Kirschner Wire as a Reference Marker for the Positioning of a Syndesmotic Screw: A Radiological Study

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Research article

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Abstract

Background: Without a reliable and static reference, the rate of eccentrically positioned distal syndesmotic screw trajectories is very high. Meanwhile, a malpositioned screw may result in poor outcomes and early osteoarthritis. As such, this article describes an additional method to improve surgeons' ability to ideally place a screw trajectory. The purposes of our study were (1) to determine if an ideal space at 2.5 cm proximal to the plafond existed between the tibia and fibula for the placement of a Kirschner (K) wire and (2) to detect if it could act as a reliable and static fibular incisura plane reference.

Methods: Computed tomography scans of 42 uninjured adult ankles with foot fractures were analysed to measure the tibiofibular vertical distance (TFVD) at 2.5 cm proximal to the tibial plafond on cross-sectional images. The TFVD was defined as the distance between two lines: Line 1 was tangent to the fibular incisura, and Line 2 was parallel to Line 1 along the medial border of the fibula. Patients were divided into 4 groups according to our TFVD data: 0–1, 1–2, 2–3, and 3–4 mm, and the number of patients in each group was counted.

Results: The TFVD measured 2.23±1.01 mm (mean ± standard deviation) at 2.5 cm proximal to the plafond. According to our grouping, TFVD occurred at 25% of the distance from 2 to 3 mm in 47.6% of patients.

Conclusions: Placing a 1.6-mm K-wire in the syndesmosis at 2.5 cm proximal to the tibial plafond is easy because of emerging TFVDs. The K-wire's path is restricted to the anterior and posterior borders of the fibular incisura pass because of the limitation of the medial border of the fibula and syndesmosis tendon. Therefore, K-wire could be used as a reliable and static intraoperative reference of the fibular incisura plane through which surgeons can accurately place a screw trajectory.

Background

Approximately 13% of all ankle fractures are accompanied by injury to the distal tibiofibular syndesmosis [1]. To optimize outcomes and prevent ankle arthritis, anatomic reduction is a critical step in the treatment of ankle fractures with syndesmotic injury [2-4]. Unstable syndesmoses need to be fixed in conjunction with operatively treated ankle fractures. More importantly, syndesmosis anatomic reduction has been the only significant predictor of improved functional outcome in short- and long-term studies [5-7]. A disrupted tibiofibular syndesmosis requires a syndesmotic screw placed perpendicular to the tibial incisura in the axial plane [8]. Trans-syndesmotic fixation via dynamic or static methods is considered the most common technique for accurate reduction, although a meta-analysis of other methods showed similar clinical outcomes [9].

While numerous surgeons have recognized the importance of the anatomic stabilization of the distal tibiofibular syndesmosis, the proportions of syndesmotic malreductions range from 16% to 52% [2, 10-12]. Previous data indicate that an eccentric clamp or screw trajectory may lead to syndesmotic malreduction [13, 14]. Ideally, the reductional clamp and screw would be placed in line with the trans-syndesmotic angle to avoid malreduction [16]. Regardless of the angle of inclination positioning, the syndesmotic screw is suggested to be 20–30° (usually 30°); however, different opinions have been reported in recent literature [16-18]. Park et al. reported that in a neutrally maintained foot, the ideal angle of screw trajectory, using the second toe as reference, is approximately 18° [19]. Putnam et al. measured this angle to be around 21° on two-dimensional computed tomography (CT) slices using a lateral radiograph as reference, but the method of syndesmotic screw placement was unclear [15]. One possible explanation for the discrepancy in the angle is the application of varying markers for syndesmotic screw placement [20]. Additionally, the surgeon´s intraoperative estimation of the horizontal plane orientation is very difficult due to foot and ankle movement. Given the continued debates related to the inclination angle of distal syndesmotic screw and reference, further studies are needed to determine a reliable and static reference for syndesmotic screw placement.

Our aim was to detect the ideal position of the insertion of a K-wire between the tibia and fibula above the ankle joint line. Verifying the use of a K-wire as a reliable and static intraoperative tibial incisura plane reference would enable even inexperienced surgeons to accurately place a distal syndesmotic screw.

Methods

Our experiment was conducted under the principles of the Declaration of Helsinki. To evaluate the ideal positional gap between the tibia and fibula in the syndesmosis for the placement of the K-wire marker, we analysed cross-sectional CT images of the ankle of patients who had foot fractures accompanied by an uninjured ankle. After obtaining approval from an institutional board, we began data collection. The inclusion criteria were available CT scans of foot fractures in short splints to maintain neutral foot and ankle positions. Patients with radical ankle osteoarthritis, a history of prior injury, or foot and ankle malformations were excluded. In cases of bilateral foot fractures, we only measured one side to avoid bias due to a two-side similar result. We reviewed the records of 42 patients (45 fractures) who underwent CT scan for foot fractures from August 2016 to June 2017 in our hospital (Table 1).

Table 1
Tibiofibular vertical distance (mm) according to independent variables

		Number	Minimum	Maximum	Mean	SD	P value
Total		42	0	3.6	2.23	1.01	
Side							0.646
	Right	23	0	3.6	2.23	1.11	
	Left	19	0	3.6	2.07	1.00	
Fractures							0.230
	Talus	12	0	3.5	1.82	1.11	
	Calcaneus	17	0.1	3.6	2.35	1.11	
	Metatarsus	13	1.6	3.5	2.46	0.65	

There was no statistically significant difference in the TFVD between the left and right sides of the patients, and the TFVD was not affected by the fracture type. The TFVD of healthy adults is a uniform and stable value.

CT scan image analysis

The CT scans of all patients were analysed using a similar method. A standard syndesmotic screw trajectory lies perpendicular and central to the fibular incisura in the axial plane [8]. Putnam et al., defines the line passing the fibular ridge and perpendicular to the fibular incisura as the anatomic axis of the syndesmosis [15]. According to abovementioned literature, this axis has two critical points: the fibular ridge, which is easily visualized, and a point perpendicular to the fibular incisura. It is imperative for surgeons to find a static and visible reference for the fibular incisura plane.

All CT scans were obtained using a 128-slice detector scanner (Siemens AG, Wittelsbacherplatz, Muenchen, Germany). These images were measured using the Picture Archiving and Communication System (Synapse 3.0, FUJI TECHNOLOGY. Co., Ltd., Tokyo, Japan), and two orthopaedic surgeons independently recorded each measurement at separate dates.

In a preliminary experiment, we aimed to determine a position proximal to the tibial plafond where the tibiofibular vertical distance (TFVD) of all patients was >0. The TFVD of each CT slice from the start of the tibial plafond was measured using our methods. Finally, we observed that distance of the 25th slice from the beginning of the plafond of all patients was >0. Because the height of each slice was 1 mm, measuring a TFVD of 2.5 cm proximal to the plafond was our objective. The choice of using a 1.6-mm K-wire was dependent on our experiences. Through that preliminary experiment, we discovered that it is very easy to place a 1.6-mm K-wire 2.5 cm proximal to the tibial plafond. Injury to the distal tibiofibular syndesmosis due to the placement of a 1.6-mm K-wire at this position may be mild due to the ease of insertion. We drew a line along the anterior and posterior borders of the fibular incisura on a transverse CT slice. This line was defined as Line 1. Then, we drew another line parallel to Line 1 and tangent to the medial border of the fibula, defined as Line 2 (Figure 1). The vertical distance between the two lines was considered to be the path of the K-wire marker (Figure 2).

Statistical analysis

Levene's test was used to confirm the Equality of Variances. Independent t-tests were used to compare intergroup differences, and a P value of <0.05 was considered significant. Statistical analyses were performed using SPSS (IBM SPSS Statistics for Windows, Version 13.0. Armonk, NY: IBM Corp.) According to the methods of Putnam et al. [15], we estimated the reliability of the described measurements with an interclass correlation coefficient (ICC). Two independent observers measured and recorded data at separate dates. The classification related to the results of the ICC was comparable to that reported by Putnam et al: poor (<0.2), fair (0.21–0.4), moderate (0.41–0.6), good (0.61–0.8), or very good (0.81–1) [15].

Results

The ideal vertical distance between the tibial and fibular cortex was determined to be 2.23±1.01 mm (mean ± standard deviation; range 0–3.6 mm) at 2.5 cm proximal to the tibial plafond, with no significant difference noted between males and females (n = 22 and 20, respectively, P = 0.995) (Table 2). The vertical distance of 20 patients was 2–3 mm (Figure 3). The interclass correlation coefficient for the measurement of TFVD was 0.915, indicating very good reliability between the two independent observers.

Table 2
Conventional computed cross-sectional image measures for male and female patients.

	All	Male	Female	*P* Value
Patients (n)	42	22	20	
Age (years)	38.8±13.8	36.9±13.5	40.9±14.1	0.366
TFVD (mm)	2.23±1.01	2.23±1.17	2.23±0.81	0.995
There was no statistically significant difference between gender and age.				

Discussion

With the ankle joint in the neutral position, we found that the average TFVD was 2.23 mm at 2.5 cm above the ankle joint line. A 1.6-mm K-wire could be easily inserted in this gap. This K-wire could be used as a static and stable marker for the accurate placement of the syndesmotic screw without the influence of ankle position and soft tissue condition around the ankle joint. The syndesmotic screw could be precisely placed perpendicular to the K-wire and parallel to the ankle joint.

We analysed ankle CT scans of patients with foot fractures to locate the optimal position for K-wire marker placement for several reasons. First, many patients with foot fractures require a CT scan for the estimation of foot injury. This allowed us to easily complete our study without additional medical costs or radiation exposure damage to patients. Second, short leg braces on patients with foot fractures ensured a neutral ankle position. From plantarflexion to dorsiflexion, the ankle joint allows 1–2 mm of widening normally. As such, the consistency of measurements on CT scans is variable without braces. In this study, patients protected by short leg braces because of foot fractures were examined by CT scans to ensure measurement consistency.

A standard screw trajectory placed perpendicular and central to the fibular incisura is important for obtaining favourable postoperative outcomes of injured ankles [8]. The conventional method, in which the screw trajectory is parallel to the ankle joint line and inclined 30° from post-lateral to anteromedial in transverse, has been used for decades [17]. Although the operative guideline of syndesmotic screw placement is very clear, the rate of malpositioned syndesmotic screws is very high, and this malpositioning could lead to reoperations of the ankle fracture [20, 21]. One possible reason is the lack of reliable and static intraoperative references for surgeons. Previously, the references markers used for the insertion of the screw trajectory were expert opinions (most used) [17], followed by the second toe [19] and malleolar tips [20]. To overcome the variation of the axial orientation of the syndesmosis dependent upon experiences and surgeon’s eyeballing, Park et al., [19] detected an incline angle of around 18° to the horizontal plane when they used the second toe as a reference with the ankle joint in a neutral position. One possible explanation for this variation is that different foot positions could lead to a falsely estimated horizontal plane when the ankle joint is neutral. Given that the estimation of the horizontal plane dependent on the ankle and foot is difficult for surgeons, finding a static reference independent of ankle and foot position is necessary. Although Kumar et al., [20] have used malleolar tips as static reference points independent of ankle and foot rotation to position syndesmotic screws, it may be difficult for surgeons to touch the malleolar tips due to ankle swelling associated with ankle injury. Therefore, there is still a need for reference points without interference of ankle and foot position and soft tissue swelling for surgeons to accurately estimate the plane of tibia incisura and place an ideal screw trajectory. Once we had detected the fibula incisura plane by a marker, we placed an ideal distal syndesmotic screw perpendicular to it because the plane of the tibial incisura did not interfere with the position and soft tissue swelling of the ankle and foot. Therefore, we hypothesized that one optimal space proximal to the tibia plafond existed for placing a K-wire touching the anterior and posterior borders of the tibial incisura, which could be used as an accurate marker of the fibular incisura for surgeons to observe during operation.

Our study found that the gap between the tibia and fibula at 2.5 cm proximal to the tibial plafond was suitable for the insertion of a 1.6-mm K-wire with no obvious deformation. The vertical distance between the tibia and fibula measured 2.23±1.01 mm. This path consisted of three points (the anterior and posterior borders of the tibial incisura and the medial border of the fibula) (Figure 2). Theoretically, these three points form a three-bone claw and hold the 1.6-mm K-wire along the fibular incisura tangent. The K-wire could then be a definite visible landmark during syndesmotic screw fixation (Figure 4). Ankle movements, swelling, or leg and foot position did not influence the accuracy of this marker. Using our marker, intraoperative screw trajectory may be closer to the line perpendicular to the fibular incisura tangent.

There are some limitations of this study. First, we used only CT scans of foot fractures with a splint; this should exclude any discrepancies in the distance between the tibia and fibula at varying talus positions. Although we did not analyse CT scans for the ankles without any damage, the syndesmosis was uninjured, and no malformation was observed in any of these patients. Moreover, additional medical costs and radioactive injuries were avoided by comparing the existing CT scans of injured extremities. Therefore, we believe that these data were suitable for this study. Second, the gap 2.5 cm proximal to the plafond was not well-matched for the positioning of a 1.6-mm K-wire. Any mismatch between the gap and K-wire could lead to an error in fibular incisura plane marking. Therefore, we believe that the insertion of a K-wire should be hit or inserted by hand, not drilled, which would ensure that the K-wire touched the anterior and posterior borders of fibular incisura. Moreover, the diameter of the K-wire could be changed according to the intraoperatively estimated width of the TFVD.

Conclusions

In this study, we analysed cross-sectional images of CT scans to locate an ideal position for the insertion of a 1.6-mm K-wire. Using a K-wire for reference, syndesmotic screw trajectories may be accurately placed perpendicular to the fibular incisura. Our method has the advantage of a clear and static reference without interference of ankle and foot position, making it a suitable alternative to conventional methods.

List Of Abbreviations

CT, computed tomography; K-wire, Kirshner wire; TFVD, tibiofibular vertical distance; ICC, interclass correlation coefficient

Declarations

Ethics approval and consent to participate

The research was approved by the Ethic Committee of HongHui Hospital, Xi’an Jiaotong University.

Consent for publication

Consent for publication was obtained from the patients.

Availability of data and materials

The data are available if necessary.

Competing interests

The authors declare that there is no conflict of interest.

Funding

None

Authors' contributions

C.M. Zhang: Designed the study, lead investigator, and first author.

Q.Wang: C.M. Zhang and Q.Wang contributed equally to this paper.

N. Duan: Study implementation, data analysis and interpretation.

T.Ma: Study implementation, data analysis and interpretation.

H.Z.Xuan: Study implementation, assistant surgeon.

Z. Li, K.Zhang: Designed the study, corresponding author, primary surgeon, approval of the final manuscript.

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Figures

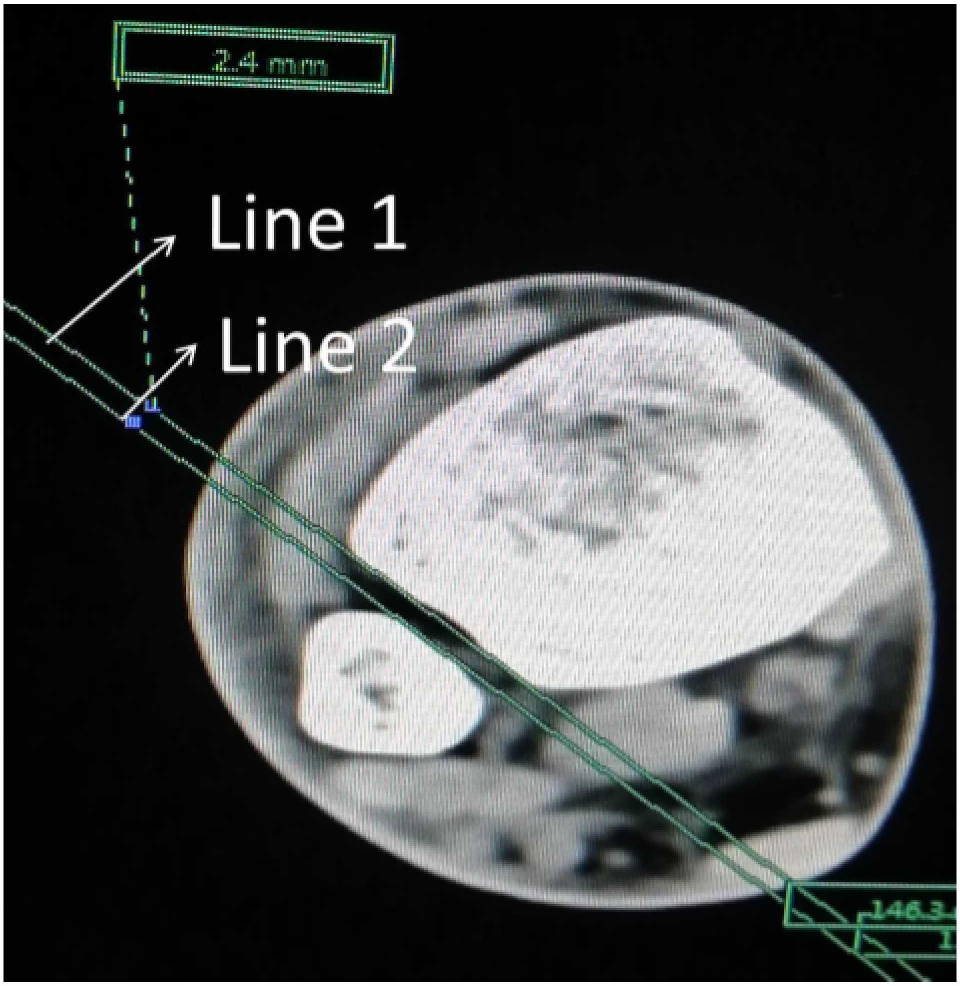
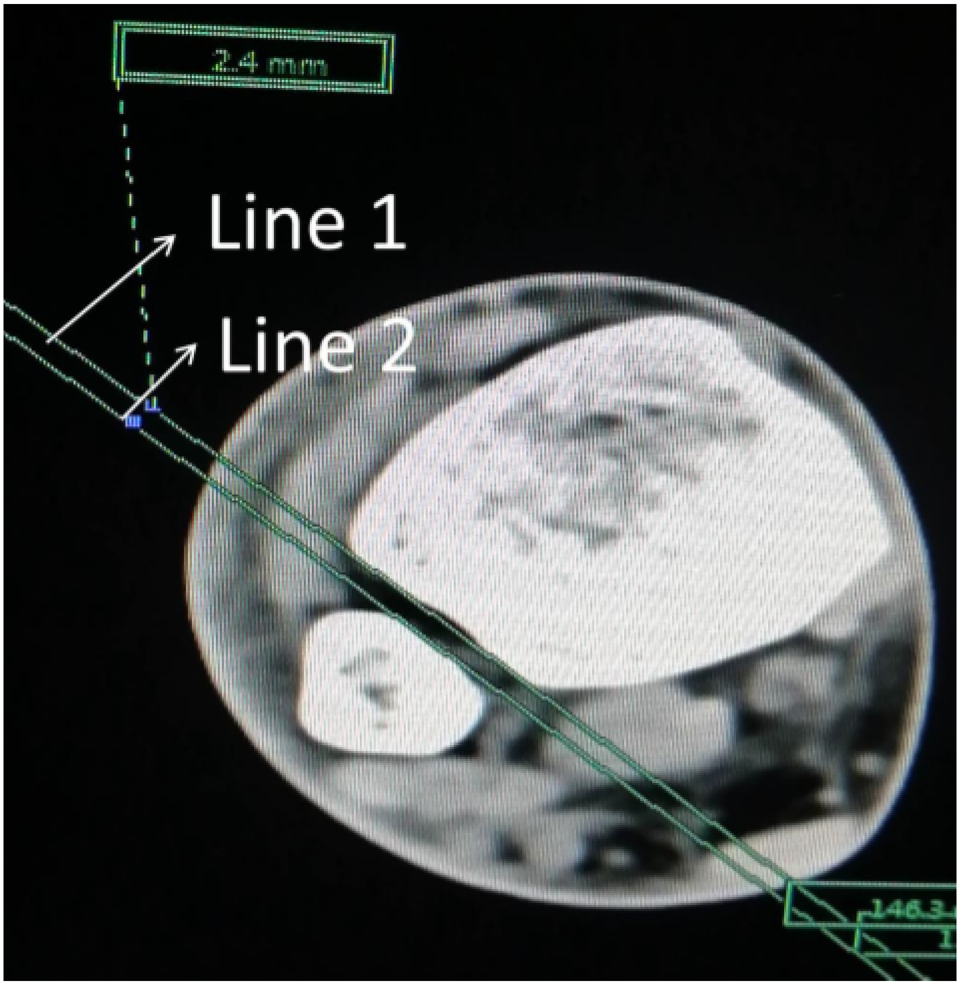


Figure 1

Graphical depiction of the method used to measure TFVD The tibiofibular vertical distance (TFVD) was defined as the vertical distance between L1 and L2 on an axial CT at 2.5 cm proximal to the ankle joint. L1 is the line along the anterior and posterior borders of the fibular incisura. L2 is the line parallel to L1 and tangent to the medial border of the fibula.



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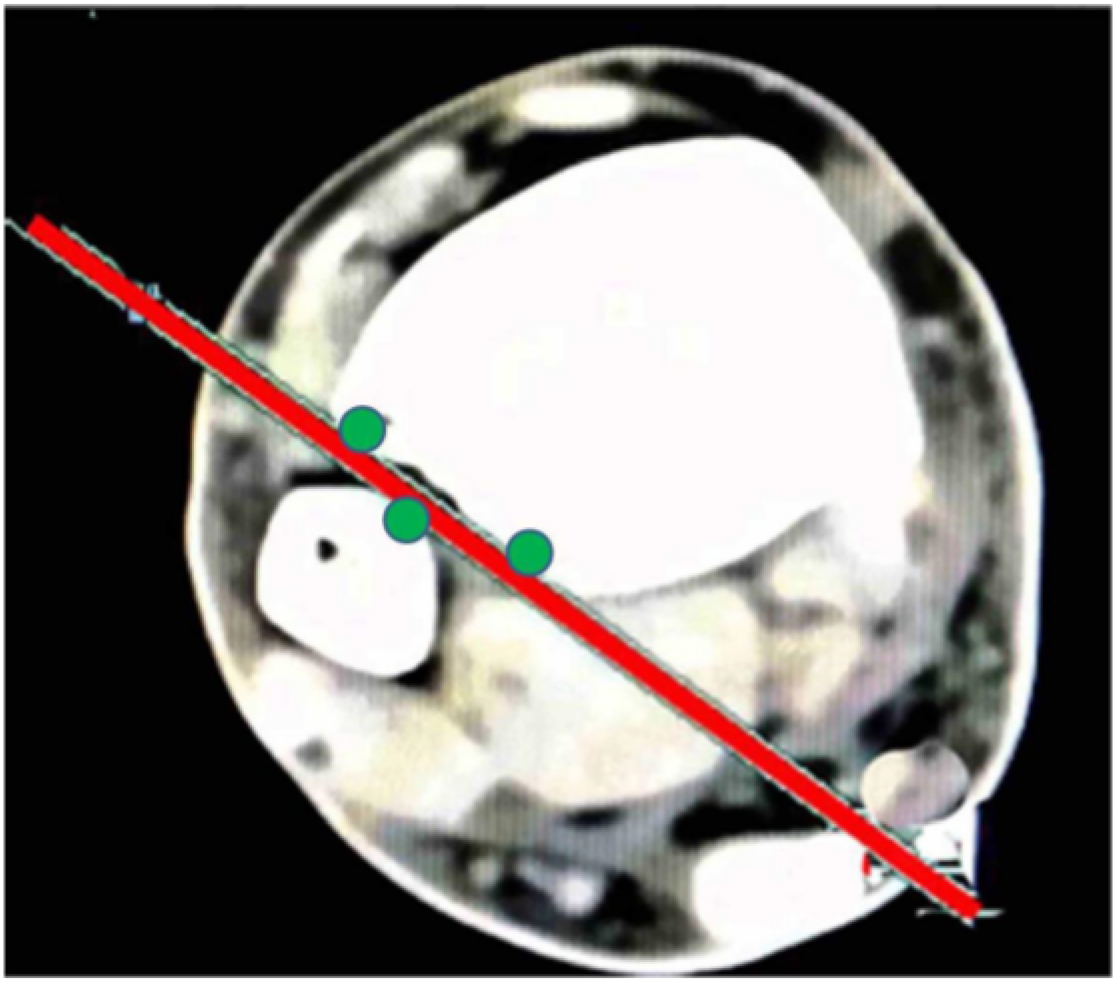
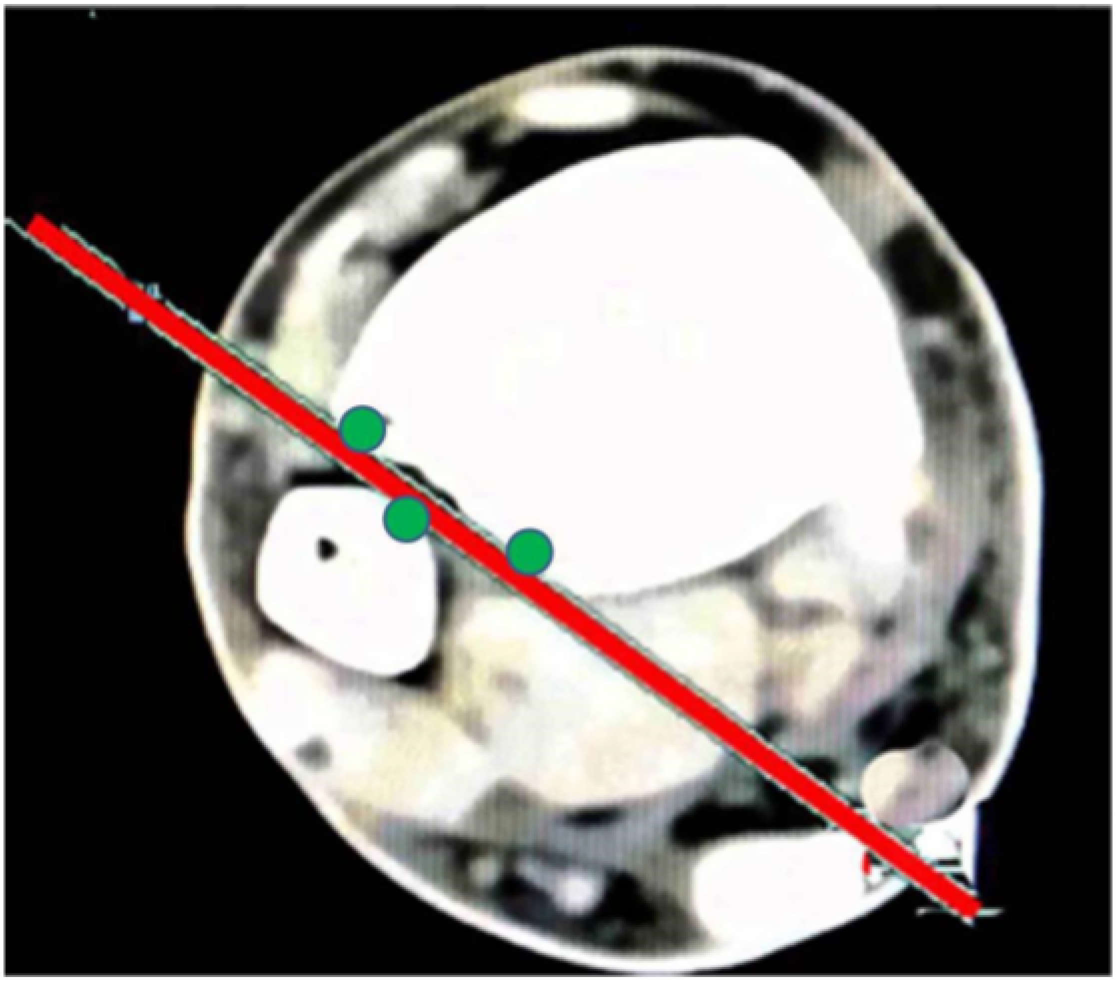


Figure 2

Graphical depiction of the pathway of the K-wire marker The red line represents the path of the K-wire marker. The three blue points represent the anterior and posterior borders of the tibia incisura and the medial border of the fibula.



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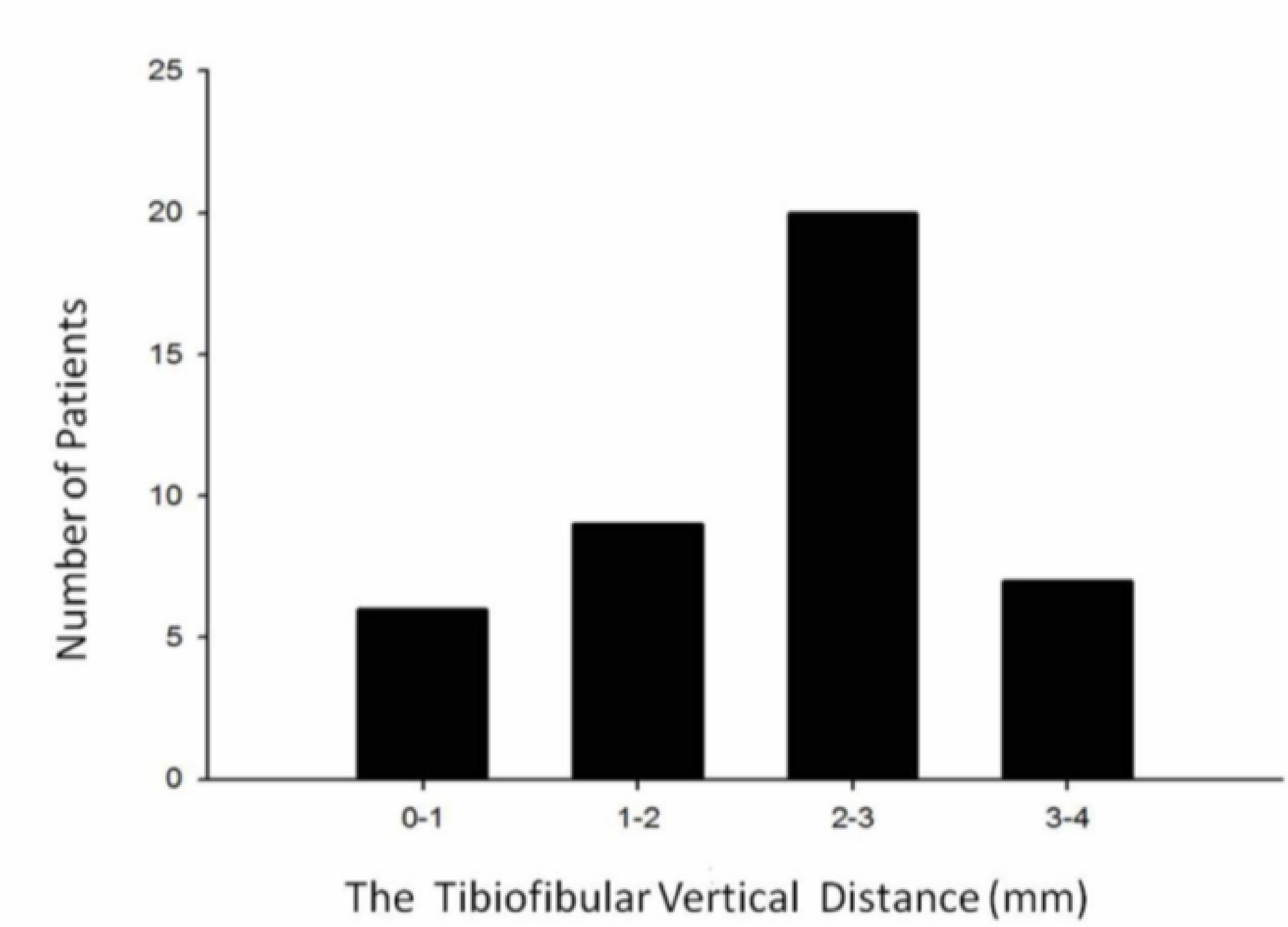

Figure 3

Histogram demonstrating the distribution of the tibiofibular vertical distance (n = 42) In 69% (29/42) of the patients, TFVD was between 1 and 3 mm, which indicated the gap of approximately patients would be enough for placing a 1.6-mm K-wire.

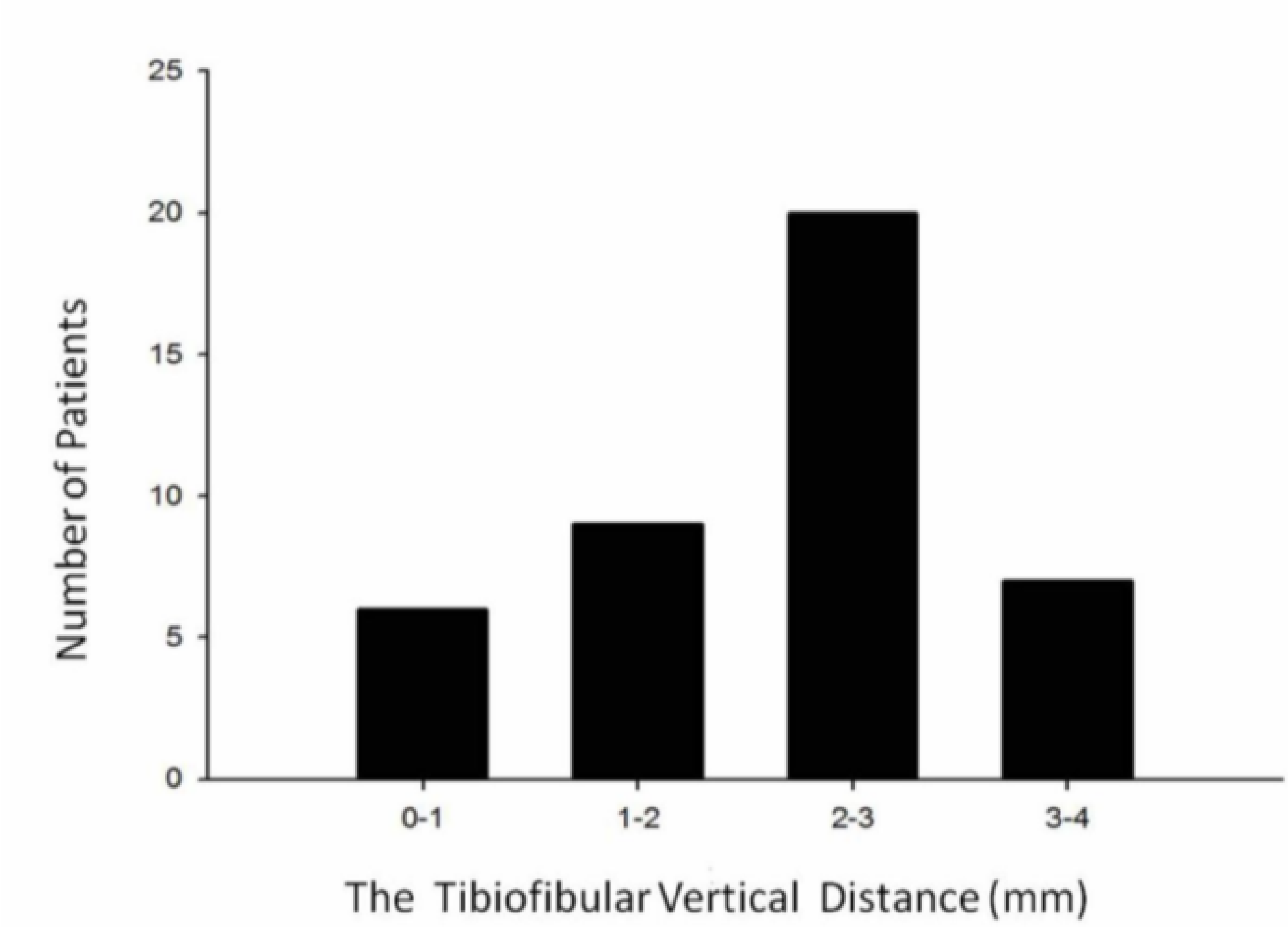

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Figure 4

K-wire as a marker during the insertion of the syndesmotic screw. The K-wire may be used as a definite static landmark for the placement of an ideal screw trajectory during syndesmotic screw fixation. The red arrow refers to the mark of the K-wire. The blue arrow refers to a drill used to place a screw trajectory during syndesmotic fixation.

Figure 4

K-wire as a marker during the insertion of the syndesmotic screw. The K-wire may be used as a definite static landmark for the placement of an ideal screw trajectory during syndesmotic screw fixation. The red arrow refers to the mark of the K-wire. The blue arrow refers to a drill used to place a screw trajectory during syndesmotic fixation.