Full length article

Ideal angle of syndesmotic screw fixation: A CT-based cross-sectional image analysis study

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ARTICLE INFO

Article history:
Accepted 30 August 2017

Keywords:
Ankle syndesmosis
Computed tomography
Ideal angle
Syndesmotic screw fixation

ABSTRACT

Without clear reference, the precision of syndesmotic screw placement cannot be guaranteed and malposition of these screws leads to poor results. Therefore, to prevent malpositioning of syndesmotic screws, an improved understanding of the orientation of tibiofibular syndesmosis is essential. We analyzed cross-sectional computed tomography (CT) scans of the foot and ankle to identify precise screw positions for the treatment of syndesmotic injuries. A total of 134 calcaneal fractures with intact tibiofibular syndesmosis were enrolled in this retrospective study. We measured the angle between the perpendicular line of the second proximal phalange and the line start apex of the lateral cortex of the fibula inseur and crossing the center of the tibia in neutral ankle joints, with the second toe positioned anteriorly using a short leg splint. The second toe was used as the reference for clarity and applicability. The ideal angle of syndesmotic screw placement in cross-sectional CT images was 18.8° ± 5.6° (mean ± standard deviation) and did not differ according to independent variables (P > 0.05). In neutral ankle joints with the second toe positioned anteriorly, the ideal angle of syndesmotic screw placement is 18.8°, which is less than that currently in used in conventional methods.

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Introduction

Syndesmotic injuries associated with rotational ankle fractures often require surgical fixation because instability of the syndesmosis may lead to talar displacement and deranged ankle mechanics [1–3]. Controversies exist regarding syndesmotic fixation [4–6], but the majority of authors recommend fixation for treatment of disrupted syndesmosis [2,3,7]. Many newly-introduced fixative devices yield good results, but traditional syndesmotic screw fixation methods remain popular [1,7,8].

Many authors recommend an angle between 20° and 30° (usually closer to 30°) posterostralateral to anteromedial in the oblique direction along the transverse plane for syndesmotic screw fixation [1,7–13]. The rationale underlying this method is that the posterostralateral location of the fibula in relation to the tibia in the transverse plane necessitates oblique screw placement bisecting the tibial incisure and crossing at least three cortices (lateral and medial fibular and lateral tibial). Second, the distal tibiofibular joint axis is externally rotated approximately 30° in relation to the femoral transepicondylar axis [14].

However, there is an inherent limitation of the conventional syndesmotic screw fixation method, which is that the lower extremity is easily rotated externally under anesthesia, so that when the syndesmotic screw is inserted at an angle, it is difficult to establish the correct degree of angulation due to the lack of reference. For convenience during surgery, padding is often placed under the buttocks to orient the tibia anteriorly. In this context, the transepicondylar axis is difficult to use as a reference due to the internal rotation of the femur. When an assistant is employed to hold the lower extremity true anteriorly, identification of the transmalleolar axis is helpful for orientation. However, this method has the disadvantage of not being visible at a glance, forcing the clinician to rely on external palpation, resulting in increased risk of placing the syndesmotic screw at an inappropriate angle. Therefore, clearer references are necessary to facilitate placement of the screw in the correct direction.

In order to address the limitations of the conventional method, in this study we aimed to identify an appropriate reference for syndesmotic screw fixation that is easily used during surgery. In addition, we analyzed cross-sectional images of computed tomography (CT) scans to identify the ideal angle for syndesmotic screw placement using this reference.

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http://dx.doi.org/10.1016/j.injury.2017.08.067
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Materials and methods

To evaluate the positional relationship between the tibia and fibula in syndesmosis and the ideal angle for placement of the syndesmotic screw, we analyzed cross-sectional CT images of calcaneal fracture which had intact syndesmosis. After obtaining approval from the local ethics committee, we reviewed the records of 396 patients (415 fractures, 19 bilateral fractures) who underwent CT scans for calcaneal fractures from January 2008 to March 2017. All CT scans for calcaneal fractures were performed at a single tertiary-care facility. Electronic medical records and diagnostic imaging studies were assessed by two orthopedic surgeons. The inclusion criteria were available CT scans of calcaneal fractures with short leg splints in neutral foot and ankle positions. Patients with bilateral fractures were included, and for these patients each foot was analyzed separately. The exclusion criteria were insufficient CT scan images that did not include the ankle syndesmosis and forefoot (162 fractures), concomitant foot and ankle disease that could affect syndesmosis or foot alignment (39 fractures), and inappropriate foot and ankle positions that were not neutral (80 fractures). After review, a total of 123 patients (134 fractures, 11 bilateral fractures) were enrolled in this retrospective study.

CT scan image analysis

We defined the ideal angle of syndesmotic screw placement as the position of the screw that can bisect the fibula and tibia in the transverse plane [15,16]. In addition, neutral position of the foot and ankle was defined as when the plantar aspect of the foot was perpendicular to the tibial axis in the sagittal plane and the longitudinal axis from the center of the ankle to the center of the second metatarsal head was located in the midline in the transverse plane [17]. The position of the foot and ankle in CT scans was assessed on sagittal views and 3D (three dimensional) reconstruction images. Decisions regarding exclusion were made through the consensus of two orthopedic surgeons.

After confirmation of neutral position, we drew a line on the longitudinal axis of the second proximal phalanx in the transverse plane (cross-sectional image) and extended it to the ankle joint level, and then drew a line perpendicular to it. This perpendicular line was defined as L1. At 2 cm above the ankle joint (just above the distal tibiofibular joint) as verified on a dynamic scout view in the coronal plane, we drew another line starting at the apex of the lateral side of the fibula that bisected the tibial incisura and crossed the center of the tibia. This line was defined as L2 and the angle between L1 and L2 was considered to represent the ideal angle for syndesmotic screw fixation (Fig. 1).

All CT scans were obtained using a 320-row detector CT scanner (Aquilion ONE; Toshiba, Tokyo, Japan) and 16-channel multi-detector row CT (Sensation 16; Siemens Medicals, Erlangen, Germany) with detector collimation of 16 × 0.75 mm, a tube energy and current of 120 kV and 250 mAs, respectively, and a 0.7-mm beam pitch in Osteo scanning mode. These images were analyzed using the Picture Archiving and Communication System (PiViewSTAR, INFINITT Co., Ltd., Seoul, Korea) and two orthopedic surgeons independently recorded each measurement twice to facilitate assessment of inter- and intra-observer reliability.

Statistical analysis

Our results examined normal distribution using the Kolmogorov-Smirnov test. Independent t-tests, analysis of variance (ANOVA) and Kruskal-Wallis test were used to determine the significance of intergroup differences according to independent variables. The inter- and intra-observer reliabilities of measurements were determined using Pearson’s correlation. All statistical analyses were performed with SPSS v20.0 (SPSS Inc., Chicago, IL, USA).

Fig. 1. (A) The ideal direction of syndesmotic screw placement in a neutral ankle joint with the second toe positioned anterior. (B) We drew a line on the longitudinal axis of the second proximal phalanx in the transverse plane (cross-sectional image) and extended it to the ankle joint level, and then drew a line perpendicular to the first (L1). (C) At 2 cm above the ankle joint as verified on a dynamic scout view in the coronal plane, we drew another line starting from the apex of the lateral side of the fibula that bisected the tibial incisura and crossed the center of the tibia. This line was defined as L2, and the angle between L1 and L2 as the ideal angle of syndesmotic screw fixation.

Please cite this article in press as: Y.H. Park, et al., Ideal angle of syndesmotic screw fixation: A CT-based cross-sectional image analysis study, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.08.067
Results

In neutral ankle joints with the second toe positioned anteriorly, the ideal angle for the syndesmotic screw in cross-sectional CT images was determined to be 18.8° ± 5.6° (mean ± standard deviation [SD]; range 7.9°–32.5°). The first quartile to the third quartile was 14.3°–22.8°. These values did not differ according to independent variables (Table 1). In addition, the values did not vary according to the classification of calcaneal fracture (P > 0.05).

There were strong correlations in measurements of ideal angles for syndesmotic screw measured by the two observers (YHP, WSC) (Pearson’s R 0.923). The intra-observer variability was also high for both observers (Pearson’s R for YHP 0.950 and for WSC 0.906).

Discussion

We decided to analyze calcaneal fractures to identify optimal angles for syndesmotic screw placement for a number of reasons. First, unlike ankle fractures, most calcaneal fractures underwent CT scans. This allowed us to identify a larger sample for study. In addition, calcaneal fractures may show intact tibiofibular positional relationships in syndesmosis more often than ankle fractures. Second, most feet and ankles in CT scans of calcaneal fractures are in neutral position due to the use of short leg splints.

In contrast, the ankle positions in CT scans that are performed without splints are variable, and the consistency of measurements in such CT scans is uncertain. Our aim in this study was to identify ideal angles for syndesmotic screw placement when the ankle joint is in neutral position with the second toe oriented anteriorly, which reduces technical error in various ankle positions during syndesmotic screw fixation. Therefore, CT scans for calcaneal fractures with short leg splints and neutral foot and ankle position were ideal for this study.

In contrast to debates regarding fixation material, screw size, timing of screw removal, and the number of cortical fixations in syndesmosis injury [1,7], the angle of syndesmotic screw placement has been agreed upon for decades. Many authors suggested conventional maneuvers for syndesmotic screw fixation that resulted in placement angles between 20° and 30° (usually 30°) in the oblique direction from posterolateral to anteromedial aspects in the transverse plane [1,8–13]. Recently, in accordance with changes in expert opinion, Mendelsohn et al. confirmed that the distal tibiofibular joint axis should be externally rotated by approximately 30° in relation to the femoral transepicondylar axis [14].

The results of our study indicate that in neutral ankle joints with the second toe positioned anteriorly, the mean ideal angle of syndesmotic screw placement from posterolateral to anteromedial aspects is 18.8°. This value is slightly lower than conventionally recommended screw angles. Nevertheless, while 30° oblique from posterolateral to anteromedial in the transverse plane is most commonly recommended, previous studies do not make specific references regarding angulation to guide the direction of screw placement. If 30° of angulation is denoted relative to ground level when the foot and ankle are positioned anteriorly, the specific definition of “anterior position of the foot” must be explained. If angulation is relative to a line perpendicular to the longitudinal axis of the foot, the second metatarsal head should be truly anterior. However, we were unable to see the metatarsal head, but rather could touch the bone and face it anteriorly, making this technique vulnerable to mistakes. Therefore, without clear references for the angle of screw placement, precision of syndesmotic screw placement cannot be guaranteed.

The second toe can be easily positioned as a definite visible landmark toward true anterior by an assistant or operator during syndesmotic screw fixation [Fig. 2]. Therefore, it is a good reliable reference for syndesmotic screw fixation angles. The most important clinical applications of our findings is that when second toe facing anterior with neutral position of ankle joint, we were able to identify the ideal angle for syndesmotic screw fixation. In this position, the angle of the syndesmotic screw should be smaller than recommended by the conventional method. The maneuvers associated with screw placement at this angle may be more applicable and may reduce the risks of inappropriate screw positioning compared to conventional methods.

There were some limitations in this study. First, we did not analyze CT scans that were performed in uninjured patients. Instead, we used only CT scans of calcaneal fractures, because it is very difficult to obtain numerous CT scans of uninjured patients. Although we analyzed CT scans of calcaneal fractures, the foot and syndesmosis were not injured in any of these patients. In addition, as noted, positioning of the foot and ankle are not guaranteed to be neutral without a splint. Therefore, we believed the use of calcaneal fracture images was suitable for this study. Second, among 415 fractures, only 134 fractures could be enrolled in this study, which may have resulted in bias. However, most of

![Table 1](https://example.com/table1.png)

**Table 1**

Ideal syndesmotic screw angle according to independent variables.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
<th>Variance</th>
<th>Median</th>
<th>Quartiles*</th>
<th>P value</th>
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<tr>
<td>Total</td>
<td>134</td>
<td>7.9</td>
<td>32.5</td>
<td>18.8</td>
<td>5.6</td>
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<td>14.3–22.8</td>
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<td></td>
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<tr>
<td>Male</td>
<td>104</td>
<td>7.9</td>
<td>32.5</td>
<td>18.8</td>
<td>5.6</td>
<td>0.6</td>
<td>19.0</td>
<td>14.3–22.8</td>
<td>0.821</td>
</tr>
<tr>
<td>Female</td>
<td>30</td>
<td>9.9</td>
<td>31.3</td>
<td>18.7</td>
<td>5.7</td>
<td>1.1</td>
<td>22.6</td>
<td>10.6–23.2</td>
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<tr>
<td>Side</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Right</td>
<td>65</td>
<td>8.9</td>
<td>31.3</td>
<td>18.2</td>
<td>5.8</td>
<td>0.7</td>
<td>18.0</td>
<td>13.0–22.7</td>
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<tr>
<td>Left</td>
<td>69</td>
<td>7.9</td>
<td>32.5</td>
<td>19.3</td>
<td>5.4</td>
<td>0.7</td>
<td>20.4</td>
<td>14.8–23.1</td>
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<tr>
<td>Tongue type</td>
<td>22</td>
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<td>32.5</td>
<td>21.7</td>
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<td>1.3</td>
<td>22.0</td>
<td>16.7–25.5</td>
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<tr>
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<td>0.5</td>
<td>18.0</td>
<td>13.8–22.3</td>
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<td>Mixed type</td>
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<td>29.4</td>
<td>17.8</td>
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<td>3.1</td>
<td>16.2</td>
<td>14.4–18.2</td>
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<tr>
<td>II</td>
<td>68</td>
<td>7.9</td>
<td>32.5</td>
<td>19.6</td>
<td>5.4</td>
<td>0.7</td>
<td>21.0</td>
<td>15.5–23.2</td>
<td>0.204</td>
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<tr>
<td>III</td>
<td>56</td>
<td>9.5</td>
<td>31.3</td>
<td>17.9</td>
<td>5.4</td>
<td>0.8</td>
<td>16.6</td>
<td>13.8–21.4</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>10</td>
<td>8.9</td>
<td>28.7</td>
<td>18.0</td>
<td>7.2</td>
<td>2.3</td>
<td>15.4</td>
<td>12.1–25.4</td>
<td></td>
</tr>
</tbody>
</table>

* First quartile to third quartile; SD, standard deviation.

Please cite this article in press as: Y.H. Park et al., Ideal angle of syndesmotic screw fixation: A CT-based cross-sectional image analysis study, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.08.067
these cases were excluded due to a lack of appropriate images or inaccurate posture. In addition, because the number of patients enrolled was sufficient to represent the entire cohort, we do not expect this to have affected the results. Third, during the study period, two different CT machines were used for imaging studies. However, the protocol for the two machines was similar and the resolution of the CT scan did not affect measurements in our study; therefore, we do not believe this influenced our results. Last, we did not verify our findings in prospective or cadaver studies. We plan further studies to remedy this omission.

Conclusion

In this study, we analyzed cross-sectional images of CT scans to identify ideal angles of screw fixation for syndesmotic injuries. In neutral ankle joints with the second toe positioned anteriorly, the ideal angle of syndesmotic screw placement was 18.8°. This value is lower than that recommended by conventional methods. Our method has the advantages of a clear angle reference and ease of application, making it a suitable alternative to conventional methods.

Conflict of interest statement

None of the author of this paper has a financial or personal relationship with other people or organization that could influence the content of the paper.

Author contributions

Y. H. Park: Designed the study, Lead investigator and first author.
W. S. Choi: Study implementation, Data analysis and interpretation.
G. W. Choi: Study implementation, Data analysis and interpretation.
H. J. Kim: Designed the study, Corresponding author, Primary surgeon, Approval of the final manuscript.

References

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