Anatomically Precontoured Locked Plates in Pilon Fractures: A Computed Tomography Based and Cadaveric Study

Abstract

Background: The treatment of comminuted tibia plafond fractures remains clinically challenging due to the complexity of the articular fracture pattern despite using the anatomically precontoured locked plates. This study describes the morphologic characteristics of the anterolateral fragment and to evaluate the fixability of the anterolateral fragment with the anatomically precontoured locked plate in the pilon fracture. **Materials and Methods:** One hundred and twenty five cases of AO 43-B and C fracture were evaluated using the computed tomography (CT) scan. The anterior-posterior distance in CT (APDc), medial-lateral distance in CT (MLDc), coronal and sagittal height, and articular surface area of the anterolateral fragment were measured in CT. Four types of anatomically precontoured locked plates were used for cadaveric measurement. Four cadaveric parameters were also evaluated; anteroposterior distance in plate (APDp), height of the screw in the medial plate, medial-lateral distance in plate (MLDp), and height of the screw in the anterolateral plate. **Results:** The anterolateral fragment was described with a mean surface area of 167.13 mm^2 (APDc: 10.89 ± 4.64 mm, MLDc: 15.02 ± 6.56 mm, sagittal height: 14.85 ± 6.25 mm, and coronal height: 17.27 ± 6.88 mm). The cadaveric measurement showed that the juxta-articular screw of the medial distal tibia plate was placed away from the anterolateral fragment. The anterolateral distal tibia plate did not purchase the anterolateral fragment due to the higher position of the most distal-lateral screw (Synthes 18.37 ± 1.86 mm and Zimmer 17.78 ± 2.37 mm of the height of screw in the anterolateral plate). **Conclusion:** Anatomical distal tibial locked plates did not take purchase on the anterolateral fragment in pilon fracture in the best anatomical fit. Preoperative CT measurement can be used for determining a fixation strategy for the anterolateral fragment. In addition, a newly designed anterolateral distal tibia plate can be another solution when the usual anatomically precontoured distal tibia locked plate fails to cover the anterolateral fragment.

Keywords: *Anatomically precontoured locked plate, anterolateral fragment, pilon fracture, CT scan, distal tibial fracture*
MeSH terms: *Tibial fractures, computed tomography scanners, x-ray, cadaver*

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Introduction

The treatment of comminuted tibia plafond fractures remains challenging due to the complexity of the fracture pattern and soft tissue compromise. For optimal preoperative strategies, computed tomography (CT) scan of the intraarticular distal tibial fracture patterns facilitates determination of the appropriate approach, how to fix the articular fragments, and choice of implant. According to CT imaging studies, there are six distinct fragments at the articular surface-anterior, posterior, medial, anterolateral, posterolateral and die-punch fragments.[1] Among these, the anterolateral fragment of the distal tibia frequently comprises the main articular fragment in pilon fractures.[2] A second common region of comminution occurred in the anterolateral quarter of the tibial plafond.[2] Although the outcomes of tibia pilon fractures are influenced by several factors, such as timing of surgery, quality of articular reduction, and type of fracture, the most important factor affecting the functional outcome for patients is the quality of reduction.[3] Although anatomically precontoured locked plates placed on the distal tibial area are commonly used to fix the comminuted articular fragment of Type B and C fractures when using the AO classification system, additional fixation methods or a supplementary surgical approach are needed in cases of small or comminuted articular fragments. Therefore, accurate reduction and a well-designed implant are important for satisfactory outcomes in pilon fractures.

This study describes the morphologic characteristics of the anterolateral fragment

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in pilon fractures and based on this information; we evaluated the fixability of the anterolateral fragment in the distal tibia using anatomically precontoured distal tibial locked plates.

Materials and Methods

202 cases (200 patients) that were diagnosed as distal tibial fractures (AO 43) were extracted from our retrospective trauma database from November 2005 to December 2014. The study was approved by the Institutional Review Board of the National Medical Centre. Fractures were classified according to the AO/OTA classification system. Of these 202 cases, 24 that did not undergo CT scans before surgery or did not include coronal and/or sagittal images, 52 cases with AO 43-A type fracture, and one case with severe comminuted anterolateral fragment on axial image were excluded. The remaining 125 cases of AO 43-B and C-type fracture were enrolled, and the morphology of the anterolateral fragment evaluated. CT scans were used to determine if there was a fracture line on the lateral articular surface and to confirm the presence of the anterolateral fragment.

Radiographic assessments

The picture archiving and communication system (PACS) was used to measure several parameters, and the authors independently reviewed all measurements. Any disagreement on the interpretation of CT scans was resolved by reaching consensus. The anterolateral fragment was defined as an isolated fragment, which had separated from the entire tibial plafond, and had a lateral cortical break point in the distal tibiofibular joint on the axial image. The anterolateral fragment was also defined as extending less than 50% of the width of the plafond.[1]

Axial image assessment

The major transarticular fracture line was identified on the axial image at the level of the articular surface. The axial image that had the largest anterolateral fragment around the

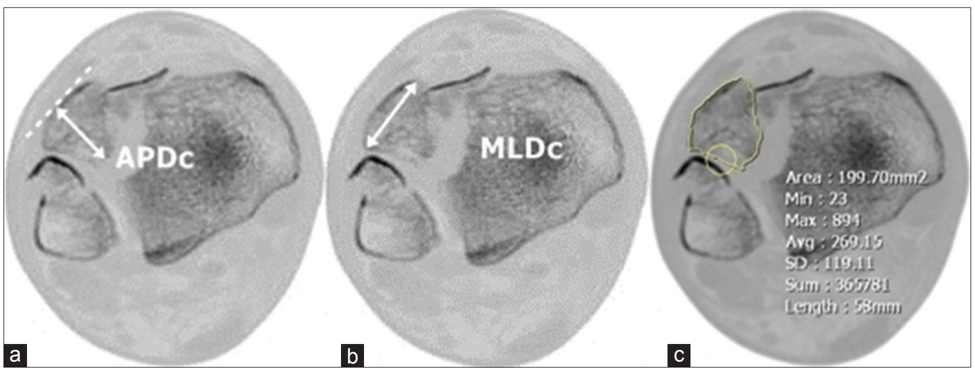

Figure 1: CT scan axial cuts showing (a) The anterior-posterior distance was defined as the longest perpendicular distance from the dotted line which traversed tangentially to the anterior cortex of the anterolateral fragment. (b) The medial-lateral distance was defined as the length between anterolateral corner of the anterolateral fragment and anterior cortical break point. (c) The surface area of the anterolateral fragment was measured at the level of the largest anterolateral fragment

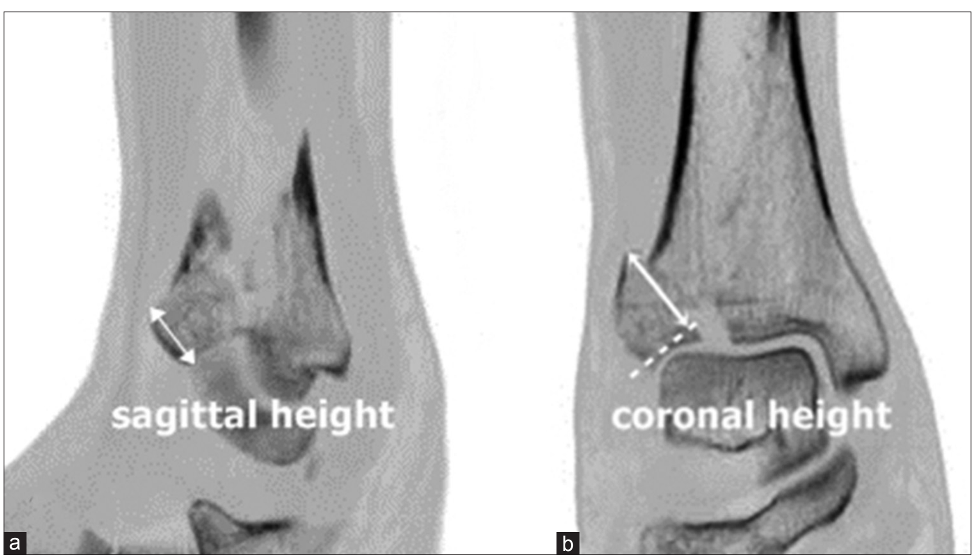

Figure 2: CT scan sagittal and coronal images showing (a) The sagittal height was the greatest distance between the far anterior distal tibial margin and anterior cortical break point. (b) The coronal height was the longest perpendicular distance from the tangential line (dotted line) which traverses the articular surface to the top of the anterolateral fragment

distal tibial articular surface was selected to measure the parameters [Figure 1]. The first line was drawn tangentially to the anterior cortex of the anterolateral fragment. A line perpendicular to the tangential line was drawn up to posterior margin of the anterolateral fragment. The longest perpendicular line was defined as the anterior-posterior distance in CT (APDc). The APDc was used to confirm the fixability of the anterolateral fragment in the medial distal tibia plate. The medial-lateral distance in CT (MLDc) was defined as the length between the anterolateral corner of the anterolateral fragment and the anterior cortical break point [Figure 1]. The MLDc is correlated with the ability to fix the anterolateral fragment using the anterolateral distal tibia plate.

The surface area of the anterolateral fragment was measured using the PACS system at the level of the largest anterolateral fragment. The entire surface area of the tibial plafond was measured by CT scans of eighty normal tibias, which were randomly extracted from our trauma database.

Sagittal and coronal image assessment

The PACS system was used to measure the height of the anterolateral fragment on both sagittal and coronal reconstructive views: Sagittal height and coronal height. The sagittal height was measured as the greatest distance between the far anterior distal tibial margin and the anterior cortical break point. The coronal height was measured as the longest perpendicular distance from the tangential line, which traverses the articular surface to the top of the anterolateral fragment on coronal reconstructed images [Figure 2].

Cadaveric measurements

This study was carried out on 16 tibias from eight cadavers donated from the anatomy laboratory. There were six male and two female cadavers with a mean age of 67.2 years (range 55–78 years). No cadavers had marked bone abnormality or a history of surgery or fracture around the ankle joint. Four types of anatomically precontoured locked plates were used: Two types of medially positioned distal tibia plate ([1] locking compression plate [LCP] medial distal tibia plate [8 holes, 161 mm; Synthes, Oberdorf, Switzerland] and [2] a periarticular distal medial tibial locking plate [10 holes, 168 mm; Zimmer, Warsaw, IN]) and two types of anterolaterally placed distal tibia plate ([3] an LCP anterolateral distal tibia plate [11 holes, 158 mm; Synthes, Oberdorf, Switzerland] and [4] a periarticular distal lateral tibial locking plate [10 holes, 142 mm; Zimmer, Warsaw, IN]) [Figure 3].

All plates were placed on the distal tibia that showed the best anatomical fit. For the medial distal tibia plate, the shortest distance between the most distal-anterior screw and the anterior cortex of the distal tibia (anterior-posterior distance in plate [APDp]) and the shortest distance from the same screw to the articulate surface (height of the screw in the medial plate) were measured. For the anterolateral distal tibial plate, we measured the shortest distance between the most distal-lateral screw and the lateral cortical margin of the distal tibia (medial-lateral distance in plate [MLDp]) and the shortest height from the most distal-lateral screw to the distal tibial anterior articular rim (height of the screw in the anterolateral plate) [Figure 4].

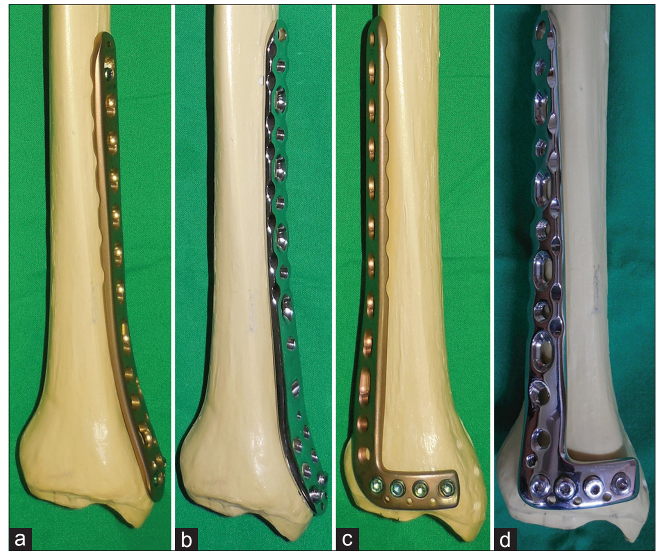

Figure 3: The photograph of the plates used in this study. (a) Locking compression plate medial distal tibia plate; (b) periarticular distal medial tibial locking plate; (c) locking compression plate anterolateral distal tibia plate; (d) periarticular distal lateral tibial locking plate

Statistical analysis

To assess intraobserver and interobserver reliability, statistical analysis was performed with an unweighted kappa statistic.

Results

Computed tomography evaluation

A total of 125 cases included CT scans: 101 male patients and 24 female patients with a mean age of 48.5 years (range 22–79 years). They included 59 cases of B-type (47.2%) and 66 cases of C-type (52.8%) fractures. Seventy four of 125 distal tibia intraarticular fractures (59.2%) had an anterolateral fragment. The anterolateral fragments were identified in 25 cases of B-type (42.4%) and 49 cases of C-type (74.2%) fractures.

The anterolateral fragments had a mean surface area of 167.13 mm^2 (11.99% of total tibial plafond surface area). The mean APDc, which represents the length purchased by the most distal-anterior screw of the medial distal tibia plate, was 10.89 mm (range 3.09–22.90 mm; standard deviation [SD], 4.64 mm). The mean MLDc, which is the available cortical area for the most distal lateral screw of the anterolateral distal tibia plate, was 15.02 mm (range 3.93–25.57 mm; SD, 6.56 mm).

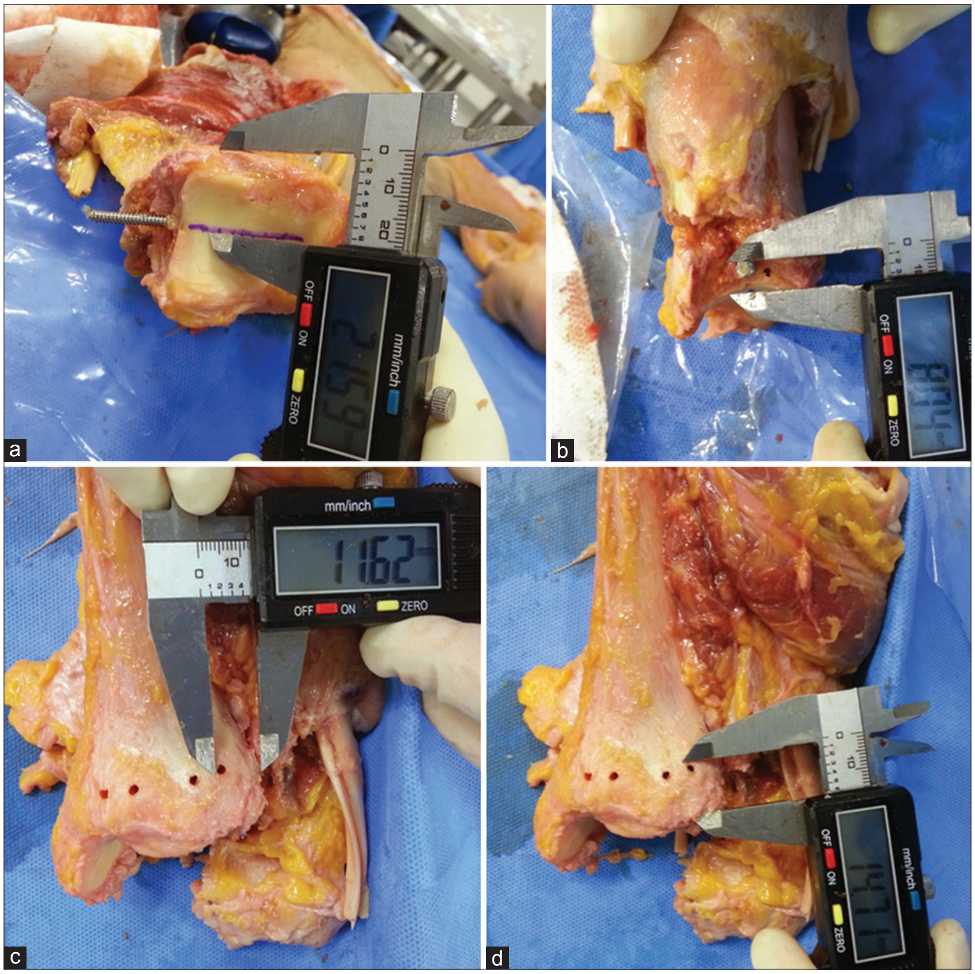

Figure 4: The cadaveric measurement in the medial distal tibia plate. (a) Anterior-posterior distance in plate. (b) The photograph of lateral aspect of the distal tibia. The shortest length from the screw to the articulate surface (height of the screw in the medial plate). For the anterolateral distal tibial plate, (c) medial-lateral distance in plate, (d) the shortest height from the most-distal lateral screw to the distal tibial anterior articular rim (height of the screw in the anterolateral plate)

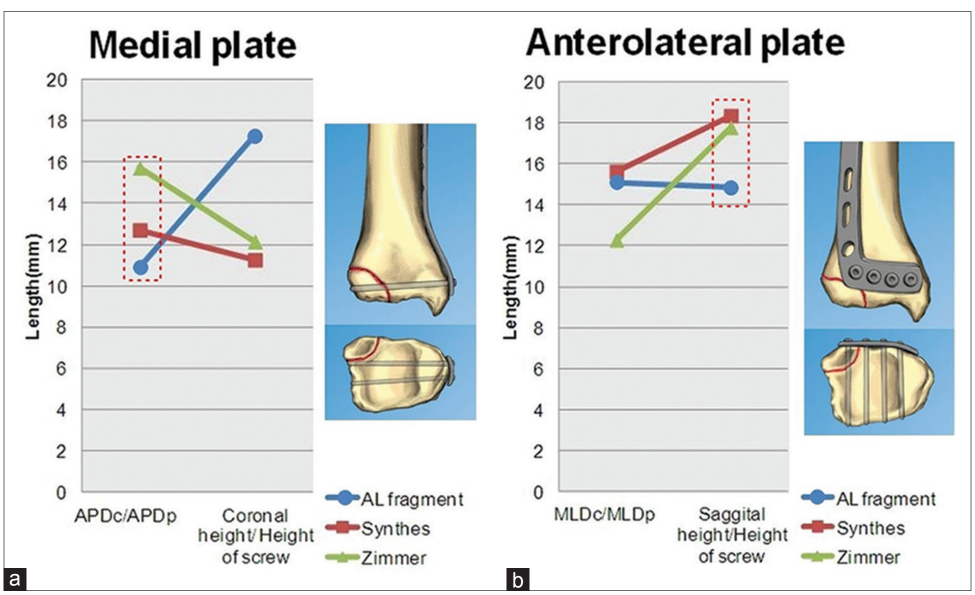

Figure 5: Final results of the fixability of the anterolateral fragment compared between the computed tomography and cadaveric measurement. (a) Medial distal tibia plate. The mean anterior-posterior distance in plates of two manufacturers was greater than the mean anterior-posterior distance in computed tomography, which means the most distal-anterior screw traversed posteriorly from the anterolateral fragment (dotted box). (b) Anterolateral distal tibia plate. Both plates did not purchase the anterolateral fragment because the mean height of the screw in the anterolateral plate was higher than sagittal height of the anterolateral fragment

An analysis of the sagittal reconstructive image showed that the mean sagittal height was 14.85 mm (range 6.29–26.77 mm; SD, 6.25 mm). The mean coronal height was 17.27 mm (range 6.44–45.08 mm; SD, 6.88 mm) in the coronal image study [Table 1].

Cadaveric measurements

In the medial distal tibia plate, the most distal-anterior screw traversed away from the anterior cortex of the distal tibia and was not able to purchase the anterolateral fragment; the mean APDp was 12.71 ± 3.67 mm (range 7.25–21.57 mm) in the LCP medial distal tibia plate and 15.72 ± 4.02 mm (range 6.25–25.21 mm) in the periarticular distal medial tibial locking plate, respectively. The most distal-anterior screw of the medial distal tibia plate was placed relatively close to the joint in the range of the mean coronal height of the anterolateral fragment (17.27 mm in CT measurement); the mean Height of the screw in the medial plate was 11.26 ± 2.55 mm (range 7.53–15.52 mm) in the LCP medial distal tibia plate and 12.14 ± 3.05 mm (range 6.47–18.40 mm) in the periarticular distal medial tibial locking plate [Figure 5a].

In the anterolateral distal tibia plate, the most distal-lateral screw of the LCP anterolateral distal tibia plate was inserted close to the anterolateral fragment but was unable to purchase it (mean MLDp was 15.63 ± 3.35 mm, range 9.92–22.78). In contrast, the mean MLDp of the periarticular distal lateral tibial locking plate (12.28 ± 2.62 mm, range 8.16–16.61 mm) was in the range of the MLD of the anterolateral fragment. In terms of height of the screw in the anterolateral plate, both plates did not purchase the anterolateral fragment because the most distal-lateral screw was inserted cephalad from the anterolateral fragment (Synthes 18.37 ± 1.86 mm, range 16.07–23.61 mm and Zimmer 17.78 ± 2.37, range 13.41–21.24 mm), [Table 2]. Final results of the fixability of the anterolateral fragment compared between the CT and cadaveric measurement are shown with linear calibration graphs and illustrations in [Figure 5b].

Table 1: Morphologic characteristics of the anterolateral fragment in computed tomography measurement

	APDc	MLDc	Coronal height	Sagittal height
Mean (mm)	10.89	15.02	17.27	14.85
Range (mm)	3.09-22.9	3.93-25.57	6.44-45.08	6.29-26.77
SD	4.64	6.56	6.88	6.25

APDc=Anterior-posterior distance in CT, MLDc=Medial-lateral distance in CT, SD=Standard deviation, CT=Computed tomography

Discussion

In this study, the incidence of anterolateral fragment combined with pilon fractures was relatively high (74 of 125 cases, 59.2%), especially in AO 43-C fractures, which occurred at a high rate of 74.24%. In a previous study by Cole *et al.*,[2] the anterolateral quarter of the tibial plafond was identified as the second most common region for comminution in AO 43-C fractures. Using CT evaluation, the present study confirmed that the morphologic characteristics of the anterolateral fragment were not favorable for fixation using anatomically precontoured distal tibial locking plates.

The anterolateral fragment, eponymically named the Tillaux-Chaput fragment, is a small fragment avulsed from the tibia by the anterior syndesmotic ligament and composed of the lateral column of the distal tibia.[4] The anterolateral fragment is often underestimated and overlooked on simple radiographs.[4] However, CT scans can be used to confirm the diagnosis, and clearly define the extent of the fracture, such as associated anterolateral or posterolateral fragment in pilon fractures.[5] Articular fragments in pilon fractures vary and commonly consist of anterior, posterior, medial, anterolateral, posterolateral, and die-punch fragments.[1] Surgical treatment of pilon fractures should aim at anatomical restoration and rigid fixation of the articular surface because the quality of reduction of the articular surface affects not only radiographic but also clinical and functional outcomes.[3,6,7]

In the current study, the average surface area of the anterolateral fragment was 167.13 mm^2 (range 49.94–250.58 mm^2, SD; 121.06 mm^2), which occupied approximately 11.99% of the total articular surface of the tibial plafond (1393.51 ± 201.16 mm^2). Although several authors reported that injury severity and quality of reduction

Table 2: Cadaveric measurement

	APDp	Height of the screw in the medial plate	MLDp	Height of the screw in the anterolateral plate
Synthes				
Mean (mm)	12.71	11.26	15.63	18.37
Range (mm)	7.25-21.57	7.53-15.52	9.92-22.78	16.07-23.61
SD	3.67	2.55	3.35	1.86
Zimmer				
Mean (mm)	15.72	12.14	12.28	17.78
Range (mm)	6.25-25.21	6.47-18.40	8.16-16.61	13.41-21.24
SD	4.02	3.05	2.62	2.37

APDp=Anterior-posterior distance for plate, MLDp=Medial-lateral distance for plate, SD=Standard deviation

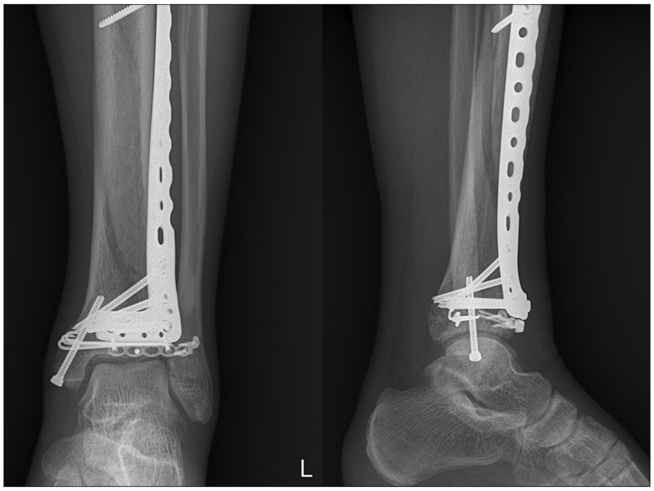

Figure 6: The anteroposterior and lateral radiographs of distal tibia fixed with anterolateral distal tibia locking plate and additional small rim plate for the anterolateral fragment

are less important than patient demographic factors and not correlated with clinical ankle score, the quality of reduction of bony fragment and the re-tensioning of ligamentous stability have a significant correlation with radiographic arthrosis.[6,7] Furthermore, Korkmaz *et al*.[3] emphasized the most important factor affecting the outcome in surgically treated pilon fractures was quality of reduction. Because the mean surface area of the anterolateral fragment in this study comprised almost 12% of the total tibial plafond, the anterolateral fragment is considered to affect the stability of ankle joint and distal tibiofibular syndesmosis. In addition, when considering the ankle stability is affected by the bonyligament complex of distal tibiofibular joint, proper evaluation and repair of the anterior inferior tibiofibular ligament, in particular, is as important as accurate reduction of the anterolateral fragment of distal tibia. Therefore, the analysis of the surface area of the anterolateral fragment in this study suggests that this fragment is not trivial and should not be neglected.

The mean APDc was 10.89 mm in the CT scan, and the average APDp was 12.71 mm in the LCP medial distal tibia plate and 15.72 mm in the periarticular distal medial tibia locking plate. Therefore, the most distal-anterior screw of the medial distal tibia plate is unable to catch the anterolateral fragment because it traverses posteriorly away from the anterolateral fragment. This happened despite the length of the screw in the medial plate being in the range of the coronal height of the anterolateral fragment. Because the pilon fracture with varus collapsed, deformity has a comminution on the medial aspect of the distal articular surface of the tibia, in practice medial buttress plating is necessary via the anteromedial approach. Although the medial distal tibial plate is not designed to catch the anterolateral fragment, the authors conducted this plate in the present study so as to determine whether the anterolateral fragment could be caught using a single medial plate alone when the separate anterolateral fragment is combined with varus-collapsed pilon fracture. The medial distal tibia plate is not able to fixate the anterolateral fragment, as the present study confirmed. Therefore, in cases of varus-collapsed pilon fracture combined with the anterolateral fragment, an additional anterolateral small stab incision for an anterior to posterior interfragmentary screw or two separate medial and lateral approaches is needed for adequate access and additional fixation.[8,9]

For pilon fracture with valgus-collapsed deformity, which has compression or comminution of the lateral part of the distal tibial articular surface, lateral or anterolateral buttress plating through an anterolateral approach is optimal.[10] Although a biomechanical study comparing the stiffness of anterolateral and medial locking plates in a distal tibial fracture model showed no statistically significant difference in compression and torsion testing,[11] the anterolateral approach with buttress plating for valgus-collapsed pilon fracture has been popularized[12] as it provides excellent visualization of the anterior tibia and access to the anterolateral fragment in particular. According to this study, however, the anterolateral distal tibia plate was not able to catch the anterolateral fragment when the plate was placed in the best anatomical fit. The mean MLDp of the periarticular distal lateral tibial locking plate was in the range of the anterolateral fragment. In contrast, the mean Height of the screw in the anterolateral plate of both anterolateral distal tibia plates was greater than the mean sagittal height measured by CT. A surgeon may try to move down the anterolateral distal locking tibia plate closer to the distal anterior articular margin so as to stabilize small distal articular fragments, such as a low-positioned anterolateral fragment. In general, the 43-B type partial articular fracture, especially in the pure split articular fracture, is not concerning whether or not the anterolateral fragment is captured. Because the trajectory of juxta-articular screw can be controlled not to penetrate the ankle joint when a nonlocking screw is used in 43-B type fracture which needs the buttress plating. However, the juxta-articular locking screws are prone to penetrate the distal tibial articular surface when being used in 43-C type fracture because the locking screw of the anterolateral distal tibia plate has a fixed angle. Therefore, if the sagittal height is shorter than 14.85 mm or the MLDc is <15.02 mm preoperatively and fixation of a locking head screw cannot be achieved through the anterolateral distal locking tibia plate, the following surgical strategy should be considered: additional fixation for the anterolateral fragment, such as separate screws from the anterior to posterior direction to the anterolateral fragment or direct small periarticular rim plating. With this modification, we have tried to add separate fixation, such as additional screws or periarticular rim plating, directly to the anterolateral fragment when the anterolateral distal locking tibia plate failed to cover the anterolateral fragment [Figure 6]. Another solution is a newly designed plate, which can be placed as close to the distal articular margin as possible, and furthermore has a variable angle holes which enable the screw to catch the small articular fragment.

The current study has several limitations. First, only two manufacturers' plates were used to conduct the cadaveric measurements. Additional tests of other manufacturers' plates might yield more information about the fixability of individual plates for the anterolateral fragment. Secondly, the number of cadaveric models was relatively small. Increasing the sample size may better represent the exact position of the screw of the medial and anterolateral distal tibia plate for the anterolateral fragment is in the general population. Thirdly, the parameters for the small fragments in CT evaluation may have poor precision, especially if there was comminution and/or multiplanar rotation of the anterolateral fragment. Moreover, there is a possibility of a mismatch of the numerical values between cadaveric and CT measurements because the CT parameters may not represent actual numerical values of the anterolateral fragment.

Conclusion

Anatomically precontoured distal tibial locked plates did not purchase the anterolateral fragment when they were placed in the best anatomical fit. In addition, a newly designed anterolateral distal tibia plate, which can catch the small articular fragment, can be another solution when the usual anatomically precontoured distal tibia locked plate fails to cover the anterolateral fragment.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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