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# Utility of Weight-Bearing Computed Tomography in Postoperative Assessment of Ankle Fractures


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# Faculty Disclosure Information

- Nothing to disclose

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**ABSTRACT:**

**Background:** Ankle fractures are among the most common injuries requiring surgical intervention. Standard radiographs are typically used for postoperative assessment; however, some patients continue to experience residual symptoms despite satisfactory radiographic outcomes. Weight-bearing computed tomography (WBCT), though not yet widely integrated into clinical practice, offers potential advantages in evaluating lower-limb deformities, injuries, and arthritis. This study explores the utility of WBCT for the midterm assessment following ankle fracture fixation and compares its findings with those obtained from standard radiographs.

**Methods:** In this retrospective case study, we analyzed the correlations between the functional outcome scores approximately one year post-surgery and parameters assessed using WBCT. Pearson's correlation coefficient was used to evaluate these correlations, and a *t*-test was performed to assess their statistical significance, with a threshold *p*-value of 0.05. Additionally, Spearman's rank correlation coefficient was calculated as a supplementary descriptive measure, without significance testing. These correlations were then compared with those obtained from standard ankle radiographic views (anteroposterior, lateral, and mortise).

**Results:** Several correlations were identified between WBCT parameters and functional scales, with certain parameters demonstrating high statistical significance ($p < 0.05$). Overall, the correlations observed for WBCT were stronger than those for standard radiographs.

**Conclusions:** Although the study cohort was limited, the findings suggest that WBCT may provide additional insights beyond conventional radiography. Further research with larger patient groups is needed to establish its clinical relevance.

## Calculations were performed as follows:

For each patient, three surgeons performed measurements of the parameters twice at three different levels for both ankles, resulting in a total of 18 values per parameter. The mean values from these measurements were then calculated and used for further analysis. Differences between the injured and non-injured sides were computed, and absolute values were recorded for statistical evaluation. Measurement reliability was assessed using the intra-class correlation coefficient (ICC) to determine both intra-rater and inter-rater reliability. The standard deviation (SD) for each parameter was also calculated.

For WBCT analysis, parameters focusing on tibial incisura anatomy were selected:
1. Depth of the incisura (depth);
2. Engagement of the fibula within the incisura (engagement);
3. Rotation of the incisura (rotation);
4. Protrusion of the fibula within the incisura (protrusion);
5. Torsion of the fibula (torsion).

For the radiograph assessments, parameters commonly used for ankle evaluation were employed:
1. Ankle joint space;
2. Medial clear space;
3. Lateral clear space;
4. Fibular overlap;
5. Syndesmosis width (mortise view).

Functional scales selected for the study:
1. Visual Analogue Score Hindfoot-Ankle (VAS-HA)
2. European Foot and Ankle Society (EFAS) Score
3. American Orthopedic Foot and Ankle Society (AOFAS) Score
4. Olerud–Molander Ankle Score (OMAS)
5. Foot and Ankle Ability Measure (FAAM)

# Some of the parameters for WBCT presented below.

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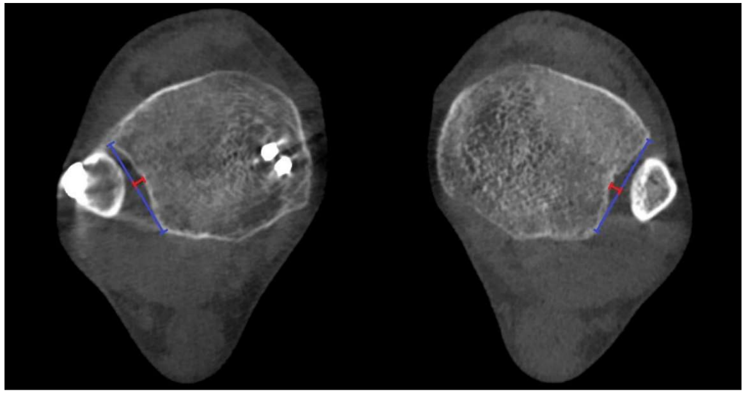

**Figure 1. Depth (red).**

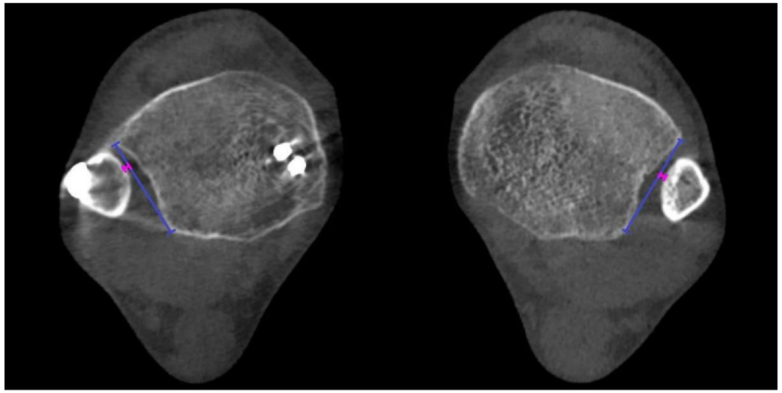

**Figure 2. Engagement (pink)**

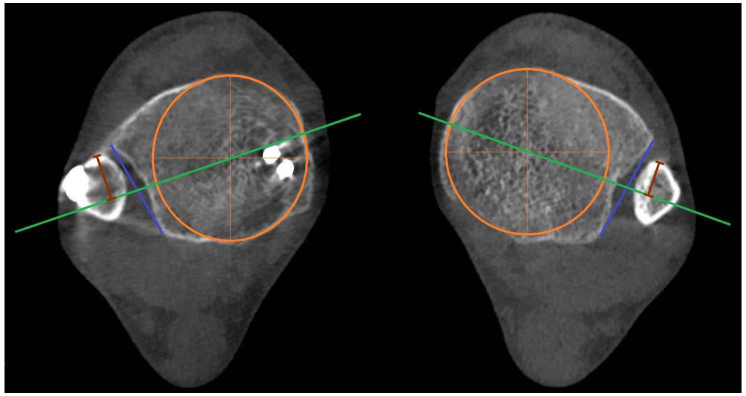

**Figure 3. Protrusion (brown)**

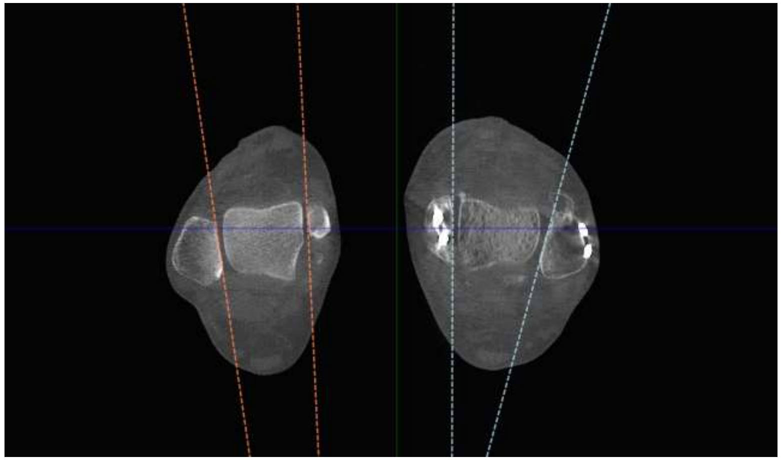

**Figure 4. Torsion (angle between orange lines [healthy side] or light blue lines [affected side])**

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# Results

WBCT parameters showed stronger correlations with functional outcomes compared to radiographs. The parameter "fibula engagement" correlated with the VAS-HA (p=0.047), EFAS (p=0.085), FAAM (p=0.01), and Olerud-Molander scales. "Fibula protrusion" correlated with FAAM (p=0.04). Radiographs demonstrated weaker correlations with no parameter where p-value was <0,05. The FAAM scale showed the most significant associations, while AOFAS and Olerud-Molander scales showed the least.

| VAS-HA Correlation | | | |
|---|---|---|---|
| WBCT Parameter | Pearson | Spearman's | p-value |
| Depth | −0.1477102 | −0.0083426 | 0.43556837 |
| Engagement | −0.3644136 | 0.40122358 | 0.04708882 |
| Rotation | 0.09818077 | −0.0804227 | 0.60547187 |
| Protrusion | −0.241647 | 0.27230256 | 0.19756955 |
| Torsion | −0.2158447 | 0.26362625 | 0.2513249 |
| Radiograph Parameter | | | |
| Ankle Joint Space | −0.0830054 | 0.09888765 | 0.66255783 |
| Lateral Clear Space | −0.1838207 | 0.21279199 | 0.3303087 |
| Medial Clear Space | 0.03794588 | 0.02847608 | 0.84210519 |
| Fibular Overlap | −0.0595995 | 0.21212458 | 0.75424124 |
| Syndesmosis Width (Mortise) | −0.1323589 | 0.24276974 | 0.48527109 |

| FAAM Correlation | | | |
|---|---|---|---|
| WBCT Parameter | Pearson | Spearman's | p-value |
| Depth | −0.18584 | −0.02703 | 0.324913 |
| Engagement | −0.45669 | 0.431146 | 0.010847 |
| Rotation | −0.08174 | −0.00634 | 0.667414 |
| Protrusion | −0.37582 | 0.339822 | 0.040087 |
| Torsion | −0.1369 | 0.174082 | 0.470262 |
| Radiograph Parameter | | | |
| Ankle Joint Space | −0.2398 | 0.261958 | 0.201124 |
| Lateral Clear Space | −0.22272 | 0.107119 | 0.236158 |
| Medial Clear Space | 0.189204 | −0.02781 | 0.316076 |
| Fibular Overlap | 0.006599 | 0.06396 | 0.972376 |
| Syndesmosis Width (Mortise) | −0.18155 | 0.359121 | 0.336428 |

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# Discussion

**1. Is Weight Bearing Truly Necessary?**

The reliability of equal weight distribution in weight-bearing imaging is questionable, especially given small sample sizes and variability in patient performance. While minor variations in load (e.g., 40–60%) may not affect healthy ankles significantly, they could impact measurements in pathological cases. WBCT conditions differ from plain radiographs, requiring further study. However, most literature supports weight-bearing imaging due to its impact on bone alignment and diagnostic accuracy, especially in surgical planning.

**2. Why Not Use Classical CT Instead of WBCT?**

Classical CT lacks the biomechanical context provided by weight bearing. While load simulators exist, they are limited and not equivalent to standing WBCT. Additionally, WBCT offers lower radiation, faster exams, and potential cost benefits. The diagnostic accuracy of WBCT is superior in detecting syndesmotic injuries, justifying its use.

**3. Is Radiography Alone Sufficient?**

Radiographs are accessible and low-radiation but often insufficient for precise syndesmosis assessment. Correlation with functional outcomes was weak in our study, with most radiographic measurements showing no statistical significance. WBCT demonstrated better diagnostic performance and should be further explored in larger cohorts.

**4. Is a One-Sided Exam Reliable Compared to Bilateral Assessment?**

Unilateral imaging may miss asymmetries or anatomical variants. Bilateral exams, although more demanding, provide essential comparative data, especially preoperatively. Our study confirms the need for bilateral assessment due to variability among patients.

**5. What About Perioperative Assessment?**

Early postoperative WBCT is limited by patient restrictions, though some studies suggest safe weight bearing after 2 weeks. Preoperative WBCT appears more promising, and future research could explore seated cone beam imaging as a non-weight-bearing alternative.

**6. Are the Measurements Too Complex?**

Manual measurement is time-consuming but yielded high reliability in our study (ICC > 0.9). While automated tools could improve efficiency, they are not yet widely used. Our findings help identify the most promising parameters for further exploration.

**7. Availability and Costs**

WBCT availability in Poland is limited. Although it can be cost-effective in high-volume settings, financial viability remains a concern when usage is low.

**8. New and Similar Studies on the Topic**

Recent studies confirm WBCT's value in syndesmosis diagnostics, despite differing methods. As standardization improves and costs decrease, WBCT is likely to see broader adoption.

**9. Limitations**

Our study included 30 patients, with no subgroups or long-term follow-up, which may affect statistical strength. Some parameters and projections were omitted for simplicity, and manual measurements introduced

**Conclusions**

The null hypothesis, which assumed no correlation between the functional scales and radiological parameters, was rejected based on our findings. Instead, our results support the alternative hypothesis, indicating that specific WBCT-derived measurements demonstrate statistically significant correlations with the functional outcomes. While this suggests that WBCT could be a valuable tool in midterm postoperative evaluation, further studies with larger cohorts are needed to validate these findings and refine the interpretation of specific parameters.

Importantly, our study was not designed to compare weight-bearing with non-weight-bearing imaging or to determine whether weight-bearing assessments inherently provide superior results. Rather, it aimed to investigate the association between imaging parameters and functional status in a clinically relevant, weight-bearing setting. Nevertheless, our results indicate that standard radiographs exhibited considerably weaker correlations with functional scales than WBCT, suggesting that WBCT may offer a more precise and informative evaluation of joint integrity and alignment following ankle fracture fixation.

These findings open up significant opportunities for further research in this field. A crucial next step would be to repeat the study on a larger patient cohort to enhance statistical power and improve the generalizability of the results. Additionally, conducting subgroup analyses could provide insights into whether specific fracture patterns or treatment methods influence the correlation between the radiological parameters and functional outcomes. Another important aspect would be the long-term follow-up of patients to determine whether the observed correlations remain stable over time and whether WBCT parameters can serve as predictive markers for long-term clinical outcomes.

Future research should also explore additional radiological parameters used in other studies to refine the understanding of their clinical relevance. Moreover, assessing the clinical significance of imaging findings in relation to real-world functional impairment could help bridge the gap between radiological assessments and patient-reported outcomes. Comparisons with conventional 3D imaging techniques such as CT and MRI may further clarify the advantages and limitations of WBCT in postoperative evaluation.

Another potential area of investigation is the impact of weight bearing on imaging results. Performing WBCT scans under both standing and seated conditions could help determine whether weight application significantly alters measurement outcomes. Additionally, it would be valuable to assess the reliability of standard radiographs by evaluating whether repeated imaging yields consistent results, thereby determining the reproducibility and accuracy of conventional radiographic assessments in postoperative monitoring.

By addressing these aspects, future studies could further establish the role of WBCT in postoperative evaluation, optimize measurement techniques, and provide valuable insights into its clinical applications.

## References


1. Barg, A.; Bailey, T.; Richter, M.; de Cesar Netto, C.; Lintz, F.; Burssens, A.; Phisitkul, P.; Hanrahan, C.J.; Saltzman, C.L. Weightbearing Computed Tomography of the Foot and Ankle: Emerging Technology Topical Review. Foot Ankle Int. 2018, 39, 376–386. https://doi.org/10.1177/1071100717740330.
2. Bruno, F.; Arrigoni, F.; Palumbo, P.; Natella, R.; Splendiani, A.; Di Cesare, E.; Guglielmi, G.; Masciocchi, C.; Barile, A. Weight-bearing MR Imaging of Knee, Ankle and Foot. Semin. Musculoskelet. Radiol. 2019, 23, 594–602. https://doi.org/10.1055/s-0039-1697940.
3. Carrara, C.; Caravaggi, P.; Belvedere, C.; Leardini, A. Radiographic angular measurements of the foot and ankle in weight-bearing: A literature review. Foot Ankle Surg. 2020, 26, 509–517. https://doi.org/10.1016/j.fas.2019.07.008.
4. Carrino, J.A.; Al Muhit, A.; Zbijewski, W.; Thawait, G.K.; Stayman, J.W.; Packard, N.; Senn, R.; Yang, D.; Foos, D.H.; York-ston, J.; et al. Dedicated cone-beam CT system for extremity imaging. Radiology 2014, 270, 816–824. https://doi.org/10.1148/radiol.13130225.
5. Godoy-Santos, A.L.; Netto, C.D.C.; Weight-bearing ct international study group. weight-bearing computed tomography of the foot and ankle: An update and future directions. Acta Ortop. Bras. 2018, 26, 135–139. https://doi.org/10.1590/1413-785220182602188482.
6. Lawlor, M.C.; Kluczynski, M.A.; Marzo, J.M. Weight-Bearing Cone-Beam CT Scan Assessment of Stability of Supination External Rotation Ankle Fractures in a Cadaver Model. Foot Ankle Int. 2018, 39, 850–857. https://doi.org/10.1177/1071100718761035.
7. Leardini, A.; Durante, S.; Belvedere, C.; Caravaggi, P.; Carrara, C.; Berti, L.; Lullini, G.; Giacomozzi, C.; Durastanti, G.; Or-tolani, M.; et al. Weight-bearing CT Technology in Musculoskeletal Pathologies of the Lower Limbs: Techniques, Initial Applications, and Preliminary Combinations with Gait-Analysis Measurements at the Istituto Ortopedico Rizzoli. Semin. Musculoskelet. Radiol. 2019, 23, 643–656. https://doi.org/10.1055/s-0039-1697939.
8. Shakoor, D.; Osgood, G.M.; Brehler, M.; Zbijewski, W.B.; de Cesar Netto, C.; Shafiq, B.; Orapin, J.; Thawait, G.K.; Shon, L.C.; Demehri, S. Cone-beam CT measurements of distal tibio-fibular syndesmosis in asymptomatic uninjured ankles: Does weight-bearing matter? Skelet. Radiol. 2019, 48, 583–594. https://doi.org/10.1007/s00256-018-3074-6.
9. Ludlow, J.B.; Johnson, B.K.; Ivanovic, M. Estimation of effective doses from MDCT and CBCT imaging of extremities. J. Radiol. Prot. 2018, 38, 1371–1383. https://doi.org/10.1088/1361-6498/aae44b.
10. Alexander, N.B.; Bettin, C.C.; Sarfani, S.; Strickland, C.D.; Richardson, D.R.; Murphy, G.A.; Grear, B.J. Cost Analysis and Utilization of Weight Bearing CT. Foot Ankle Orthop. 2022, 7, 2473011421S00075. https://doi.org/10.1177/2473011421S00075. PMCID: PMC8793528.
11. Alexander, N.B.; Sarfani, S.; Strickland, C.D.; Richardson, D.R.; Murphy, G.A.; Grear, B.J.; Bettin, C.C. Cost Analysis and Reimbursement of Weightbearing Computed Tomography. Foot Ankle Orthop. 2023, 8, 24730114231164143. https://doi.org/10.1177/24730114231164143.
12. Richter, M.; Lintz, F.; de Cesar Netto, C.; Barg, A.; Burssens, A. Results of more than 11,000 scans with weightbearing CT—Impact on costs, radiation exposure, and procedure time. Foot Ankle Surg. 2020, 26, 518–522. https://doi.org/10.1016/j.fas.2019.05.019.
13. Conti, M.S.; Ellis, S.J. Weight-bearing CT Scans in Foot and Ankle Surgery. J. Am. Acad. Orthop. Surg. 2020, 28, e595–e603. https://doi.org/10.5435/JAAOS-D-19-00700.
14. Hirschmann, A.; Pfirrmann, C.W.; Klammer, G.; Espinosa, N.; Buck, F.M. Upright cone CT of the hindfoot: Comparison of the non-weight-bearing with the upright weight-bearing position. Eur. Radiol. 2014, 24, 553–558. https://doi.org/10.1007/s00330-013-3028-2.
15. Kim, J.; Ellis, S.; Carrino, J.A. Weight-Bearing Computed Tomography of the Foot and Ankle—What to Measure? Foot Ankle Clin. 2023, 28, 619–640. https://doi.org/10.1016/j.fcl.2023.04.004.
16. Li, J.; Fang, M.; Van Oevelen, A.; Peiffer, M.; Audenaert, E.; Burssens, A.; International Weightbearing CT Society. Diagnostic applications and benefits of weightbearing CT in the foot and ankle: A systematic review of clinical studies. Foot Ankle Surg. 2024, 30, 7–20. https://doi.org/10.1016/j.fas.2023.09.001.
17. Lintz, F.; Beaudet, P.; Richardi, G.; Brilhault, J. Weight-bearing CT in foot and ankle pathology. Orthop. Traumatol. Surg. Res. 2021, 107, 102772. https://doi.org/10.1016/j.otsr.2020.102772.
18. Lintz, F.; Bernasconi, A.; Ferkel, E.I. Can Weight-Bearing Computed Tomography Be a Game-Changer in the Assessment of Ankle Sprain and Ankle Instability? Foot Ankle Clin. 2023, 28, 283–295. https://doi.org/10.1016/j.fcl.2023.01.003.
19. Lintz, F.; de Cesar Netto, C.; Barg, A.; Burssens, A.; Richter, M.; Weight Bearing CT International Study Group. Weight-bearing cone beam CT scans in the foot and ankle. EFORT Open Rev. 2018, 3, 278–286. https://doi.org/10.1302/2058-5241.3.170066.
20. Lôbo, C.F.T.; Bordalo-Rodrigues, M.; Weight-Bearing Computed Tomography International Study Group. Weight-bearing cone beam ct scans and its uses in ankle, foot, and knee: An update article. Acta Ortop. Bras. 2021, 29, 105–110. https://doi.org/10.1590/1413-785220212902236939.
21. Patel, S.; Malhotra, K.; Cullen, N.P.; Singh, D.; Goldberg, A.J.; Welck, M.J. Defining reference values for the normal tib-io-fibular syndesmosis in adults using weight-bearing CT. Bone Jt. J. 2019, 101, 348–352. https://doi.org/10.1302/0301-620X.101B3.BJJ-2018-0829.R1.
22. Richter, M.; de Cesar Netto, C.; Lintz, F.; Barg, A.; Burssens, A.; Ellis, S. The Assessment of Ankle Osteoarthritis with Weight-Bearing Computed Tomography. Foot Ankle Clin. 2022, 27, 13–36. https://doi.org/10.1016/j.fcl.2021.11.001.
23. Tassone, J.; Violand, M.; Heigh, E.G.; Hubbard, C.; Tien, A.; Shapiro, J. Update on Investigation Methods for Lower Ex-trem-ity Biomechanics. Clin. Podiatr. Med. Surg. 2020, 37, 23–37. https://doi.org/10.1016/j.cpm.2019.08.003.
24. Zhang, J.Z.; Lintz, F.; Bernasconi, A.; Weight Bearing CT International Study Group; Zhang, S. 3D Biometrics for Hindfoot Alignment Using Weightbearing Computed Tomography. Foot Ankle Int. 2019, 40, 720–726. https://doi.org/10.1177/1071100719835492.
25. Bartonícek, J. Anatomy of the tibiofibular syndesmosis and its clinical relevance. Surg. Radiol. Anat. 2003, 25, 379–386. https://doi.org/10.1007/s00276-003-0156-4.
26. Boszczyk, A.; Kwapisz, S.; Krümmel, M.; Grass, R.; Rammelt, S. Anatomy of the tibial incisura as a risk factor for syn-des-motic injury. Foot Ankle Surg. 2019, 25, 51–58. https://doi.org/10.1016/j.fas.2017.08.003.
27. Ceccarini, P.; Donantoni, M.; Milazzo, F.; Prezioso, V.; Petruccelli, R.; Samaila, E.M.; Marcolli, D.; Leigheb, M.; Rinonapoli, G.; Caraffa, A. Fixation of Posterior Malleolus in Trimalleolar Ankle Fractures: Anteroposterior Screw or Posterolateral Plate? Appl. Sci. 2024, 14, 802. https://doi.org/10.3390/app14020802.
28. Gardner, M.J.; Demetrakopoulos, D.; Briggs, S.M.; Helfet, D.L.; Lorich, D.G. Malreduction of the tibiofibular syndesmosis in ankle fractures. Foot Ankle Int. 2006, 27, 788–792. https://doi.org/10.1177/107110070602701005.
29. Spindler, F.T.; Böcker, W.; Polzer, H.; Baumbach, S.F. A systematic review of studies on the diagnostics and classification system used in surgically treated, acute, isolated, unstable syndesmotic injury: A plea for uniform definition of syndesmotic injuries. EFORT Open Rev. 2024, 9, 16–24. https://doi.org/10.1530/EOR-23-0097.
30. Amin, A.; Janney, C.; Sheu, C.; Jupiter, D.C.; Panchbhavi, V.K. Weight-Bearing Radiographic Analysis of the Tibiofibular Syndesmosis. Foot Ankle Spec. 2019, 12, 211–217. https://doi.org/10.1177/1938640018766631.
31. Beumer, A.; van Hemert, W.L.; Niesing, R.; Entius, C.A.; Ginai, A.Z.; Mulder, P.G.; Swierstra, B.A. Radiographic meas-ure-ment of the distal tibiofibular syndesmosis has limited use. Clin. Orthop. Relat. Res. 2004, 423, 227–234. https://doi.org/10.1097/01.blo.0000129152.81015.ad.
32. Pneumaticos, S.G.; Noble, P.C.; Chatziioannou, S.N.; Trevino, S.G. The effects of rotation on radiographic evaluation of the tibiofibular syndesmosis. Foot Ankle Int. 2002, 23, 107–111. https://doi.org/10.1177/107110070202300205.
33. Shah, A.S.; Kadakia, A.R.; Tan, G.J.; Karadsheh, M.S.; Wolter, T.D.; Sabb, B. Radiographic evaluation of the normal distal tibiofibular syndesmosis. Foot Ankle Int. 2012, 33, 870–876. https://doi.org/10.3113/FAI.2012.0870.
34. Abbasian, M.; Biglari, F.; Sadighi, M.; Ebrahimpour, A. Reliability of Postoperative Radiographies in Ankle Fractures. Arch. Bone Jt. Surg. 2020, 8, 598–604. https://doi.org/10.22038/abjs.2020.43134.2173.
35. De Luna, V.; Caterini, A.; Casci, C.; Marsiolo, M.; Efremov, K.; De Maio, F.; Farsetti, P. Clinical and Radiological Results after Fracture-Dislocations of the Ankle: A Medium- to Long-Term Followup Study. J. Funct. Morphol. Kinesiol. 2022, 7, 30. https://doi.org/10.3390/jfmk7020030.
36. Biloglav, Z.; Medaković, P.; Buljević, J.; Žuvela, F.; Padjen, I.; Vrkić, D.; Ćurić, J. The analysis of waiting time and utilization of computed tomography and magnetic resonance imaging in Croatia: A nationwide survey. Croat. Med. J. 2020, 61, 538–546. https://doi.org/10.3325/cmj.2020.61.538.
37. van Sambeek, J.; Luinstra, M.; Te Loo, E.; Pijl, M. The success of walk-in-computed tomography in practice. Eur. J. Radiol. 2018, 109, 88–94. https://doi.org/10.1016/j.ejrad.2018.09.031.
38. Gądek, A.; Liszka, H.; Zając, M. The effect of pre-operative high doses of methylprednisolone on pain management and convalescence after total hip replacement in elderly: A double-blind randomized study. Int. Orthop. 2021, 45, 857–863. https://doi.org/10.1007/s00264-020-04802-8.
39. Heller, G.Z.; Manuguerra, M.; Chow, R. How to analyze the Visual Analogue Scale: Myths, truths and clinical relevance. Scand. J. Pain. 2016, 13, 67–75. https://doi.org/10.1016/j.sjpain.2016.06.012.

40. Hong, C.C.; Roy, S.P.; Nashi, N.; Tan, K.J. Functional outcome and limitation of sporting activities after bimalleolar and trimalleolar ankle fractures. Foot Ankle Int. 2013, 34, 805–810. https://doi.org/10.1177/1071100712472490.
41. Langley, G.B.; Sheppeard, H. The visual analogue scale: Its use in pain measurement. Rheumatol. Int. 1985, 5, 145–148. https://doi.org/10.1007/BF00541514.
42. Matheny, L.M.; Clanton, T.O. Rasch Analysis of Reliability and Validity of Scores from the Foot and Ankle Ability Measure (FAAM). Foot Ankle Int. 2020, 41, 229–236. https://doi.org/10.1177/1071100719884554.
43. Martin, R.L.; Irrgang, J.J.; Burdett, R.G.; Conti, S.F.; Van Swearingen, J.M. Evidence of validity for the Foot and Ankle Ability Measure (FAAM). Foot Ankle Int. 2005, 26, 968–983. https://doi.org/10.1177/107110070502601113.
44. McKeown, R.; Parsons, H.; Ellard, D.R.; Kearney, R.S. An evaluation of the measurement properties of the Olerud Molander Ankle Score in adults with an ankle fracture. Physiotherapy 2021, 112, 1–8. https://doi.org/10.1016/j.physio.2021.03.015.
45. Nair, A.V.; Shamsuddin, K.; John, P.S.; Hämäläinen, J.A.; Kurien, M.A. Correlation of visual analogue scale foot and ankle (VAS-FA) to AOFAS score in malleolar fractures using Indian language questionnare. Foot Ankle Surg. 2015, 21, 125–131. https://doi.org/10.1016/j.fas.2014.10.006.
46. Paget, L.D.A.; Sierevelt, I.N.; Tol, J.L.; Kerkhoffs, G.M.M.J.; Reurink, G. The completely patient-reported version of the American Orthopaedic Foot and Ankle Society (AOFAS) score: A valid and reliable measurement for ankle osteoarthritis. J. ISAKOS 2023, 8, 345–351. https://doi.org/10.1016/j.jisako.2023.07.003.
47. Ribeiro de Ávila, V.; Bento, T.; Gomes, W.; Leitão, J.; Fortuna de Sousa, N. Functional Outcomes and Quality of Life After Ankle Fracture Surgically Treated: A Systematic Review. J. Sport Rehabil. 2018, 27, 274–283. https://doi.org/10.1123/jsr.2016-0199.
48. Richter, M.; Agren, P.H.; Besse, J.L.; Cöster, M.; Kofoed, H.; Maffulli, N.; Rosenbaum, D.; Steultjens, M.; Alvarez, F.; Bosz-czyk, A.; et al. EFAS Score-Multilingual development and validation of a patient-reported outcome measure (PROM) by the score committee of the European Foot and Ankle Society (EFAS). Foot Ankle Surg. 2018, 24, 185–204. https://doi.org/10.1016/j.fas.2018.05.004.
49. Stüber, J.; Zech, S.; Bay, R.; Qazzaz, A.; Richter, M. Normative data of the Visual Analogue Scale Foot and Ankle (VAS FA) for pathological conditions. Foot Ankle Surg. 2011, 17,166–172. https://doi.org/10.1016/j.fas.2010.05.005.
50. Wojcieszek, A.; Kurowska, A.; Majda, A.; Liszka, H.; Gądek, A. The Impact of Chronic Pain, Stiffness and Difficulties in Per-forming Daily Activities on the Quality of Life of Older Patients with Knee Osteoarthritis. Int. J. Environ. Res. Public Health 2022, 19, 16815. https://doi.org/10.3390/ijerph192416815.
51. van Vlijmen, N.; Denk, K.; van Kampen, A.; Jaarsma, R.L. Long-term Results After Ankle Syndesmosis Injuries. Orthopedics 2015, 38, e1001–e1006. https://doi.org/10.3928/01477447-20151020-09.
52. Boszczyk, A.; Kwapisz, S.; Krümmel, M.; Grass, R.; Rammelt, S. Correlation of Incisura Anatomy With Syndesmotic Mal-re-duction. Foot Ankle Int. 2018, 39, 369–375. https://doi.org/10.1177/1071100717744332.
53. Cherney, S.M.; Spraggs-Hughes, A.G.; McAndrew, C.M.; Ricci, W.M.; Gardner, M.J. Incisura Morphology as a Risk Factor for Syndesmotic Malreduction. Foot Ankle Int. 2016, 37, 748–754. https://doi.org/10.1177/1071100716637709.
54. Ebraheim, N.A.; Lu, J.; Yang, H.; Rollins, J. The fibular incisure of the tibia on CT scan: A cadaver study. Foot Ankle Int. 1998, 19, 318–321. https://doi.org/10.1177/107110079801900509.
55. Höcker, K.; Pachucki, A. Die Incisura fibularis tibiae. Die Stellung der Fibula in der distalen Syndesmose am Querschnitt [The fibular incisure of the tibia. The cross-sectional position of the fibula in distal syndesmosis]. Unfallchirurg 1989, 92, 401–406. (In German)
56. Brinch, S.; Wellenberg, R.H.H.; Boesen, M.P.; Maas, M.; Johannsen, F.E.; Nybing, J.U.; Turmezei, T.; Streekstra, G.J.; Hansen, P. Weight-bearing cone-beam CT: The need for standardised acquisition protocols and measurements to fulfill high ex-pec-tations—A review of the literature. Skelet. Radiol. 2023, 52, 1073–1088; Erratum in Skelet. Radiol. 2023, 52, 1431. https://doi.org/10.1007/s00256-022-04223-1.
57. Chen, Y.; Qiang, M.; Zhang, K.; Li, H.; Dai, H. A reliable radiographic measurement for evaluation of normal distal tib-io-fibular syndesmosis: A multi-detector computed tomography study in adults. J. Foot Ankle Res. 2015, 8, 32. https://doi.org/10.1186/s13047-015-0093-6.
58. Ebinger, T.; Goetz, J.; Dolan, L.; Phisitkul, P. 3D model analysis of existing CT syndesmosis measurements. Iowa Orthop. J. 2013, 33, 40–46.
59. Lee, S.W.; Lee, K.J.; Park, C.H.; Kwon, H.J.; Kim, B.S. The Valid Diagnostic Parameters in Bilateral CT Scan to Predict Un-sta-ble Syndesmotic Injury with Ankle Fracture. Diagnostics 2020, 10, 812. https://doi.org/10.3390/diagnostics10100812.
60. Nault, M.L.; Hébert-Davies, J.; Laflamme, G.Y.; Leduc, S. CT scan assessment of the syndesmosis: A new reproducible method. J. Orthop. Trauma. 2013, 27, 638–641. https://doi.org/10.1097/BOT.0b013e318284785a.
61. Osgood, G.M.; Shakoor, D.; Orapin, J.; Qin, J.; Khodarahmi, I.; Thawait, G.K.; Ficke, J.R.; Schon, L.C.; Demehri, S. Reliability of distal tibio-fibular syndesmotic instability measurements using weightbearing and non-weightbearing cone-beam CT. Foot Ankle Surg. 2019, 25, 771–781. https://doi.org/10.1016/j.fas.2018.10.003.
62. Miller, C.P.; Ghorbanhoseini, M.; Ehrlichman, L.K.; Walley, K.C.; Ghaheri, A.; Kwon, J.Y. High Variability of Observed Weight Bearing During Standing Foot and Ankle Radiographs. Foot Ankle Int. 2017, 38, 690–693. https://doi.org/10.1177/1071100717695361.
63. Malhotra, K.; Welck, M.; Cullen, N.; Singh, D.; Goldberg, A.J. The effects of weight bearing on the distal tibiofibular syn-desmosis: A study comparing weight bearing-CT with conventional CT. Foot Ankle Surg. 2019, 25, 511–516. https://doi.org/10.1016/j.fas.2018.03.006.
64. Raheman, F.J.; Rojoa, D.M.; Hallet, C.; Yaghmour, K.M.; Jeyaparam, S.; Ahluwalia, R.S.; Mangwani, J. Can Weightbearing Cone-beam CT Reliably Differentiate Between Stable and Unstable Syndesmotic Ankle Injuries? A Systematic Review and Meta-analysis. Clin. Orthop. Relat. Res. 2022, 480, 1547–1562. https://doi.org/10.1097/CORR.0000000000002171.
65. Souleiman, F.; Heilemann, M.; Hennings, R.; Hepp, P.; Gueorguiev, B.; Richards, G.; Osterhoff, G.; Gehweiler, D. Effect of weightbearing and foot positioning on 3D distal tibiofibular joint parameters. Sci. Rep. 2022, 12, 9357. https://doi.org/10.1038/s41598-022-12963-2.
66. Boszczyk, A.; Kwapisz, S.; Piciński, M.; Kordasiewicz, B.; Liszka, H. Non-weightbearing compared with weightbearing x-rays in hallux valgus decision-making. Skelet. Radiol. 2020, 49, 1441–1447. https://doi.org/10.1007/s00256-020-03441-9.
67. Mehta, J.S.; Reed, M.R.; McVie, J.L.; Sanderson, P.L. Weight-bearing radiographs in thoracolumbar fractures: Do they in-flu-ence management? Spine 2004, 29, 564–567. https://doi.org/10.1097/01.brs.0000113873.07484.5d.
68. Burssens, A.; Vermue, H.; Barg, A.; Krähenbühl, N.; Victor, J.; Buedts, K. Templating of Syndesmotic Ankle Lesions by Use of 3D Analysis in Weightbearing and Nonweightbearing CT. Foot Ankle Int. 2018, 39, 1487–1496. https://doi.org/10.1177/1071100718791834.
69. Hamard, M.; Neroladaki, A.; Bagetakos, I.; Dubois-Ferrière, V.; Montet, X.; Boudabbous, S. Accuracy of cone-beam com-put-ed tomography for syndesmosis injury diagnosis compared to conventional computed tomography. Foot Ankle Surg. 2020, 26, 265–272. https://doi.org/10.1016/j.fas.2019.03.006.
70. Kang, D.H.; Kang, C.; Hwang, D.S.; Song, J.H.; Song, S.H. The value of axial loading three dimensional (3D) CT as a sub-stitute for full weightbearing (standing) 3D CT: Comparison of reproducibility according to degree of load. Foot Ankle Surg. 2019, 25, 215–220. https://doi.org/10.1016/j.fas.2017.10.014.
71. Kubik, J.F.; Rollick, N.C.; Bear, J.; Diamond, O.; Nguyen, J.T.; Kleeblad, L.J.; Helfet, D.L.; Wellman, D.S. Assessment of mal-reduction standards for the syndesmosis in bilateral CT scans of uninjured ankles. Bone Jt. J. 2021, 103, 178–183. https://doi.org/10.1302/0301-620X.103B1.BJJ-2020-0844.R1.
72. Godoy-Santos, A.L.; Bernasconi, A.; Bordalo-Rodrigues, M.; Lintz, F.; Lôbo, C.F.T.; de Cesar Netto, C. Weight-bearing cone-beam computed tomography in the foot and ankle specialty: Where we are and where we are going-an update. Radiol. Bras. 2021, 54, 177–184. https://doi.org/10.1590/0100-3984.2020.0048.
73. Loizou, C.L.; Sudlow, A.; Collins, R.; Loveday, D.; Smith, G. Radiological assessment of ankle syndesmotic reduction. Foot 2017, 32, 39–43. https://doi.org/10.1016/j.foot.2017.05.002.
74. Rasi, A.M.; Kazemian, G.; Omidian, M.M.; Nemati, A. Syndesmotic Malreduction after Ankle ORIF; Is Radiography Suf-fi-cient? Arch. Bone Jt. Surg. 2013, 1, 98–102.
75. Futamura, K.; Baba, T.; Mogami, A.; Morohashi, I.; Kanda, A.; Obayashi, O.; Sato, K.; Ueda, Y.; Kurata, Y.; Tsuji, H.; et al. Malreduction of syndesmosis injury associated with malleolar ankle fracture can be avoided using Weber's three indexes in the mortise view. Injury 2017, 48, 954–959. https://doi.org/10.1016/j.injury.2017.02.004.
76. Anand Prakash, A. Syndesmotic stability: Is there a radiological normal?—A systematic review. Foot Ankle Surg. 2018, 24, 174–184. https://doi.org/10.1016/j.fas.2017.02.004.

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77. Tourné, Y.; Molinier, F.; Andrieu, M.; Porta, J.; Barbier, G. Corrigendum to "Diagnosis and treatment of tibiofibular syn-desmosis lesions". Orthop. Traumatol. Surg. Res. 2022, 108, 103237; Erratum in Orthop. Traumatol. Surg. Res. 2019, 105, S275–S286. https://doi.org/10.1016/j.otsr.2022.103237.
78. Hagemeijer, N.C.; Chang, S.H.; Abdelaziz, M.E.; Casey, J.C.; Waryasz, G.R.; Guss, D.; DiGiovanni, C.W. Range of Normal and Abnormal Syndesmotic Measurements Using Weightbearing CT. Foot Ankle Int. 2019, 40, 1430–1437. https://doi.org/10.1177/1071100719866831.
79. Aitor, I.G.; Galvez-Sirvent, E.; Martinez-Diez, J.M.; Pallares-Sanmartín, J.; Kalbakdij-Sanchez, C.; Mills, S.; Rubio-Suarez, J.C.; Gil-Garay, E.; Rodriguez-Merchan, E.C. Comparative CT Study on Syndesmosis Mobility after Static or Dynamic Fixation for Ankle Fractures with Syndesmotic Rupture: A Pilot Study. Arch. Bone Jt. Surg. 2022, 10, 702–711. https://doi.org/10.22038/ABJS.2022.61845.3020.
80. Kaya, E.; Tasdemir, Z.; Erdogan, O.; Akbas, F. Reliability of preoperative CT and intraoperative manual tests in syn-desmo-sis injury. N. Clin. Istanb. 2024, 11, 52–59. https://doi.org/10.14744/nci.2023.15975.
81. Lei, Q.; Chen, P.; He, X.; Xu, Z.; He, W. Preoperative CT parameters to predict tibiofibular syndesmosis injury associated with ankle fracture: A propensity score-matched analysis. Eur. J. Trauma. Emerg. Surg. 2023, 49, 1883–1890. https://doi.org/10.1007/s00068-023-02256-2.
82. Firoozabadi, R.; Harnden, E.; Krieg, J.C. Immediate weight-bearing after ankle fracture fixation. Adv. Orthop. 2015, 2015, 491976. https://doi.org/10.1155/2015/491976.
83. Dehghan, N.; McKee, M.D.; Jenkinson, R.J.; Schemitsch, E.H.; Stas, V.; Nauth, A.; Hall, J.A.; Stephen, D.J.; Kreder, H.J. Early Weightbearing and Range of Motion Versus Non-Weightbearing and Immobilization after Open Reduction and Internal Fixation of Unstable Ankle Fractures: A Randomized Controlled Trial. J. Orthop. Trauma. 2016, 30, 345–352. https://doi.org/10.1097/BOT.0000000000000572.
84. de Sa, R.; Shah, N.; Rudge, B.; Ieong, E. Safety of early weightbearing after ankle fracture fixation. Eur. J. Orthop. Surg. Trau-matol. 2024, 34, 1003–1007. https://doi.org/10.1007/s00590-023-03758-w.
85. Khojaly, R.; Rowan, F.E.; Hassan, M.; Hanna, S.; Mac Niocail, R. Weight-bearing Allowed Following Internal Fixation of Ankle Fractures, a Systematic Literature Review and Meta-Analysis. Foot Ankle Int. 2022, 43, 1143–1156. https://doi.org/10.1177/10711007221102142.
86. King, C.M.; Doyle, M.D.; Castellucci-Garza, F.M.; Nguyentat, A.; Collman, D.R.; Schuberth, J.M. Early Protected Weightbearing after Open Reduction Internal Fixation of Ankle Fractures with Trans-syndesmotic Screws. J. Foot Ankle Surg. 2020, 59, 726–728. https://doi.org/10.1053/j.jfas.2020.01.003.
87. Bhimani, R.; Ashkani-Esfahani, S.; Lubberts, B.; Kaiser, P.; Kerkhoffs, G.M.M.J.; Waryasz, G.; DiGiovanni, C.W.; Guss, D. Utility of WBCT to Diagnose Syndesmotic Instability in Patients with Weber B Lateral Malleolar Fractures. J. Am. Acad. Or-thop. Surg. 2022, 30, e423–e433. https://doi.org/10.5435/JAAOS-D-21-00566.
88. Marzo, J.M.; Kluczynski, M.A.; Clyde, C.; Anders, M.J.; Mutty, C.E.; Ritter, C.A. Weight bearing cone beam CT scan versus gravity stress radiography for analysis of supination external rotation injuries of the ankle. Quant. Imaging Med. Surg. 2017, 7, 678–684. https://doi.org/10.21037/qims.2017.12.02.
89. Beck, M.; Brunk, M.; Wichelhaus, A.; Mittlmeier, T.; Rotter, R. Intraoperative three-dimensional imaging in ankle syn-des-motic reduction. BMC Musculoskelet. Disord. 2021, 22, 116. https://doi.org/10.1186/s12891-020-03931-w.
90. Ceccarini, P.; Rinonapoli, G.; Antinolfi, P.; Caraffa, A. Effectiveness of ankle arthroscopic debridement in acute, subacute ankle-bimalleolar, and trimalleolar fractures. Int. Orthop. 2021, 45, 721–729. https://doi.org/10.1007/s00264-020-04882-6.
91. Chan, K.B.; Lui, T.H. Role of Ankle Arthroscopy in Management of Acute Ankle Fracture. Arthroscopy 2016, 32, 2373–2380. https://doi.org/10.1016/j.arthro.2016.08.016.
92. Palmanovich, E.; Brin, Y.S.; Kish, B.; Nyska, M.; Hetsroni, I. Value of Early Postoperative Computed Tomography As-sess-ment in Ankle Fractures Defining Joint Congruity and Criticizing the Need for Early Revision Surgery. J. Foot Ankle Surg. 2016, 55, 465–469. https://doi.org/10.1053/j.jfas.2016.01.013.
93. Rammelt, S.; Boszczyk, A. Computed Tomography in the Diagnosis and Treatment of Ankle Fractures: A Critical Analysis Review. JBJS Rev. 2018, 6, e7. https://doi.org/10.2106/JBJS.RVW.17.00209.
94. Vasarhelyi, A.; Lubitz, J.; Gierer, P.; Gradl, G.; Rösler, K.; Hopfenmüller, W.; Klaue, K.; Mittlmeier, T.W. Detection of fibular torsional deformities after surgery for ankle fractures with a novel CT method. Foot Ankle Int. 2006, 27, 1115–1121. https://doi.org/10.1177/107110070602701219.
95. de Carvalho, K.A.M.; Walt, J.S.; Ehret, A.; Tazegul, T.E.; Dibbern, K.; Mansur, N.S.B.; Lalevée, M.; de Cesar Netto, C. Com-parison between Weightbearing-CT semiautomatic and manual measurements in Hallux Valgus. Foot Ankle Surg. 2022, 28, 518–525. https://doi.org/10.1016/j.fas.2022.02.014.
96. Day, J.; de Cesar Netto, C.; Richter, M.; Mansur, N.S.; Fernando, C.; Deland, J.T.; Ellis, S.J.; Lintz, F. Evaluation of a Weightbearing CT Artificial Intelligence-Based Automatic Measurement for the M1-M2 Intermetatarsal Angle in Hallux Valgus. Foot Ankle Int. 2021, 42, 1502–1509. https://doi.org/10.1177/10711007211015177.
97. Kwolek, K.; Gądek, A.; Kwolek, K.; Kolecki, R.; Liszka, H. Automated decision support for Hallux Valgus treatment options using anteroposterior foot radiographs. World J. Orthop. 2023, 14, 800–812. https://doi.org/10.5312/wjo.v14.i11.800.
98. Kwolek, K.; Liszka, H.; Kwolek, B.; Gądek, A. Measuring the Angle of Hallux Valgus Using Segmentation of Bones on X-ray Images. In Artificial Neural Networks and Machine Learning ICANN 2019: Workshop and Special Sessions; Tetko, I.V., Theis, F., Eds.; Springer Nature: Cham, Switzerland, 2019; pp. 313–325. https://doi.org/10.1007/978-3-030-30493-5_32.
99. Richter, M.; Duerr, F.; Schilke, R.; Zech, S.; Meissner, S.A.; Naef, I. Semi-automatic software-based 3D-angular measurement for Weight-Bearing CT (WBCT) in the foot provides different angles than measurement by hand. Foot Ankle Surg. 2022, 28, 919–927. https://doi.org/10.1016/j.fas.2022.01.001.
100. Zaidi, R.; Sangoi, D.; Cullen, N.; Patel, S.; Welck, M.; Malhotra, K. Semi-automated 3-dimensional analysis of the normal foot and ankle using weight bearing CT—A report of normal values and bony relationships. Foot Ankle Surg. 2023, 29, 111–117. https://doi.org/10.1016/j.fas.2022.12.001.
101. Bhimani, R.; Ashkani-Esfahani, S.; Lubberts, B.; Guss, D.; Hagemeijer, N.C.; Waryasz, G.; DiGiovanni, C.W. Utility of Vo-lu-metric Measurement via Weight-Bearing Computed Tomography Scan to Diagnose Syndesmotic Instability. Foot Ankle Int. 2020, 41, 859–865. https://doi.org/10.1177/1071100720917682.
102. Chun, D.I.; Cho, J.H.; Min, T.H.; Park, S.Y.; Kim, K.H.; Kim, J.H.; Won, S.H. Diagnostic Accuracy of Radiologic Methods for Ankle Syndesmosis Injury: A Systematic Review and Meta-Analysis. J. Clin. Med. 2019, 8, 968. https://doi.org/10.3390/jcm8070968.
103. Abdelaziz, M.E.; Hagemeijer, N.; Guss, D.; El-Hawary, A.; El-Mowafi, H.; DiGiovanni, C.W. Evaluation of Syndesmosis Reduction on CT Scan. Foot Ankle Int. 2019, 40, 1087–1093. https://doi.org/10.1177/1071100719849850.
104. Rooney, P.; Haller, J.; Kleweno, C.; Glass, N.; Davison, J.; Miller, A.; Anderson, D.D.; Marsh, J.L.; Willey, M. Syndesmosis Malposition Assessed on Weight-Bearing CT Is Common After Operative Fixation of Intra-articular Distal Tibia Plafond Fracture. J. Orthop. Trauma. 2022, 36, 658–664. https://doi.org/10.1097/BOT.0000000000002443.
105. Peiffer, M.; Dhont, T.; Cuigniez, F.; Tampere, T.; Ashkani-Esfahani, S.; D'Hooghe, P.; Audenaert, E.; Burssens, A. Application of external torque enhances the detection of subtle syndesmotic ankle instability in a weight-bearing CT. Knee Surg. Sports Traumatol. Arthrosc. 2023, 31, 4886–4894. https://doi.org/10.1007/s00167-023-07536-3.


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