Rotational Profile of Anteromedial Surface of Distal Tibia: A Computerized Tomography Study

Distal Tibia Anteromedial Yüzeyinin Rotasyonel Profili: Bilgisayarlı tomografi çalışması

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ABSTRACT

Background: Closed surgical treatment of long bone fractures by minimally invasive percutaneous plate osteosynthesis (MIPO) is prone to malrotation. In this study we aimed to determine the transverse plane torsional axis differences of medial surface of distal tibia and tibial diaphysis, involved in anatomical plate minimal invasive percutaneous osteosynthesis.

Materials and method: The computerized tomography (CT) images from PACS archive of computerized tomography unit of the institution were reviewed retrospectively. Tibia scans of forty male cases meeting inclusion and exclusion criteria were evaluated. The inclination of the plane of the surface of the tibia was measured. Plane of the surface is defined as axis of the surface of tibia involved in distal medial plating. Sections were measured starting from one centimeter proximal to the tip of medial malleolus and continued proximally in one centimeter intervals for next twenty-five sections. Results were analyzed after grouping the cases according to average stature (as below average and above average).

Results: At the level of 5 cm. proximal to the tip of medial malleolus, approximately 13º of external rotation of medial surface of tibia was noted. After 11-12 cm level, external rotation exceeds 20º. At 16-19 cm, amount of rotation reaches 30º. Change in the axis occurs more proximally in cases above average stature. More proximally amount of external rotation decreases gradually. At 26 cm level, a mean of 23.21º of external rotation was measured. Amount of rotation did not differ according to stature.

Conclusion: Up to 30º of external rotational plane difference was observed notably after 17-20 cm from the tip of the medial malleolus. Inadvertent leaning of proximal extension of a straight/untwisted anatomical distal tibial plate may result with significant external rotational malalignment, especially in comminuted fractures where fixation was extended towards tibial diaphysis.

Key Words: Distal tibia, Fracture, Anatomical plate osteosynthesis, MIPO, malrotation

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ÖZET

Amaç: Uzun kemik kırıklarının minimal invaziv perkütan plak yöntemi (köprü plaklama) ile tespiti, rotasyonel redüksiyon kusuru ile sonuçlanabilmektedir (malrotasyon). Bu çalışmada, distal tibia kırıklarında minimal invaziv köprü plaklama esnasında plak uygulanan kemik yüzeylerden distal tibia ve tibial diyalif yüzeylerinin transvers düzlemdeki torsiyonel farklılıklar belirlenmesi amaçlanmıştır.

Yöntemler: Hastanemiz PACS arşivi bilgisayarlı tomoğraftır görüntü havuzu girile ve tarafların çalışmasına alınma kriterlerine uygun 40 erkek hastanın tibia BT görüntülerine ulaştık. Aksiyel plan görüntülerde plak uygulanan anteromedial yüzeyin eğimi ölçüldü. Ölçümler medial malleolunun 1 cm. proksimalinde başlayarak proksimala birer cm.arakla toplam 26 kesit (1 baseline- 25 kesit) devam edildi. Ölçülen değerler olgunun ortalaması boyunca alınan altında veya üzerinde olma durumlarına göre tekrar gruplanması sonrası analiz edildi.

Bulgular: Medial malleolunun seviyesinde 5 cm. proksimalının itibaren yuzeye distaldeki ilk başlayan naktasına göre yüzeyin eğimini yaklaşık 13º dış rotasyon yönünde farklılık gösterdiği görülür. Bu farklılık 11-12 cm. seviyesinde 20º’yi geçiş olup 16-19 cm seviyelerinde 30º’ye ulaşmış gözlenmiştir. Daha proksimalde ise eğim azaldığı ve en proksimal olcum kesiti olan medial malleolunun 26 cm proksimalinde ise ortalamada 23,21º bir dış rotasyon yönünde düşme farkı gözlenmiştir. Rotasyon miktari boya göre farklılık göstermemiştir.

Sonuç: Distal tibianın anteromedial yüzeyinde, medial malleolunun 17-20 cm proksimalinde en belirgin olmak üzere 30º’ye varan dış rotasyon yönünde yüzey torsiyonundan farklılık gözlenmektedir. Bu farklılık köprü plaklama yaparken dış bir plak kullanım esnasında plakın yerleştirilmesi ve kemikte tespiti esnasında dikkat edilmesi gereken bir faktör olarak karşımıza çıkmaktadır. Özellikle kıkır hattının proksimalde uzandığı veya parçalı kıkırdaklarla dış /yanatomik torsiyonu olmayan bir plak köprü plaklama esnasında yüzeye tamamen yanışanak tespiti, belirgin dış rotasyon düzleminin bulunmaması neden olabileceği tespit edilmiştir.

Anahtar Sözcükler: Distal tibia, kıkır, anatomik plak tespiti, MIPO, malrotasyon

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INTRODUCTION

Minimally invasive percutaneous plate osteosynthesis (MIPO) with locking anatomical plates became the choice of treatment of both extra- and intra-articular distal tibial fractures (1). With indirect reduction techniques utilizing c-arm imaging, combined with bridge plating without exposing the fracture site, successful results were reported (2-4). Despite modern imaging and fixation techniques, malrotation in closed treatment of fractures of tibia is still a concern. Although malrotation is a major problem of intramedullary nailing of tibial shaft fractures with incidences up to 20-30% (5,6), rotational malpositioning during MIPO plating of tibia were also reported (7-10). Due to proximity to ankle and relative stabilizing effect of fibula, malrotation following MIPO of distal tibial fractures is not reported or investigated into account in previous case series published in literature, until the study published by Sitinik et al. Twenty-five percent malrotation exceeding 10° was reported after MIPO of distal tibial fractures (3). Especially in comminuted fractures, it may be challenging to restore rotational alignment of fracture fragments.

Various manufacturers have introduced distal tibia anatomical plates to be used with MIPO principles. To avoid implant prominence and skin problems, perfect fit is desired in distal fixation of the plate under imaging control in sagittal and coronal plane. During fixation of proximal fragment, plate fit is not taken into consideration. When using long plates extending towards tibial diaphysis, significant rotational mismatch may occur with the plane of the plate and anteromedial tibial surface involved during bridge plating. If proximal extension of a straight plate (3.5 mm. Synthes distal tibia LCP plate) is erroneously fit over anteromedial surface of tibia, significant rotational malalignment and displacement may occur (Figure 1).

MATERIALS and METHODS

The images to be evaluated were extracted from PACS archive of CT unit of Bulent Ecevit University, department of radiology. The CT images were taken for routine clinical diagnostic purposes. Indications for CT included; trauma, soft tissue problems and possible neoplastic and infectious processes. Out of 860 extremity scans performed between years 2012 and 2015, 124 patients had tibial CT images scanned from ankle (tip of the malleolus) towards tibial diaphysis. Exclusion criteria were defined as; children and adolescents younger than 18 years of age, displaced fracture, neoplasia and other dysplastic and traumatic conditions (post-operative images etc.) changing the alignment during surgical treatment of distal tibia fractures.

In this study we aimed to define the transverse plane rotational differences of the medial and antero-medial surfaces of tibia, involved in MIPO plating of distal tibial periarticular fractures, from a set of computerized tomography images and emphasize the possible importance in establishment of rotational alignment during surgical treatment of distal tibia fractures.

In previous case series published in literature, until the study published by Sitinik et al. Twenty-five percent malrotation exceeding 10° was reported after MIPO of distal tibial fractures (3). Especially in comminuted fractures, it may be challenging to restore rotational alignment of fracture fragments.
RESULTS

Age and stature details of study population were given in Table 1. Mean age of cases was 34.5±9.78 years. Average stature of cases was calculated as 173.5±4.88 cm. Approximately 8 cm. of difference was observed between mean statures of groups. Starting from baseline and continuing proximally, an external rotation of the plane of medial surface of tibia was noted (Figure 3).

Table 1. Study population details.

| Study population | Age (yrs.) | Stature (cm.) |
|------------------|------------|---------------|
| Overall (n=40)   | 34.5±9.78  | 173.5±4.88    |
| Group 1          | 35.16±8.67 | 170.25±2.02   |
| Group 2          | 33.5±11.83 | 178.5±3.39    |

Inter-observer measurement variation was analyzed using Bland-Altman method. Significant measurement differences were observed at 5º, 11º, 17º, 18º, 20º and 21º levels (p<0.05). Overall measurement variation in those levels ranged between –2.25º and +1.32º, summing a 3.57 degrees of maximal measurement variation. The measurement variation in remaining levels was insignificant.

This rotation was measured as the decrease in the inclination of the plane of that level. Amount of decrease relative to baseline on each level was detailed in Table 2. At the level of 4º cm. proximal to baseline (5 cm. proximal to medial malleolar tip), approximately 13º of external rotation of medial surface of tibia was noted. After 10º cm. level in group 1 and 11º cm. level in group 2, the amount of external rotation exceeded 20º. At 15º cm in group 1 and 18º cm in group 2, amount of external rotation reaches 30º. Maximal amount of rotation was measured at 17º level as 30.75º in group 1 and at 19º level as 30.78º in group 2. There was no difference regarding the maximal amount of external rotation between groups. At following sections proximally, it decreased gradually. At 25º cm level, mean external rotation was recorded as 23.21º. As expected, due to decreased tibial length, the increase in external rotation started more distally in group 1 compared to group 2. In majority of levels (except levels 1, 18, 20, 21, 22 and 23) the differences between group 1 and 2 were significant. The results of combined measurements of groups 1 and 2 were also detailed in table 2. The change in the inclination of each level was demonstrated as a graph in Figure 4.

Table 2. Details of the amount of decrease in the inclination of the plane of tibial surface relative to baseline.

| Levels proximal to baseline in 1 cm intervals | 1º | 2º | 3º | 4º | 5º | 6º | 7º | 8º | 9º | 10º | 11º | 12º | 13º | 14º | 15º | 16º | 17º | 18º | 19º | 20º | 21º |
|-----------------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Group 1                                       |    | 2.39 | 5.60 | 9.87 | 13.54 | 13.69 | 14.17 | 14.43 | 14.87 | 17.81 | 20.75 | 23.75 | 26.73 | 27.83 | 28.98 | 30.06 | 30.71 | 30.75 | 30.52 | 29.06 | 29.31 | 28.60 | 26.52 | 25.52 | 24.08 | 22.72 |
| SD²                                           | 0.36 | 0.41 | 0.42 | 0.53 | 0.62 | 0.69 | 0.66 | 0.66 | 0.62 | 0.83 | 0.75 | 0.82 | 0.84 | 0.77 | 0.65 | 0.53 | 0.53 | 0.62 | 1.00 | 0.85 | 1.70 | 2.04 | 0.95 | 0.73 | 0.59 |
| Group 2                                       |    | 2.41 | 0.31 | 8.97 | 12.16 | 12.05 | 12.09 | 12.47 | 12.43 | 15.09 | 18.09 | 20.97 | 23.78 | 24.51 | 25.05 | 26.69 | 27.94 | 28.47 | 30.06 | 30.78 | 30.30 | 29.28 | 27.09 | 25.97 | 24.87 | 23.94 |
| SD²                                           | 0.52 | 0.44 | 0.34 | 0.44 | 0.52 | 0.52 | 0.50 | 0.60 | 0.85 | 0.90 | 0.74 | 0.75 | 0.57 | 0.67 | 0.57 | 0.67 | 0.57 | 0.89 | 1.08 | 1.05 | 0.89 | 0.73 | 0.62 | 0.44 |
| Combined (group 1 & 2)                        |    | 2.40 | 0.89 | 9.51 | 12.59 | 13.09 | 13.14 | 13.65 | 13.50 | 19.73 | 19.69 | 22.64 | 25.55 | 25.42 | 27.41 | 28.71 | 29.00 | 29.95 | 30.34 | 29.75 | 29.70 | 28.87 | 26.75 | 25.70 | 24.40 | 23.21 |
| SD²                                           | 0.42 | 0.57 | 0.39 | 0.64 | 0.90 | 1.20 | 1.11 | 1.22 | 1.15 | 1.57 | 1.56 | 1.66 | 1.62 | 2.06 | 2.19 | 2.51 | 2.21 | 1.03 | 1.04 | 1.00 | 0.87 | 0.79 | 0.80 |

* SD: Standard deviation.
** p-value was defined to determine the significance between groups 1 and 2.

DISCUSSION

Rotational positioning during MIPO of distal tibial fractures may be challenging if fracture is comminuted and when fibula is not involved in alignment of the limb. Up to 25% rotational malpositioning was observed exceeding 10º(3). In general distal tibial malrotation is not accepted as a major concern. Very few studies are available regarding acceptable malrotation of distal tibia affecting ankle joint functions. In a cadaveric study, Svoboda et al. reported altered ankle biomechanics when rotational malalignment exceeds 20º(13). Conversely, Theriault et al. reported similar intermediate-term lower extremity functional scores in patients with or without malrotation following tibial intramedullary nailing (14). Whereas, van der Werken and Marti recommended correction for deformities exceeding 20º external and 15º internal malrotation, from the results of their case series (15). In this study, we aimed to investigate the torsional axis change of the medial surface of distal tibia and antero-medial surface of tibial diaphysis involved in MIPO plating. We observed a significant torsional change reaching 30º at about 16-19 cm. proximal to the tip of medial malleolus. Inadvertent leaning and fitting of proximal extend of a straight (un-twisted) plate on tibial diaphysis may result with a significant rotational mismatch between proximal and distal fragments, especially in comminuted fractures. Even after eliminating the possible side variations of tibial torsion (2.5º-4º) reported in the literature (16,17) and measurement variations calculated in this study (3.57º), still a remarkable difference exists. Therefore we believe that, rotational axis change of tibial surfaces must be taken into consideration during bridge plating of distal tibial fractures.

Plate-bone congruency in distal tibial anatomical plate osteosynthesis was reported to vary between 43-62% of cases (18). Also, a perfect bone-implant fit is not a demanded factor in percutaneous plating using locked plates, in conjunction with the internal fixator philosophy of modern fracture treatment protocols which involves load transfer through shear force coupled by screw heads (19).
But minimizing the distance between plate and bone surface not only minimizes implant prominence on the skin, also help to improve screw-plate biomechanics. Rotational malpositioning can be avoided by four ways: (1) Preoperative imaging of uninvolved side. (2) Plate may be rotated/twisted externally 20º at approximately 10-11 cm. from the tip of the plate, and twisting may be increased to 25-30 degrees after 15-18º cm. before spanning through fracture fragments. Such a modification not only increase plate-bone conformity, but also may help in reduction of fragments and may facilitate alignment. Although minor bending and torsions rarely damage screw holes, significant and acute bending and twisting of locking plates may interrupt screw head-plate fixation and may result with hardware failure and thus not recommended (20,21). (3) Using pre-contoured / twisted distal medial anatomical plates. (4) Fixation of the proximal fragment without leaning of plate to tibial diaphysis by locking screws, also without twisting the plate, being aware of the rotational profile of the bony surfaces. But in this case, contact mismatch of 20-30 degrees between plate and anteromedial tibial surface of diaphysis may have a negative influence on construct stiffness.

Our study has some limitations. Due to limited number of cases, these findings do not represent the whole population; therefore cannot be generalized and accepted as descriptive. Studies with bigger samples including gender and racial variations should be made. The aim of this study is not to define a specific torsional profile of the anteromedial surface of distal tibia. Specific topographic evaluation of surfaces of tibia involved during internal fixation may be performed using whole tibia CT or 3D scanning instruments on cadaver bones. We aimed to provide an insight about the torsional profile change of tibia for future studies and avoid rotational malposition especially in comminuted fractures, when proximal extension of the plate is extended to tibial diaphysis. Further clinical and radiological follow-up studies investigating importance of distal tibial axial plane alignment are necessary.

CONCLUSION

Transverse plane profiles of medial and anteromedial surface of tibia involved in minimally invasive percutaneous plate osteosynthesis (MIPO) are subject to change. Stature also has influence on the level of change, but has no change on overall change. Awareness of the rotational variation of tibial surfaces involved during locked bridge plate osteosynthesis, may avoid external rotational malpositioning.

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Conflict of interest
No conflict of interest was declared by the authors.

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