Injury, Int. J. Care Injured xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Radiological indicator of reduction adequacy during ankle syndesmosis surgery: A computational cadaveric study

Jun-Young Lee[a], Jae Hwan Lim[b], Gu-Hee Jung[b,*]

[a] Department of Orthopaedic Surgery, Chosun University, Chosun University Hospital, 365 Pilmundae-ro, Dong-gu, Gwangju, 61453, Republic of Korea
[b] Department of Orthopaedic surgery, Gyeongsang National University, College of Medicine, Gyeongsang National University Changwon Hospital, 11, Samjeongja-ro, Seongsan-gu, Changwon-si, Gyeongsangnam-do, 51472, Republic of Korea

A R T I C L E I N F O

Keywords:
Ankle syndesmosis
Screw fixation
Reduction adequacy
Radiologic indicator

A B S T R A C T

Purpose: We introduced the intraoperative radiological indicator to assess the reduction adequacy without additional procedure or instrument, and propose the optimal syndesmotic screw trajectory.
Methods: Thirty adult cadavers (15 males and 15 females) without ankle problems were enrolled and subjected to continuous 0.75 mm-slice computed tomography (CT) scans. CT images were imported into Mimics® software to reconstruct three-dimensional (3D) model of ankle. Using free 360° rotations with magnification, the 3D mutual relationships of ankle syndesmosis were assessed, and the fibular congruency of incisura was evaluated to determine the optimal screw trajectory. By reformatting the CT scanning plane along the screw direction, the coronal relation of ankle syndesmosis was evaluated to verify the distance between the adjacent bones.
Results: The fibula was placed in the concentric position of fibular incisura in the 20 models (concentric group) and 40 models, in an eccentric position (eccentric group). Despite this variant, all fibulas were changed into the concentric position in the proximal part of syndesmotic footprint, which might be the ideal height for syndesmotic screw in our study. The fibular bisecting screw trajectory associated with the ideal height of screw was parallel to the ground if the tibial tubercle was directed to the superior and nearly vertical to the ground floor (TT view). Through the reformatted scanning plane parallel to the screw, the lateral border of talus was always placed more medial than the lateral border of distal tibia in the coronal image. All models had a perfectly equidistant and parallel joint space except the medial aspect.
Conclusion: The lateral border of talus in the TT view was intraoperatively used as the radiological indicator for ankle syndesmosis widening because it was always placed more medial than the lateral border of distal tibia. The optimal syndesmotic screw trajectory was placed around the proximal syndesmotic footprint and parallel to the ground via the TT view.

Introduction

In the management of distal tibio-fibular syndesmotic joint (ankle syndesmosis) injury, accurate reduction and restoration of ankle mortise is the most significant factor preventing poor outcomes [1–3]. During the management of ankle syndesmosis injury, most surgeons use mortise and anteroposterior (AP) radiographs for the accurate restoration of ankle syndesmosis (reduction adequacy), utilizing various radiologic indicators such as medial clear space (MCS), tibiofibular clear space (TFCS), and tibiofibular overlap (TFO) [4–6]. However, these radiographic indicators may be unreliable for the assessment of the reduction adequacy [1,2,7]. Recently, Summers et [8] al and Loizou et al [8] proposed new parameters of the fibular position in the dome lateral view, which may be used intraoperatively for the assessment of reduction adequacy. However, despite significant emphasis, the reduction inadequacy was reported up to 52% via postoperative computed tomography (CT) scans [2,3,9].

Based on the utility of postoperative CT scans in the assessment of reduction adequacy compared with AP and mortise radiographs, an intraoperative CT scan has been attempted in a few studies [10–13]. However, despite these concerns of accuracy in the detection of reduction inadequacy, standard fluoroscopic imaging is universally available for intraoperative assessment, and most orthopedic surgeons are very familiar with this modality. Therefore, a continued effort to optimize fluoroscopic imaging

* Corresponding author.
E-mail address: jyujin2001@gnu.ac.kr (G.-H. Jung).

https://doi.org/10.1016/j.injury.2018.06.004
0020-1383/© 2018 Published by Elsevier Ltd.

has been shown to resolve challenges with accuracy and reproducibility. Although the provisional reduction of ankle syndesmosis was obtained by restoring the length and rotation of fibula and distal tibia, the intraoperative factors including the application of reduction clamp and inadequate screw trajectory caused iatrogenic malreduction of ankle syndesmosis [1]. Thus, a three-dimensional (3D) understanding based on surgical insights into the anatomy of ankle syndesmosis is a prerequisite for optimizing the surgical technique.

The aim of this study was to introduce the intraoperative radiologic indicator, which was easily reproduced without additional procedure or instrument to assess the intraoperative reduction adequacy and propose the optimal screw trajectory by elucidating the computational anatomy of 3D rendering software.

Materials and methods

Digital data of cadavers were collected from the Korean Institute of Science and Technology Information and used with permission. All the cadavers underwent CT scanning (Definition AS +, Siemens, Germany) with a continuous 0.75 mm slice thickness in the supine position. Among them, 30 adult cadavers (15 males and 15 females) were enrolled and none of the cadavers showed ankle problems based on a review of their medical records. The mean age of cadavers was 52.1 years (range, 21–60 years; SD, 9.2) and the mean height was 161.3 cm (range, 146–176 cm; SD, 7.1). The CT data in Digital Imaging and Communications in Medicine (DICOM) format were imported into Mimics® software (Materialise Interactive Medical Image Control System; Materialise, Antwerp, Belgium) to reconstruct a 3D ankle model including the talus and the medullary canal of tibia and fibula. To simulate the ankle syndesmotic screw fixation, the actual size of the 3D straight cylinder (Ø 3.5 mm, syndesmotic screw) was used in the stereolithograph (STL) format.

After generating the 3D ankle model, the CT scanning plane was re-oriented to produce the standardized axial and coronal images parallel to the tibial plafond in neutral rotation using the Mimics® software. By removing the fibula models using the 'move tool' of software, the interosseous tibiofibular ligament footprint (syndesmotic footprint) was exposed and the height of depression from tibial plafond was measured (Fig. 1). In the axial plane, the shape and the fibular congruency of the fibularis incisura was evaluated at the proximal 10 mm to the tibial plafond and classified into the crescent and the rectangular groups [14–17]. As the syndesmotic screw, first, the 3D straight cylinder was placed using Mimics® software and the position was fine-tuned via four synchronized windows composed of axial plane, coronal, sagittal, and 3D biplanar images [18–20]. Using the features of free 360° rotations with magnification in any plane, the 3D mutual relations (steady-state of ankle syndesmosis) of tibial plafond, fibula, and talus were evaluated to introduce convenient and reproducible indicators for reduction adequacy during the fluoroscopic imaging of syndesmotic screw placement. After ideally placing the syndesmotic screw, the CT scanning plane was reformatted along the screw trajectory to assess the 2D mutual relation of ankle syndesmosis in the coronal plane and evaluate the various indicators including the distance between the adjacent bones, a non-irregular Shenton's line, and the Weber's indices [21,22]. (Fig. 2: CT plane and relation)

All data are presented as mean, range, and standard deviation (SD). Chi-square test and two sample t-test were used to compare means between the crescent and the rectangular groups. Statistical significance was set at $p < 0.05$. SPSS statistical software package for Windows version 23.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses.

Results

Based on the shape of syndesmosis, there were 22 models of crescent type and 38 models of rectangular shape. The height of

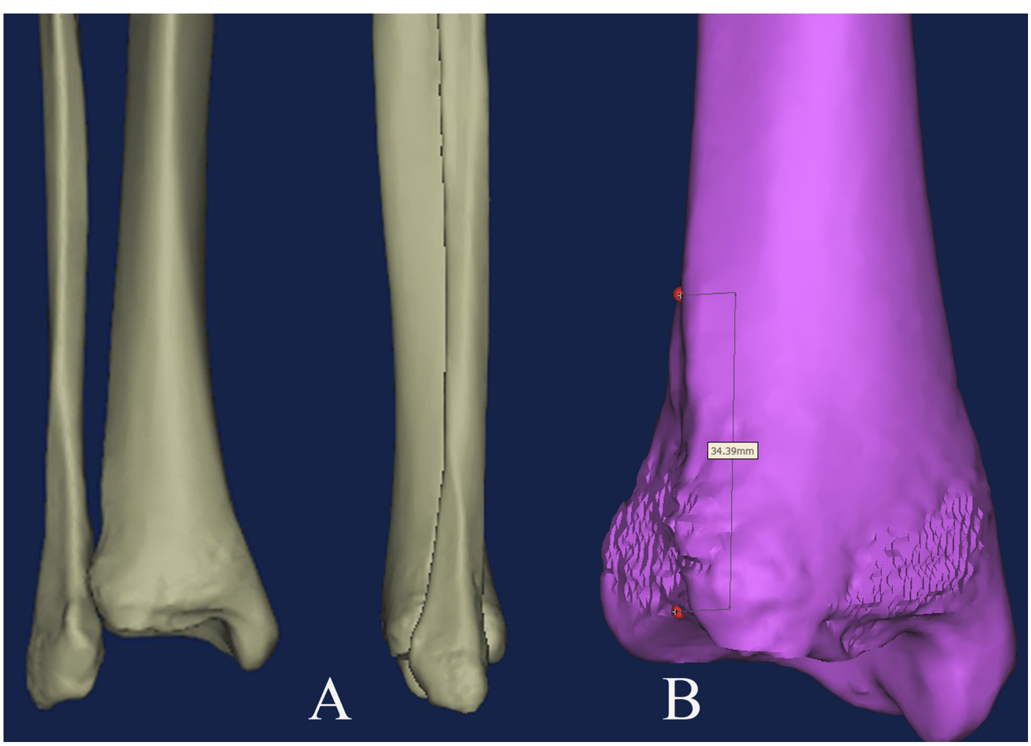

Fig. 1. (A) Using CT data, the 3D ankle model including the talus and the medullary canal of tibia and fibula was created. (B) By removing the fibula models the interosseous tibiofibular ligament footprint (syndesmotic footprint) was exposed to measure the height of depression from tibial plafond.