rotation differences did not show conformity to normal (Gaussian) distribution or symmetrical distribution, non-parametric tests were used. A value of $p < 0.05$ was accepted as statistically significant.

RESULTS

The MDR was determined as 3.8° in Group 1 and 8.1° in Group 2 and the difference was statistically significant (p:0.001) (Table I). The MDR was statistically significantly lower in Group 1 ($p < 0.05$). In the group where IRCM was used, rotation closer to the healthy leg rotation was achieved (Table II).

The MDRs were evaluated between the groups according to fracture localisation. No statistically significant difference was determined in the MDR according to the localisation within each group (p:0.05), but a statistically significant difference was determined between the groups according to the localisation. The MDR according to the localisation

Table 2. — Statistically analysis of the mean delta rotation between group 1 and 2

Group	N	Mean±SD	Median (MDR)	Minimum (MDR)	Maximum (MDR)	P
1	21	4.40±2.58	3.80	0.7	11.10	0.001
2	21	8.85±3.89	8.10	3.10	15.10	

SD: Standard Deviation, N: No of patients, MDR: Mean Delta Rotation, Group 1: IRCM group, Group 2: control group.

was determined as 4.9° in middle-third localisation in Group 1 and 10.1° in Group 2 and as 2.4° in distal-third localisation in Group 1 and 8.0° in Group 2. The MDR according to localisation in Group 1 was found to be statistically significantly lower ($p < 0.05$). According to the localisation, rotation closer to the healthy leg rotation was achieved in the group where IRCM was used (Table 3).

MDR values were evaluated between the groups according to the AO/OTA fracture pattern. No statististically significant difference was determined between Type A and B fractures within the groups in respect of MDR ($p > 0.05$). According to the AO Type A fracture pattern, MDR was determined as 4.45° in Group 1 and 8.1° in Group 2 and as 3.6° in AO Type B fracture pattern in Group 1 and 7.85° in Group 2. The MDR was statistically significantly lower in Group 1 than in Group 2 for both AO fracture types (p**:0.009, p***:0.008). According to the AO fracture type, rotation closer to the healthy leg rotation was achieved in the group where IRCM was used (Table 4).

When the rotation difference according to the Johner and Wrush criteria was compared with the contralateral unaffected extremity, malrotation was defined as >10° (23, 14). Malrotation was determined in 1 (5%) patient in Group 1 and in 7 (33%) patients in Group 2 (Table 5).

The MDRs were found to be statistically significantly lower in the group where IRCM was used. The reliability of the method was tested in sub-groups according to the fracture localisation and the AO fracture pattern.

According to both fracture localisation and the AO fracture pattern, rotation closer to that of the healthy leg rotation was achieved in the group where IRCM was used.

DISCUSSION

In the treatment of tibial diaphyseal fractures, closed intramedullar nailing is accepted as the gold standard treatment method *(18)*. When nailing is applied with closed methods in tibial fractures,

Table 3. — Statistical analysis of MDR according to localisation

Group	Fracture localisation	N	Mean±SD	Median (MDR)	Minimum (MDR)	Maximum (MDR)	P**	P***
1	m	10	4.52±1.18	4,90	2,30	6,10	0.013	0.017
	d	11	4.28±3.47	2,40	0,70	11,10		
	P*	0,360						
2	m	10	9.44±4.43	10,10	3,10	14,90		
	d	11	8.31±3.46	8,00	3,90	15,10		
	P*	0,672						

(m): middle-third localisation, (d): distal-third localisation, (p*) : m-d comparison results , (p**) : results of comparisons of 2 groups for m, (p***): results of comparisons of 2 groups for d.

Table 4. — Statistical analysis of MDR according to the AO fracture pattern

Group	AO fracture pattern	N	Mean±SD	Median (MDR)	Minimum (MDR)	Maximum (MDR)	P**	P***
1	A	14	4.71±3.03	4.45	0.70	11.10	0.009	0.008
	B	7	3.77±1.28	3.60	2.20	5.30		
	P*	0.551						
2	A	11	8.73±3.73	8.10	3.90	14.90		
	B	10	8.98±4.27	7.85	3.10	15.10		
	P*	0.944						

(p* : results of the within group comparisons of A and B , p** : results of the comparisons of group 1A with group 2A , p*** : results of the comparisons of group 1B with group 2B, A: AO type A fracture pattern, B: AO type B fracture pattern

Table 4. — Mean Delta Rotational values in the operated limb compared to the normal contralateral limb

	Group 1	Group 2
Excellent (0-5°)	14	5
Good (6-10°)	6	9
Fair (11-20°)	1	7
Poor (>20°)	Nil	Nil

not only does it make a significant contribution to fracture non-union but can also entail problems such as malrotation which are problems for both the surgeon and the patient. When the DR according to the Johner and Wrush criteria was compared with the contralateral unaffected extremity, malrotation was defined as angle s> 10° *(23,14,28)*. Tibial malrotation is an extremity deformity which affects clinical and functional results. Several studies on this subject have shown that it could cause osteoarthritis in adjacent joints in the long term *(23,21,13,27)*. Therefore, one of the most important steps in the treatment of these fractures is the avoidance of tibial malrotation.

The prevalence of malrotation following intramedullar nailing of the tibia has been reported as 0%- 36% *(3,8,16,21,23,29)*. In a series of 21 tibial shaft fractures, Krettek reported clinical malrotation of 15% in non-grooved nailing. In CT evaluation of rotation, Puloski determined malrotation of >10° at the rate of 20% in 25 consecutive tibia diaphyseal fractures treated with IMN *(23)* and Jafarinejad determined the rate at 30% in a series of 60 tibia diaphyseal fractures *(12)*.

The intraoperative determination of rotation in closed IMN of tibial fractures is difficult. The cable method and cortical comparison methods are often used *(15)*. Jafarinejad et al stated that the current methods were not sufficient for the intraoperative evaluation of tibial torsion and emphasised the importance of the development of new methods for correct intraoperative measurement *(12)*. Clements and Magnusson defined the use of fluoroscopy in the intraoperative measurement of tibial rotation. In this method, rotational malalignment is measured by comparing the ankle real mortise to the knee real AP image. Generally in this measurement, the ankle real mortise image is obtained with an additional 10-15° rotation compared to the real AP image of the knee and it is compared to the unaffected side *(5)*. Even though this method has been shown to be reliable and repeatable, this technique has not yet been reported for practical use. In the current study, fixation of the tibial fracture in appropriate rotation was achieved with the intraoperative rotation control method (IRCM). When providing appropriate angular alignment in these fractures, malrotation faults which may be overlooked or not considered important during the operation can be decreased. This is an easily applied method which does not require additional fluoroscopy, thereby reducing fluoroscopy exposure for both the surgeon and the patient. The apparatus used is that which provides tibial component alignment in knee arthroplasty and provides a straight line from the nail proximal to distal intraoperatively. Therefore, it can be considered a more simple, easy to use method compared to other methods.

Prasad reported that fixation of the fibular reduced malrotation in the treatment of tibial fractures with intramedullar nailing *(22)*. However, Jafarinejad et al found no statistically significant difference in malrotation with fibula plating *(12)*. In a study of 26 patients by Say and Bulbul, malrotation of >1 0° was determined in 7% and no statistically significant association was found between rotational difference of > 10° and AO fracture type, fracture localisation and fibular fixation *(24)*. In the current study, in distal tibia-fibula fractures, the distal fibula fractures were plated with the consideration that it would contribute to rotational alignment and provide length.

Clinical evaluation of malrotation is extremely difficult. Using the x-ray method for tibial rotation measurement, Hutter and Scott defined the radiographic method (11). CT scan has recently been accepted as the gold standard method in rotation measurement *(6,13,23,25)*, and it has been reported that CT and MRI measurement results correlate with each other in the evaluation of lower extremity rotation, there is excellent inter-observer reliability and in MRI there is no risk of radiaiton exposure *(1)*. In the current study, to evaluate rotation changes without exposure to radiation, MRI was used.

In the rotation evaluation made with MRI in the current study group of 42 patients, malrotation of > 10° was determined in 8 (19%) patients; 1 (5%) from the group where IRCM was used and 7 (33%) from the control group. Malrotation was determined at a statistically significantly lower rate in Group 1. The DR value was also found to be statistically significantly lower in Group 1 according to both fracture localisation and AO fracture pattern. Thus, the method used can be considered to be effective in the prevention of malrotation.

In conclusion, according to both fracture localisation and the AO fracture pattern, rotation closer to that of the healthy leg rotation was achieved in the group where IRCM was used. With the use of this method, tibial malrotation was reduced by 85.7% compared with the control group.

This method which we have developed for rotation control does not require exposure to radiation like other radiological methods, and can be easily applied in a short time without prolonging operating time. When interpreting the results of this study, some limitations must be taken into consideration. First, the number of patients was low. Second, no patients with proximal fracture localistion and AO type C fracture pattern were included. Finally, there remains a 2% measurement error in CT or MRI evaluations. There is a need for further studies with a greater number of patients for the development of this method.

CONCLUSION

In the future, this method could be a leading method with the creation of a rotation map by monitoring the data obtained from the healthy extremity with more advanced and sensitive techniques, then by performing the same function on the fractured extremity intra-operatively and with the simultaneous use of the data in the fractured extremity, it could reduce to a minimum the rotational misalignment which may have been overlooked. While eliminating malrotation problems provides a greater contribution to patient gait and daily living activities, it also provides safe surgery for both surgeon and patient by minimising fluoroscopy use. Just as this method can be implemented as a routine intraoperative application as the apparatus used is simple and easy to apply, so postoperative MRI examination of rotation analysis will also reduce exposure to radiation.

REFERENCES

1. **Abd R. Muhamad, Joana M** *et al.* CT and MRI lower extremity torsional profile studies: measurement reproducibility. *J Child Orthop* 2012 ; 6 : 391-396.
2. **Aksahin E, Yılmaz S, Karasoy I** *et al.* Sagittal patellar tilt and concomitant quadriceps hypotrophy after tibial nailing. *Knee Surg Sports Traumatol Arthrosc.* 2016 ; 24 : 2878-83.
3. **Boucher M, Leone J, Pierrynowski M, Bhandari M.** Three-dimensional assessment of tibial malunion after

intramedullary nailing: a preliminary study. *J Orthop Trauma.* 2002 ; 16 : 473-83.
4. **Buckley R, Mohanty K, Malish D.** Lower limb malrotation following MIPO technique of distal femoral and proximal tibial fractures. *Injury.* 2011 ; 42 : 194-9.
5. **Clementz BG, Magnusson A.** Fluoroskopic measurement of tibial torsion in adults. A comparison of three methods. *Acta Orthop Trauma Surg.* 1989 ; 108 : 150-3.
6. **Eckhoff D, Jhonson K.** Three-dimensional computed tomography reconstruction of tibial torsion. *Clin Orthop Relat Res.* 1994 ; 42-6.
7. **Fortis A, Dimas A, Lamprakis A.** Expandable nailing system for tibial shaft fractures. *Injury* 2008 ; 39 : 940-6.
8. **Gregory P, Sanders R.** The treatment of closed, unstable tibial shaft fractures with unreamed interlocking nails. *Clin Orthop Relat Res.* 1995 ; 48-55.
9. **Gustilo R, Anderson J.** Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg (Am)* 1976 ;58 : 453-8.
10. **Heckman J, Sarasohn-Khan J.** The economics of treating tibia fractures. The cost of delayed unions. *Bull Hosp Jt Dis.* 1997 ; 56 : 63-72.
11. **Hutter CG, Scott W.** Tibial torsion. *J Bone Joint Surg Am.* 1949 ; 31 : 511-8.
12. **Jafarinejad AE, Bakhshi H, Haghnegahdar M, Ghomeishi N.** Malrotation following reamed IMNof closed tibial fractures. *Indian J Orthop.* 2012 ; 46 : 312-316.
13. **Jend H, Heller M, Dallek M, Schoettle H.** Measurement of tibial torsion by computer tomography. *Acta Radiol Diagn (Stockh)* 1981 ; 22 : 271-6.
14. **Johner, R., and O. Wruhs.** “Classification of tibial shaft fractures and correlation with results after rigid internal fixation.” C*linical orthopaedics and related research 178* 1983 ; 7-25.
15. **Krettek C, Miclau T, Grün O, Schandelmaier P, Tscherne H.** Intraoperative control of axes, rotation and lenght in femoral and tibial fractures. Technical note. *Injury.* 1998 ; 29-39.
16. **Krettek C, Schandelmaier P, Tsherne H.** Nonreamed interlocking nailing of closed tibial fractures with severe soft tissue injury. *Clin Orthop Relat Res.* 1995 ; 34-47.
17. **Koenig J, Pring M, Dwek J.** MR evaluation of femoral neck version and tibial torsion. *Pediatr Radiol* 2012 ; 42 : 113-115.
18. **Littenberg B, Weinstein LP, McCarren M** *et al.* Closed fractures of the tibial shaft. A meta-analysis of three methods of treatment. *J Bone Joint Surg Am.* 1998 ; 80 : 174-83.
19. **Merchant T, Dietz F.** Long-term follow-up after fractures of the tibial and fibular shafts. *J Bone Joint Surg Am.* 1989 ; 71 : 599-606.
20. **Netz P, Olsson E, Ringertz H** *et al.* Functional restitution after lower leg fractures. A long-term follow-up. Arc *Orthop Trauma Surg.* 1991 ; 110 : 238-241.
21. **Prasad C, Khalid M, McCarthy P, O’Sullivan M.** CT assessment of torsion following locked IMNof tibial fractures. *Injury* 1999 ; 30 : 467-70.
22. **Prasad M, Yadav S, Sud A, Arora N** *et al.* Assessment of the role of fibular fixation in distal-third tibia–fibula fractures and its significance in decreasing malrotation and malalignment. *Injury* 2013 ; 44 : 1885-1891.
23. **Puloski S, Romano C, Buckley R, Powell J.** Rotational malalignment of the tibia following reamed intramedullary nail fixation. *J Orthop Trauma.* 2004 ; 18 : 397-402.
24. **Say F, Bulbul M.** Findings related to rotational malalignment in tibial fractures treated with reamed intramedullary nailing. *Arch Orthop Trauma Surg* 2014 ; 134 : 1381-1386.
25. **Sayli U, Bölükbasi S, Atik O S, Gündogdu S.** Determination of tibial torsion by computed tomography. *J Foot Ankle Surg* 1993 ; 33 , 144-147.
26. **Svoboda S, McHale K, Belkoff S** *et al.* The effects of tibial malrotation on the biomechanics of the tibiotalar joint. *Foot Ankle Int.* 2002 ; 23 : 102-106.
27. **Turner M.** The association between tibial torsion and knee joint pathology. *Clin Orthop Rel Res* 1994 ; 302 : 47-51.
28. **van der Werken C, Marti RK.** Post-traumatic rotational deformity of the lower leg. *Injury.* 1983 ; 15 : 38-40.
29. **Wiss D, Stetson W.** Unstable fractures of the tibia treated with a reamed intramedullary interlocking nail. *Clin Orthop Relat Res.* 1995 ; 56-63.