Intraoperative Three-Dimensional Imaging in Ankle Syndesmotic Reduction.

Markus Beck (m.beck@bernward-khs.de)  
St. Bernward Krankenhaus

Manuela Brunk  
Universitätsmedizin Rostock

Alice Wichelhaus  
Universitätsmedizin Rostock

Thomas Mittlmeier  
Universitätsmedizin Rostock

Robert Rotter  
Universitätsmedizin Rostock

Research article

Keywords:

Posted Date: May 12th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-26631/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published on January 26th, 2021. See the published version at https://doi.org/10.1186/s12891-020-03931-w.
Abstract

Purpose

Injuries of the distal syndesmosis in ankle fractures are traditionally treated with a temporary adjusting screw fixation. Conventional fluoroscopic and X-ray examinations cannot reliably diagnose malpositions of the fixed tibiofibular syndesmosis. Postoperative computer tomography allows a reliable control of the transfixed region. The aim of the study was to clarify whether an intraoperative 3D image intensifier examination can detect malpositions of the syndesmosis already intraoperatively and whether the examination has an influence on the postoperative revision rate.

Methods

In 200 patients with tibiofibular syndesmosis injuries, an intraoperative 3D scan was performed after reduction of the distal tibiofibular syndesmosis and placement of the adjusting screw. Postoperative computer tomography of both ankle joints was performed in all patients.

Results

15% of all intraoperative 3D scans (30 patients) showed a finding requiring correction in the area of the ankle fork. In 7% of the cases, a malposition of the fibula in the tibial incisura requiring correction was found. Further corrections were necessary due to the extent and position of the osteosynthesis material (7%) and for the removal of joint bodies (1%). Postoperative computer tomographies of the ankle joints showed no deformities requiring revision.

Conclusion

An intraoperative 3D scan allows a reliable assessment of the injured ankle region and reduces the postoperative revision rate. This makes a postoperative routine CT examination of the ankle joint dispensable.

Background

Osteoligamentous injuries to the ankle joint are the most common injuries to the lower limb. The total percentage of fractures of the foot and ankle joint is 56% [1]. Criteria for the choice of therapy are the degree of dislocation and instability of the fracture [2]. Fractures with accompanying unstable syndesmosis injuries are considered a reliable indication for surgery. The incidence of this additional injury in upper ankle fractures is 16% [3]. The accompanying tibiofibular ligament injury significantly worsens the clinical and radiological outcome of the patients [4]. Intra- and postoperative fluoroscopic and radiographic examinations show a very low sensitivity and specificity in the detection of postoperative malpositions of the fibula in the tibial incisura [5, 6, 7]. If postoperative malpositions are not detected and the injury heals into a malposition, this will be associated with poor function and premature arthrosis [8].
Postoperative computer tomography is clearly superior to conventional X-rays for the exact assessment of the reduction of the fibula in the tibial incisura [9]. Postoperative CT examinations after ankle osteosynthesis show malpositions in the distal syndesmosis of up to 52% [10]. Detected relevant malpositions must be corrected in a second operation.

An alternative to this procedure is the intraoperative use of 3D image intensifiers. These devices allow a multidimensional imaging of the ankle joint [11, 12, 13].

The objective of the retrospective single-center study was to assess whether the position of the fibula in the tibial incisura can be determined by intraoperative 3D scanning with sufficient precision. Furthermore, it had to be clarified whether the intraoperative 3D image intensifier examination had an influence on the postoperative revision rate.

**Methods**

From September 2007 to December 2015, 200 intraoperative 3D scan of the ankle region were performed at the University Rostock in patients with instability of the distal tibiotalar syndesmosis after reduction and fixation of the fibula in the tibial incisura using one or two syndesmotic screws. All patients were placed on a carbon table in supine position with slightly raised ipsilateral pelvis. The healthy contralateral leg, bent in hip and knee, was placed on a leg shell. After reconstruction and stabilisation of the bone injuries, open reduction of the fibula into the tibial incisura and fixation with one or two tricortical syndesmotic screws (3.5 mm small fragment) was performed under conventional radiographic control. The 3D scan was performed before closing the wound.

The "Vario 3D Image Intensifier" from Ziehm was used. Primarily the "region of interest" and thus the "isocenter" of the 3D scan was determined in the anterior-posterior and in the lateral beam projection by means of fluoroscopy. In order to guarantee a collision-free 3D scan, the isocenter was defined as a radiation-free 135° movement of the C-arm around the injured ankle joint. For definitive imaging, the motorised C-arm performed an orbital movement around the fixed isocenter with a maximum rotation radius of 135° and produced 120 single fluoroscopic images in different angular positions from which the 3D scan was calculated. The three-dimensional data set represents an area with an edge length of 120 mm and allows reconstructions in all three planes (transversal, coronal, sagittal).

The following evaluation parameters for a correct joint position were defined in a standard protocol:

1) central position of the fibula in the tibial incisura 10 mm above the ankle plafond (transversal reconstructions)

2) central position of the fibula in the tibial incisura at the level of the ankle plafond (transversal reconstructions)

3) same articular space width between talus and medial and lateral malleolus at joint line (transversal and coronal reconstructions)
4) Congruence of the lateral malleolus joint surface to the lateral talus wall as an indication of correct rotation (coronal reconstructions)

All reconstruction planes were also used to assess fracture reduction, joint reconstruction and implant position. Whenever the 3D scan showed findings requiring correction, immediate correction followed. After position correction of the fibula in the tibial incisura, a new 3D scan was performed in all cases.

Postoperatively, computer tomography of both ankle joints was performed on all patients. A deviation of >2 mm in comparison to the healthy contralateral side was defined as a malposition of the fibula in the tibial incisura requiring revision. Exclusion criteria for the study was an acute or healed contralateral ankle fracture.

**Results**

A 3D scan was performed on 200 patients with unstable syndesmosis injury during the study period. The mean patient age was 47.4 years (18–83), gender distribution showed 128 (64.0%) male and 72 female (36.0%) patients. Syndesmosis injuries were associated with 120 sole fibula fractures (14 Maisonneuve), 26 isolated inner malleolus fractures, and 30 bi- and 22 trimalleolar fractures. 2 patients showed a purely ligamentous injury of the syndesmosis complex. In 190 patients 1, in 10 patients 2 syndesmotic screws were implanted.

186 of the intraoperative 3D scans (93.0%) showed a correct adjustment of the fibula in the tibial distal incisura according to the surgeon's assessment.

In 14 cases (7%), the fibula position was corrected after intraoperative evaluation of the 3D scan (Fig. 1a,1b).

In 8 patients (4.0%), the 3D scan detected overlong implants and replaced the affected screws with shorter implants.

In 6 patients (3%), the 3D scan showed that inner malleolus and Volkmann triangle fragments were not sufficiently stable osteosynthetically. Osteosynthesis was then extended to improve stability.

In 2 patients (1%), an intraarticular osteochondral fragment was detected by the 3D scan, which was not detected by conventional fluoroscopy (Fig. 2). An intraoperative revision of the internal joint space and removal of the fragment were performed.

In summary, 30 of 200 patients (15%) underwent a correction of the surgical restoration based on the intraoperative evaluation of the 3D scan.

In comparison with the healthy contralateral side, evaluations of postoperative CT examinations in no case revealed a defective position of the fibula in the tibial incisura worth revision, a relevant defective
position of the joint or an osteosynthesis requiring revision. Hence, the postoperative revision rate was 0%.

The subjective four-stage assessment of the image quality of the 3D scans by the surgeon resulted in 69.3% of the scores being rated “good”, 26.7% as “satisfactory” and 4.0% as “sufficient”. No scan received the evaluation criterion “not assessable”.

Discussion

Ankle fractures involving the syndesmosis complex generally have a worse prognosis than comparable fractures without tibiofibular ligament injuries. In 347 examined patients, Egol et al. were able to demonstrate that after 12 months the functional outcome and the pain level were significantly worse in the group with syndesmosis injuries [4]. Chissel et al. already reported poor clinical results in 1995 when syndesmosis width after surgical treatment exceeded the radiologically measured value of >1.5 mm [14]. Andersen noted a difference of more than 2 mm of the sagittal anterior tibiofibular distance as a predictor for poorer clinical outcome [15]. Moreover, Leeds and Ehrlich proved a significant correlation between arthrosis development and accompanying syndesmosis injury [8]. Current medium-term study results obtained by Veen et al. confirm a significantly higher arthrosis rate associated with ankle fractures with syndesmosis injury [16]. In addition, Ovaska et al. were able to show that, at 59%, misrepositioned syndesmosis is the most frequent cause of revision surgery of ankle fractures [17].

The intraoperative malposition rate of the distal tibiofibular syndesmosis in closed reduction is up to 52% and can be reduced to 15% by open reduction of the fibula with direct visualisation of the syndesmosis region [3, 18]. However, also malposition rates after open reduction are still high and require a reliable position control of the distal syndesmosis region. All conventional X-ray parameters (tibiofibular clear space, tibiofibular overlap, etc.) do not allow a sufficient assessment of the fibula position to the tibia [5, 19].

This applies to all syndesmosis injuries since Franke et al. could not identify risk factors such as injury type or fracture morphology after analysing 251 patients with syndesmosis injuries, which are associated with a lower rate of syndesmosis malposition [20].

Relevant evaluation criteria are the position of the fibula in the tibial incisura and the rotation of the fibula considering correct length reconstruction [9]. Measurements 10 mm above the tibial plafond taking into consideration the diastasis and anterior-posterior translation of the fibula were found to be parameters with high interobserver and intraobserver reliability with the position of the foot having no influence on the measurements [21].

Intraoperative control of the syndesmosis region is possible using 3D image intensifiers. A small case series of 10 patients with syndesmosis injuries was presented by Ruan et al. in 2011 [22]. An intraoperative 3D scan was performed before positioning the adjusting screw with the joint being temporarily adjusted by means of reduction forceps. The measurement parameter was the distance to
the anterior and posterior facets of the tibia. The aim was to achieve equal measuring distances. Once fine correction and adjusting screw application had been completed, a final second 3D scan was performed. In all cases, this scan showed a central and symmetrical positioning of the fibula in the tibial incisura.

Moon et al. reported an intraoperative revision rate of 23% using a 3D image intensifier for ankle fractures with syndesmosis injuries [23].

Franke et al. performed intraoperative 3D scans in 251 consecutive patients with syndesmosis injuries after adjusting screw placement, which resulted in direct intraoperative correction of osteosynthesis in 32.7% of patients [24]. The main reason was a malposition of the fibula in the tibial incisura in 25.5% and a necessary correction of the fracture reduction in 5.2% of the patients. Corrections due to implant misalignments were necessary in 2% of patients.

Davidovitch et al. compared the conventional versus 3D scan controlled intraoperative reduction of the ankle fork in 36 patients. In the relevant measuring range of 2 mm difference, significantly more postoperative malpositions in the control CT were found in the conventionally radiologically controlled group [25]. Our own data showed a lower malpositioning and correction rate of 7% which may be explained by the generally direct visualization of the syndesmosis stabilisation. Another surgical parameter that significantly influences the reduction result is the positioning of the reduction forceps in the anterior third of the tibia [26].

Compared to CT examinations, intraoperative radiation exposure resulting from the 3D scan can be classified as very low in total. Beerekamp et al. reported a maximum dose of 17 µSV for a 3D extremities scan compared to a 200 µSV dose for a postoperative CT examination [27].

**Conclusion**

The results of our study confirm that an intraoperative 3D image intensifier examination allows a reliable assessment of the anatomy of the distal syndesmosis region and the reconstructed ankle joint. Malpositions of the fibula in the tibial incisura and defective osteosyntheses were reliably detected and corrected intraoperatively. According to our data, a routine postoperative CT examination of the region is dispensable if the 3D scan can be easily assessed.

**Abbreviations**

Not applicable

**Declarations**

- Ethics approval and consent to participate
All procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. There was no informed consent requested in this trial. No personal or confidential data were included in this analysis. This article does not contain any studies with human participants or animals performed by any of the authors. The need for ethics approval was waived since data checking was anonymous and retrospective.

- **Availability of data and material**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- **Competing interests**

The authors declare that they have no competing interests.

- **Funding**

none

- **Authors' contributions**

Each author has participated in the work. MB: performing the surgical interventions, conception and design of the study, radiographic examination, analysis and interpretation of the data and writing of the manuscript. MaBr: radiographic examination, acquired the patient data, analysis and interpretation of the data. AW, RR, TM: performing the surgical interventions, conception and design of the study, interpretation of the data, revising manuscript critically for important intellectual content. All authors read and approved the final manuscript.

- **Acknowledgements**

Not applicable.

**References**

1. Shibuya N, Davis ML, Jupiter DC. - Epidemiology of foot and ankle fractures in the United States: an analysis of the National Trauma Data Bank (2007 to 2011). J Foot Ankle Surg. 2014;53(5):606–8.
2. Van Schie-Van der Weert EM, Van Lieshout EM, De Vries MR, Van der Elst M, Schepers T. - Determinants of outcome in operatively and non-operatively treated Weber-B ankle fractures. Arch Orthop Trauma Surg. 2012;132:257–63.

3. Sagi HC, Shah AR, Sanders RW. - The functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. J Orthop Trauma. 2012;26:439–43.

4. Egol KA, Pahk B, Walsh M, Tejwani NC, Davidovitch RI, Koval KJ. - Outcome after unstable ankle fracture: effect of syndesmotic stabilization. J Orthop Trauma. 2010;24:7–11.

5. Beumer A, van Hemert WLW, Niesing R, Entius CAC, Ginai AZ, Mulder PGH. Swierstra BA - Radiographic measurement of the distal tibiobular syndesmosis has limited use. Clin Orthop Relat Res. 2004;423:227–34.

6. Krähenbühl N, Weinberg MW, Davidson NP, Mills MK, Hintermann B, Saltzman CL, Barg A. – Imaging in syndesmotic injuty: a systemic review. Skeletal Radiol. 2018;47(5):631–48.

7. Marmor M, Hansen E, Han HK, Buckley J, Matityahu A. - Limitations of standard fluoroscopy in detecting rotational malreduction of the syndesmosis in an ankle fracture model. Foot Ankle Int. 2011;32:616–22.

8. Leeds HC, Ehrlich MG. - Instability of the distal tibiobular syndesmosis after bimalleolar and trimalleolar ankle fractures. J Bone Joint Surg Am. 1984;66:490–503.

9. van den Heuvel SB, Dingemans SA, Gardenbroek TJ, Schepers T. - Assessing Quality of Syndesmotic Reduction in Surgically Treated Acute Syndesmotic Injuries: A Systematic Review. J Foot Ankle Surg. 2019; (1):144–150.

10. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL. Lorich DG - Malreduction of the tibiobular syndesmosis in ankle fractures. Foot Ankle Int 2006 27: 788–792.

11. Atesok K, Finkelstein J, Khoury A, Peyser A, Weil Y, Liebergall M, Mosheiff R. - The use of intraoperative three-dimensional imaging (ISO-C-3D) in fixation of intraarticular fractures. Injury. 2007;38:1163–9.

12. Beerekamp MS, Sulkers GS, Ubbink DT, Maas M, Schep NW, Goslings JC. - Accuracy and consequences of 3D-fluoroscopy in upper and lower extremity fracture treatment: a systematic review. Eur J Radiol. 2012;81:4019–28.

13. Carelsen B, Haverlag R, Ubbink DT, Luitse JS, Goslings JC. - Does intraoperative fluoroscopic 3D imaging provide extra information for fracture surgery? Arch Orthop Trauma Surg. 2008;128:1419–24.

14. Chissell HR, Jones J. - The influence of a diastasis screw on the outcome of Weber type-C ankle fractures. J Bone Joint Surg Br. 1995;77:435–8.

15. Andersen MR, Diep LM, Frihagen F, Hellund JC, Madsen JE. Figved W – Importance of syndesmotic reduction on clinical outcome after syndesmotic injuries. J Orthop Trauma. 2019;33(8):397–403.

16. Veen EJD. Zuurmond RG - Mid-term results of ankle fractures with and without syndesmotic rupture. Foot Ankle Surg. 2015;21:30–6.
17. Ovaska MT, Mäkinen TJ, Madanat R, Kiljunen V, Lindahl J. - A comprehensive analysis of patients with malreduced ankle fractures undergoing re-operation. Int Orthop. 2014;38:83–8.

18. Miller AN, Carroll AE, Parker RJ, Boraiah S, Helfet DL. Lorich DG - Direct visualization for syndesmotic stabilization of ankle fractures. Foot Ankle Int. 2009;30:419–26.

19. Höcker K -. The skeletal radiology of the distal tibiobular joint. Arch Orthop Trauma Surg. 1994;113:345–6.

20. Franke J, von Recum J, Suda AJ, Vetter S, Grützner PA, Wendl K. - Predictors of a persistent dislocation after reduction of syndesmotic injuries detected with intraoperative three-dimensional imaging. Foot Ankle Int. 2014;35:1323–8.

21. Levack AE, Dvorzhinskiy A, Gausden EB, Garner MR, Warner SJ, Fabricant PD. Lorich DG – Sagittal ankle position does not affect axial CT measurements of the syndesmosis in a cadaveric model. Arch Orthop Trauma Surg. 2020;140(1):25–31.

22. Ruan Z, Luo C, Shi Z, Zhang B, Zeng B, Zhang C. Intraoperative reduction of distal tibiobular joint aided by three-dimensional fluoroscopy. Technol Health Care. 2011;19:161–6.

23. Moon SW, Kim JW. - Usefulness of intraoperative three-dimensional imaging in fracture surgery: a prospective study. J Orthop Sci. 2014;19:125–31.

24. Franke J, von Recum J, Suda AJ, Grützner PA. Wendl K - Intraoperative three-dimensional imaging in the treatment of acute unstable syndesmotic injuries. J Bone Joint Surg Am. 2012;94:1386–90.

25. Davidovitch RI, Weil Y, Karia R, Forman J, Looze C, Liebergall M, Egol K. Intraoperative syndesmotic reduction: Three-dimensional versus standard fluoroscopic imaging. J Bone Joint Surg Am. 2013;95:1838–43.

26. Cosgrove CT, Putnam SM, Cherney SM, Ricci WM, Spraggs-Hughes A, McAndrew CM, Gardner MJ. – Medial clamp tine positioning affects ankle syndesmosis malreduction. - J Orthop Trauma. 2017;31(8):440–6.

27. Beerekamp MS, Ubbink DT, Maas M, Luitse JS, Kloen P, Blokhuis TJ, Segers MJ, Marmor M, Schep NW, Dijkgraaf MG. Goslings JC - Fracture surgery of the extremities with the intra-operative use of 3D-RX: a randomized multicenter trial (EF3X-trial). BMC Musculoskelet Disord. 2011;12:151–60.

**Figures**
Figure 1

Figure 1a Dorsal malposition of the fibula, axial view. Figure 1b Correct position of the fibula in the tibial incisura after intraoperative correction, axial view.

Figure 2
Intraarticular osteochondral fragment medial joint space, coronar view.