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ORIGINAL ARTICLE

Determination of the Optimal Syndesmosis Fixation Angle Using Mortise View of the Ankle

Joint

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Background: Syndesmosis is an important soft tissue component supporting the ankle stability and commonly injured accompanying with ankle fractures. The accurate reduction and fixation of syndesmosis is essential to obtain better functional results. Therefore, we aimed to find a

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practical method using the mortise view of ankle to determine the optimal syndesmosis fixation angle intraoperatively.

Methods: We randomly selected 200 adults (100 women and 100 men) between 18 – 60 years of age. Three-dimensional anatomical models of tibia and fibula were created using Materialise MIMICS 21. We created a best fit plane on articular surface of medial malleolus and a ninety degrees vertical plane to medial malleolus plane. We determined two splines on cortical borders of tibia and fibula distant from the most superior point of ankle joint in horizontal view. We created two spheres that fit to the predefined splines. The optimal syndesmosis fixation angle was determined measuring the angle between the line connecting the center points of spheres, and the ninety degrees vertical plane to medial malleolus plane.

Results: We observed no statistically significant difference between gender groups in terms of optimal syndesmosis fixation angles. The mean age of our study population was 47.1 ± 10.5 . The optimal syndesmosis fixation angle according to mortise view was found as 21 ± 4.3 degrees.

Conclusions: We determined the optimal syndesmosis fixation angle as 21 ± 4.3 degrees in accordance with the mortise view of ankle. The surgeon could evaluate the whole articular surface of ankle joint with the medial and lateral syndesmotic space in mortise view accurately and at the same position syndesmosis fixation could be performed at 21 ± 4.3 degrees.

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Malleolar fractures are one of the most encountered injuries of the lower extremity and these fractures are frequently accompanied by soft tissue and ligament injuries ¹⁻⁴. Surgical interventions are often preferred for the treatment of displaced malleolar fractures, which are intra articular fractures, to obtain the absolute anatomical reduction ⁵. The main goal of the treatment is to restore the ankle joint congruency through not only bony structures but also the soft tissue components of the joint.

Syndesmosis is an important soft tissue component supporting the ankle joint stability. Distal tibiofibular joint is stabilized by anterior (ATFL), posterior (PTFL) and interosseous (ITFL) tibiofibular ligaments, which generate the anatomical structure of syndesmosis ³. Although the anatomical and biomechanical features of the syndesmosis were largely investigated in the literature, the accurate diagnosis and optimal fixation methods are still controversial ^{1,2,5-7}.

In a study of Page et al., the incidence of syndesmosis injuries concomitant with ankle fractures were reported as high as 24% ⁸. Due to its frequency, the importance of the accurate diagnosis and appropriate treatment of syndesmosis injuries have been emphasized in many studies ^{5,9,10}. Misdiagnosis and inadequate treatment of syndesmosis injuries could lead ankle joint malreduction, instability and progressive arthrosis ^{1-3,5,11}.

Although, suture-button implants have gained popularity in the last decade due to its biomechanical and anatomical advantages, trans-syndesmotic screws are still the most preferred fixation method to temporarily stabilize the distal tibiofibular joint during the healing

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process of syndesmotomic ligaments^{2,3,5,6,8}. Historically, the accurate screw and suture-button fixation angles had been suggested as 30 degrees from posterolateral to anteromedial direction, however the current studies about syndesmosis fixation have reported different optimal fixation angles^{5,8-10,12}. The reason for the variability of optimal angles in the literature are due to selecting different reference anatomical landmarks and using different imaging modalities^{5,8-10}. Although, two-dimensional (2D) imaging modalities are the most commonly used techniques in the literature to determine the optimal syndesmosis angle, it has been stated that 2D imaging is insufficient to evaluate syndesmosis in several studies¹²⁻¹⁴.

The mortise view at 15 - 20 degrees of internal rotation of ankle joint is the basic imaging method to evaluate the whole articular surface of the ankle joint^{15,16}. Medial and lateral syndesmotomic space and lateral articular surface of talus could be imaged with this view^{15,16}. Futamura et al. have also reported the high reliability of the mortise view to detect the malreduction of syndesmosis, intraoperatively¹¹. Besides, not only the mortise view, but also the accurate lateral ankle view is important to evaluate the reduction of syndesmosis.

To the best of our knowledge, there is no consensus about the optimal fixation angle of syndesmosis injuries. Therefore, we aimed to determine the optimal angle by using the mortise view for the accurate fixation of the syndesmosis on three-dimensional (3D) anatomical models in our study.

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Patients and Methods

The approval for this experimental study was obtained from the Ethics Committee of Ankara City Hospital. The lower extremity computed tomography (CT) images of the patients between 18 and 60 years of age, who were consulted in Orthopedics and Traumatology Department of Erzincan Binali Yıldırım University between 2017 - 2020, were reviewed via the radiological records. The patients, who have prior orthopedic interventions of the ankle, oncological interventions, incomplete computed tomography images of tibia and fibula, total ankle arthroplasties, deformity corrections, fracture fixation procedures and the patients with ankle osteoarthritis, were excluded from the study.

The data of all patients were anonymized using the software Mimics 21 (Materialise, Leuven, Belgium). Sample size was calculated by accepting type 1 error level as 0.05, the effect size and the power of the study as 0.8. The total sample size was calculated to be at least 52 models using G*Power 3.1. (Düsseldorf University, Düsseldorf, Germany). Among the adults who met the study criteria, 100 females and 100 males were randomly selected using a true random number generator program (www.random.org).

A total of 400 ankles (100 female and 100 male) were evaluated in our study. CT scans were performed on a Siemens SOMATOM Emotion (Siemens, Erlangen, Germany) (110 kV- 90 mAs, slice thickness 0,6 mm). The tibia and fibula of the patients were segmented using advanced segment option of the software Mimics 21 (Materialise, Leuven, Belgium) to create

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CT-based 3D anatomical models. Thresholding limits were determined as between 200 –3071 Hounsfield Unit to isolate the bone tissue from other tissues.

An automatized best fit plane was created using fit to surface option of Mimics 21 according to the articular surface of medial malleolus (Figure 1 and 2). The optimal syndesmosis fixation level was referred to two centimeters proximal to the most superior point of distal tibial articular surface in sagittal view in many studies in the literature ^{1,5,9,10}. Therefore, we determined the optimal syndesmosis fixation level on two centimeters proximal to the most superior point of distal tibial articular surface in sagittal view (Figure 3). At this level, multiple points on outer cortex of tibia and fibula were marked separately to create a closed spline in horizontal view (Figure 4). All data were transferred to Materialise 3-Matic 13 (Materialise, Leuven, Belgium).

We created two separate spheres in accordance with predefined splines on tibia and fibula. A line was drawn between the center points of these spheres (Figure 5). Then in horizontal view, we created a ninety degrees vertical plane to predefined medial malleolus plane. We determined the optimal syndesmosis fixation angle by measuring the angle between the line connecting the center points of spheres and the ninety degrees vertical plane (Figure 6).

The statistical analysis was performed with SPSS 25 (IBM, NY, USA). At first, the distribution of all samples was evaluated with Kolmogorov-Smirnov normality test. All samples

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have shown a normal distribution. Therefore, the means and standard deviations were calculated with one-way ANOVA using Bonferroni correction. The level of statistical significance was accepted as 0.05.

Results

The most important finding of our current study is that the optimal syndesmosis fixation angle according to mortise view was found as 21 ± 4.3 degrees.

The mean and standard deviations of gender groups in terms of optimal syndesmosis fixation angles were given in Table 1. According to the study results, we detected no statistically significant difference between gender groups in terms of age and optimal syndesmosis fixation angles.

Due to the absence of statistically significant difference between gender groups in terms of optimal syndesmosis fixation angle, all patients were re-evaluated in a single group.

The mean age of our study population was 47.1 ± 10.5 (range, 18 – 60 years).

Discussion

Malleolar fractures are common fractures encountered by orthopedic surgeons and displaced intra-articular fractures are often treated surgically¹⁻³. Soft tissue injuries often accompany ankle fractures. The most commonly injured soft tissue component of the ankle joint is

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syndesmosis, which has an important role in maintaining the distal tibiofibular integrity⁸. The stability and congruence of ankle joint is supported with both bony and soft tissue structures. Due to the complex biomechanics of ankle joint, accurate reconstruction of these structures are important to prevent postoperative ankle osteoarthritis and to maintain better functional results^{5,11}.

Although the importance of accurate reduction of distal tibiofibular joint and treatment of syndesmosis injuries has been emphasized in many publications, postoperative malreduction is still frequently observed^{1-3,5,6,10,11}. Malreduction could cause repetitive surgeries, decrease in functional scores and increased healthcare costs. The studies, that examining the ideal syndesmosis reduction methods, have generally been performed on patients with syndesmosis injury or on cadaveric syndesmotic injury models^{1,11,12}. According to the results of these studies, the most important step in the treatment of syndesmosis injury is the accurate reduction of the distal tibiofibular joint. In order to achieve satisfactory functional results, not only the accurate reduction of distal tibiofibular joint, but also the syndesmosis fixation at an appropriate angle is needed^{1,5}. Therefore, we aimed to investigate the optimal syndesmosis fixation angles to be applied after the correct reduction of the distal tibiofibular joint on the uninjured ankle anatomical models.

The optimal fixation angle, that we determined in our study, represents the collinear angle where the tibia and fibula are centrally located on each other. Non-concentric fixation of

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syndesmosis may impair the properly achieved syndesmotic reduction. We think that syndesmosis fixation performed at our determined angle could protect the obtained concentric reduction of distal tibiofibular joint.

The appropriate and an easily accessible reference anatomical landmark is an important factor to achieve a successful syndesmosis fixation ¹⁶. The commonly used anatomical landmarks to evaluate the syndesmotic injuries are the tibiofibular overlap, medial and tibiofibular clear space. Tibiofibular overlap is defined as the maximum overlap between medial fibula and lateral tibia on both mortise and anteroposterior views ¹⁷. Decreased overlapping as a result of external rotational stress of the ankle joint is an indicator of syndesmotic injury ¹⁷. Medial clear space is the distance between the medial border of talus and lateral border of medial malleolus, measured at the level of the talar dome ¹⁷. In the mortise view of the ankle, the medial clear space should be equal to or less than the superior clear space between tibial plafond and talar dome ¹⁸. Tibiofibular clear space is the distance between the medial border of the fibula and the lateral border of the posterior tibia as it extends into the incisura fibularis ¹⁷. The tibiofibular clear space is measured 1 cm proximal to the plafond and should be <6 mm in both the AP and mortise views ^{17,19}.

The mortise view is an easily applicable imaging method to evaluate the whole articular surface of ankle joint with medial and lateral syndesmotic space ^{15,16}. In a study of Futamura et al., it was emphasized that the mortis view has high reliability in determining syndesmosis

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damage and the malreduction rates can be reduced to 4% using the mortise view ¹¹. Due to these advantages, we decided to use the mortise view as a reference anatomical landmark to determine the optimal syndesmosis fixation angle. In the mortise view, surgeon could evaluate the syndesmosis reduction accurately and could fix the syndesmosis at the appropriate angle.

Distal tibiofibular joint has a complex 3D anatomy. It has been stated that 2D imaging is insufficient to evaluate 3D anatomy of distal tibiofibular joint in several studies ¹²⁻¹⁴. Besides, the superiority of CT and magnetic resonance imaging for the evaluation of syndesmosis was emphasized in a study of Patel et al ¹⁴. Therefore, we created 3D anatomical models of tibia and fibula from native CT-based data of adults to perform the angle measurements.

Although the different methods were performed to determine the center points of tibia and fibula in horizontal CT sections, center-center method is one of the most commonly preferred technique in the literature ^{1,2,5}. At two centimeters proximal from distal tibial articular surface, tibia and fibula have an irregular shape. Therefore, we created separate splines that fits to the cortex of tibia and fibula and 3-Matic 13 program has created automatized 3D spheres, that fit to these splines. Then, we determined the mechanical centers of tibia and fibula for the angle measurement.

AO (Arbeitsgemeinschaft für Osteosynthesefragen) recommends the optimal syndesmosis angle as 30 degrees ²⁰. In daily practice, due to the errors in syndesmosis fixation has led to an increasing interest about the search of optimal fixation angle ^{3,5,9}. Although the optimal fixation

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angles were determined using different reference anatomical landmarks and measurement methods in current literature, there is still no consensus about the optimal fixation angle^{5,7,9,10,12}. Therefore, we aimed to determine the optimal angle by using the mortise view for the accurate fixation of the syndesmosis on three-dimensional (3D) anatomical models in our study. Different from the recommendations of AO, we observed the optimal syndesmosis fixation angle as 21 ± 4.3 degrees in our study.

Our current study has some limitations. We investigated in our study a total of 400 ankles. Although the total number of our study group may seem to be small to generalize our study results universally, our sample size includes the largest study population in the current literature. Besides, the post-hoc analysis has revealed that the power of our study is 99%. All 3D measurements were performed by a single investigator, who has experience about Materialise MIMICS and 3-Matic 13. However, the automatized measurement tools of these programs minimize the measurement errors. Our study is a radiological measurement study on native 3D ankle models. The results of our study should be confirmed with prospectively designed clinical studies.

Conclusions

In conclusion, we determined the optimal syndesmosis fixation angle as 21 ± 4.3 degrees in accordance with the mortise view of ankle. Primarily, the surgeon could evaluate the whole

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articular surface of the ankle joint with the medial and lateral syndesmotic space in mortise view accurately. Secondarily at the same position, syndesmosis fixation could be performed at 21 ± 4.3 degrees using a fixation device. Further studies should focus on to confirm the accuracy and reliability of this angle with a clinical study.

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Conflict of Interest: None reported.

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Table 1. The mean $\pm$ standard deviations and the comparison of gender groups in terms of optimal syndesmosis fixation angles

	Female	Male	<i>P</i> Value ^a
Age	49 $\pm$ 10.1	45.3 $\pm$ 10.8	0.135
Right Ankle	21.4 $\pm$ 4	20.6 $\pm$ 4.8	0.439
Left Ankle	20.8 $\pm$ 4.1	21.4 $\pm$ 4.4	0.55

^aStatistical significance level $P < 0.05$.

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Figure 1 Marking of the articular surface of medial malleolus.

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Figure 2 Creating an automated best fit plane according to the marked area of medial malleolus.

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Figure 3 Determination of the optimal syndesmosis fixation level on two centimeters proximal to the most superior point of distal tibial articular surface in sagittal view.

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Figure 4 Marking multiple points on outer cortex of tibia and fibula to create a closed spline.

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Figure 5 The line connecting the center points of tibial and fibular anatomical spheres (red line).

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Figure 6 Optimal syndesmosis angle measurement between the line connecting the center points of tibial and fibular anatomical spheres and ninety degrees vertical plane to medial malleolus plane.