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Traction radiographs versus CT in the evaluation of fracture morphology and consecutive treatment decisions in OTA/AO 43C3 fractures

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ABSTRACT

Background: Standard radiographs are limited in the evaluation of fracture characteristics and preoperative planning of OTA/AO 43C3 fractures. Therefore, CT imaging is an accepted as a useful method. CT is however expensive and has high radiation, and traction radiographs could be an alternative. This study aimed to compare fracture fragment and comminution zone visualization between traction radiographs and CT and any potentially resulting differences in consecutive treatment and surgical approach recommendations.

Methods: Twenty orthopaedic surgeons assessed traction radiographs and CT images of 12 OTA/AO 43C3 type fractures. Each observer was required to identify the anterolateral, posterolateral, and medial malleolus fragments and the lateral, central, and medial shoulder comminution zones. They then had to recommend treatment (nonoperative, ORIF, closed reduction and external fixation, percutaneous screw fixation, or primary tibiotalar arthrodesis) with the best surgical approach (medial, anterolateral, posterolateral, posteromedial, or combined). Intra- and interobserver reliability, correct identification of fracture fragments and comminution zones on both images, and consistency of treatment recommendations and surgical approaches were analyzed.

Results: The agreement of each observer's assessment of the presence or absence of specific fracture fragments and comminution zones was substantially increased for CT as compared to traction radiographs, particularly for the posterolateral ($p = 0.000$) and anterolateral fragment ($p = 0.000$), and the lateral ($p = 0.000$), central ($p = 0.000$), and medial shoulder comminution zone ($p = 0.000$). The interobserver reliability when assessing the three fracture fragments and comminution zones on the traction radiographs was moderate, whereas it was substantial when assessing these characteristics on CT. The medial malleolus fragment was more often correctly identified on traction radiographs than CT images ($p = 0.001$). The ability to correctly identify lateral, central, and medial shoulder comminution zones was higher for CT than traction radiographs ($p = 0.000$). The treatment and surgical approach recommendations after traction radiograph and CT evaluation were similar ($p < 0.05$).

Conclusions: Traction radiographs may be a useful alternative to CT imaging in the preoperative planning of pilon fracture repair. Despite less reliable fracture fragment and comminution zone identification on traction radiographs, treatment recommendations and surgical approach were not influenced.

Introduction

Pilon fractures are mostly high-energy distal tibial fractures affecting up to 10% of patients with lower extremity fractures [1]. Management of this injury remains challenging because of articular comminution, multiple fracture lines, and substantial soft tissue

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injury [2]. Several surgical approaches and numerous fixation techniques dependent on individual fracture characteristics have been developed for the management of pilon fractures [3]. The OTA/AO [4] and Rüedi-Allgöwer [5] classification systems, which are both based on standard radiographs, have been most commonly used to describe pilon fractures. However, these classification systems fail to accurately describe the most frequent fracture lines, their vectors and the typically comminuted zones. Since it is believed that an appropriate surgical approach may only be chosen after a full appreciation of individual fracture patterns, new CT-based mapping and classification systems have been developed to optimally guide treatment strategies [6,7]. A CT scan is often obtained following the application of a spanning external fixator to evaluate fracture morphology in pilon fracture patients in more detail and to facilitate preoperative planning [3]. Also, associated soft tissue injuries may be reliably demonstrated on CT [2,8–10].

Although CT is very advantageous in preoperative fracture detail imaging, there is a need for alternative methods due to its high cost, availability difficulties and high radiation exposure. Traction radiographs may be an alternative to CT in pilon fractures. It allows better visualization of individual fracture fragments than standard radiographs [11]. To the best of our knowledge, the literature so far does not report on the differences between traction radiographs and CT imaging in the OTA/AO 43C group of fractures with regard to the identification of fracture fragments and comminution zones, and consecutive surgical approach and treatment modality decisions.

This study primarily aimed to analyse the interobserver and intraobserver reliability in the evaluation of the fragment and comminution zone characteristics of 43C type distal tibia fractures when assessing anteroposterior and lateral traction radiographs as compared to axial, coronal and sagittal CT images. Secondarily, we wanted to compare the treatment recommendations resulting from either traction radiographs and CT. We hypothesized that specific fracture fragments would be interpreted differently on the traction radiographs as compared with CT, and that intra- and interobserver agreement with regard to the recommended treatment would be strong.

Materials and methods

After the approval from our hospital's institutional review board, we reviewed the medical files of 15 patients with surgically treated OTA/AO 43 C3 type fractures. The inclusion criteria were an intra-articular distal tibial fracture of the AO/OTA 43C3 type in an adult (18 years and older) with two traction images and axial, sagittal and coronal CT images of adequate quality available for review. Exclusion criteria were an open physis, previous ankle injury or operation, open fractures, poor soft tissue condition, and suboptimal traction radiographs and CT images. Two sets of images were excluded because of at least one missing traction radiograph in the picture archiving and communication system (PACS), and one was excluded because of inadequate CT images. After these exclusions, 12 OTA/AO 43C3 type fractures were included in the study.

The traction radiographs included two standardized anteroposterior (AP) and lateral images taken with a spanning external fixator applied. Traction images were performed under general or regional anesthesia in the operating room. All images were captured with a radiographic image intensifier (Shimadzu Collimator type-R 300, Kyoto, Japan) at an image distance of 51 cm from the intensifier and stored in the PACS. The CT images were made using a sixteen-slice scanner (Siemens Somatom Emotion, Erlangen, Germany). All images were formatted in the axial, sagittal and coronal planes respective to the axis of the tibia with bone-level windowing.

Twenty observers (15 orthopedic surgeons and 5 orthopaedics residents in their 4th and 5th postgraduate year) were asked to systematically evaluate the images according to our instructions.

The images were made available to each observer in the form of two PowerPoint presentations (Microsoft® Office 2011 for Mac; Microsoft, Redmond, WA) created by the first author (A.M.). The first presentation comprised individual all 12 cases with the two traction radiographs in AP and lateral view. Each observer was asked to review the set of images for each patient and describe a) the presence or absence of a posterolateral, anterolateral, or medial malleolus fragment, b) the presence or absence of a lateral, central, or medial shoulder zone of comminution, c) the surgical approach they would choose, and d) the overall treatment plan they would recommend. An illustration was supplied to them detailing each fragment and zone of comminution. They could choose a medial, anterolateral, posterolateral, posteromedial, or combined surgical approach. The choices of treatment were nonoperative, ORIF, closed reduction and external fixation, percutaneous screw fixation, and primary tibiotalar arthrodesis. The second presentation consisted of the CT images for each case chosen by the first author (A.M.). These images included axial, coronal and sagittal slices including the subtalar joint distally and 5 cm from the fracture proximally, which could be scrolled through by the observer.

The sets of images in each of the presentations did not contain any patient information or final treatment radiographs. Two randomizations took place to obtain a random order of patients in each of the two presentations. The sets of traction images were randomized prior to their inclusion in the first presentation, and the CT images were separately randomized prior to inclusion in the second presentation. The observers first received the presentation with the radiographs for assessment. Once they had concluded the evaluation, they received the CT images for assessment. The time between completion of the evaluation of the traction radiographs and receiving the CT images was two weeks. The individual observer responses for the fragment and comminution zone identification were graded as correct or incorrect regarding traction radiographs and CT images compared with the gold standard CT evaluation read by a more than 10-year experienced radiologist.

The treatment options offered were purposefully kept general because of the wide variation in the observers' experience. The goal was to obtain a decision for either of the main five treatment options mentioned above. No differentiation in the type or mode of external fixation (static, dynamic, or joint spanning) was required. Treatment recommendations resulting from either traction radiographs or the CT were compared.

Statistical analysis

The descriptive statistics used for the data were mean, standard deviation, median, lowest and highest value, frequency, and ratio. Intraobserver and interobserver reliability for the assessment of traction radiographs and CT images regarding fracture lines and comminution zones identification were calculated with Fleiss' kappa coefficients. Kappa values were assigned to the subdivisions on the basis of the strength of agreement in the following manner: poor (0.01–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), and nearly perfect (0.81–1.00). The chi-square test was used for qualitative independent analysis. The qualitative dependent analysis was performed using McNemar test. Descriptive information was calculated to show changes in the treatment modality and surgical approach decisions. A p-value < 0.05 was considered statistically significant. All statistical analysis was performed using IBM SPSS for Windows, version 22 (IBM corp., Armonk, NY).

Results

The agreement of each observer's assessment of the presence or absence of specific fracture fragments in traction radiographs compared with CT images was as follows: for the posterolateral fragment, it increased from 48% to 75.5% (p = 0.000) and for the anterolateral fragment from 54% to 79% (p = 000), respectively. For the medial malleolus fragment the increase was not statistically significant (51% to 58%, p = 0.125).

The interobserver reliability in the identification of the three specific fracture fragments and comminution zones on the traction radiographs was moderate overall (Table 1). The interobserver reliability in the identification of these fracture fragments and comminution zones on the CT images was substantial (Table 1).

The medial malleolus fragment was correctly identified more often on the traction radiographs than on the CT images (82.5% vs. 71.5%, p = 0.001) The ability to correctly identify the anterolateral and posterolateral fragments was higher for the CT images than for the traction radiographs (77% vs. 62% (p = 0.000) and 79% vs. 58% (p = 0.001), respectively).

The agreement of each observer's assessment of the presence or absence of specific comminution zones on the traction radiographs compared with the CT images was as follows: for the lateral comminution zone, it increased from 59.5% to 77% (p = 0.000). For the central comminution zone, it increased from 46% to 82.5% (p = 000). It was increased from 44% to 71.5% (p = 0.000) for the medial shoulder comminution zone (Tables 2 and 3).

The ability to correctly identify lateral, central, and medial shoulder comminution zones on CT images was higher than on traction radiographs (75.5% vs. 59% (p = 0.000), 79% vs. 54% (p = 0.000), and 71.5% vs. 44% (p = 0.000), respectively).

A total of 240 treatment recommendations were analysed. When the traction radiographs were evaluated, operative treatment was recommended in 98.75% of cases. ORIF was the most often recommended method of fixation (215 of 240 cases, (89.6%)). The treatment recommendations based on CT evaluation were similar. Operative treatment was recommended for all patients (100%). ORIF was the most preferred treatment method of fixation (224 of 240 cases, (93.4%) (Table 4).

With regard to the surgical approach, a combined approach was chosen in 196 of 240 cases (81.7%) when traction radiographs were evaluated and in 205 of 240 cases (85.4%) when CT images were evaluated. The preferred surgical approach based on traction radiograph assessment compared with CT image assessment is shown in Table 5.

Discussion

The most important finding of this study was that CT imaging is superior to traction radiographs in the correct identification of fracture fragments and comminution zones in OTA/AO 43C3 fractures. However, both evaluation methods led to consistent treatment recommendations and surgical approaches. The interobserver reliability in the identification of the three specific fracture fragments and comminution zones was moderate. However, it was substantial for the assessment of CT images.

The higher radiation dose delivered to the patient in CT as compared to radiography examinations is one of the disadvantages of CT imaging. Also, CT is more expensive than radiography. These are the reasons why we explored the alternative of traction radiographs. Ultra-low-dose CT scanning protocols may be used to decrease radiation exposure [13]. Although higher effective radiation dose than traction radiographs, ultra-low-dose CT scanning achieves a ten- to fourteenfold decrease of the effective radiation dose [14] and therefore presents a viable alternative. But, it is not widely available. Also, minor image quality loss may be seen [14].

Sirkin [16] described three articular fragments (posterolateral, medial malleolus and anterolateral fragment) and zones of comminution (lateral, central, and medial shoulder comminution) in pilon fractures. In our study of OTA/AO 43C3 type fractures, all fractures included the fragment and comminution zone characteristics described in the literature. Identifying these fracture fragments and comminution zones is important in the preoperative planning. Previous studies showed how Y- or T- shaped fracture line configurations are associated with areas of impaction [1,15,17].

The available anterolateral osteosynthesis plates were tested in both Y- and T-shaped fracture patterns, and none was found to be superior to another due to their general deficiency in capturing all pilon fracture fragments [1,18]. One may provide better cross-sectional fracture coverage of the lateral than the medial pilon, and another might achieve better fixation of the medial fragment [1]. Most of the comminuted pilon fractures may require combined stabilization where further methods are used in addition to anterolateral plate stabilization. In our study, most of the observers selected a combined surgical approach after evaluation of traction radiographs and CT images.

The risks and benefits of any approach must be carefully taken into consideration. Extensile or dual approaches, although leading to perfect visualization of fracture fragments, perfect articular reduction, and stable fixation, carry a risk of nonunion, especially in anterior-posterior fixations [19,20]. In our study, surgeons preferred a combined approach more often, both after traction radiograph and CT evaluation.

Several concepts have been developed for the surgical management of pilon fractures [2,3]. In view of the almost ubiquitous soft tissue problems with their high risk of impaired wound healing and infection, temporary external fixation has been accepted as the first-line intervention [2]. Definitive fixation following initial external fixation has some basic principles: articular reduction with stable fixation, restoration of alignment, management of bone loss, fracture fixation methods that account for the soft tissue condition, and early restoration of the range of motion. Surgeons decide on the optimum treatment strategy based on these principles [3]. In our study, surgeons had to make

Table 1
Kappa values for interobserver reliability in three fracture fragments and comminution zones of traction radiographs and CT images. The values were given as kappa coefficient (95%CI).

Fracture fragment and comminution zone	Traction radiographs	Computed tomography images
Medial malleolus fragment	0.45 (0.41-0.49	0.67 (0.61-0.73)
Anterolateral fragment	0.57 (0.54-0.60)	0.72 (0.65-0.69)
Posterolateral fragment	0.52 (0.47-0.59	0.62 (0.58-0.66)
Lateral zone of comminution	0.48 (0.45-0.51)	0.65 (0.60-0.70)
Central zone of comminution	0.57 (0.54-0.60)	0.76 (0.72-0.80)
Medial shoulder zone of comminution	0.51 (0.49-0.53)	0.64 (0.61-0.67)

Table 2
Comparison of traction radiographs and gold standard CT regarding correct fragment and comminution zone identification by surgeon groups. The values were given as percentage.

	Medial malleolus fragment	Anterolateral fragment	Posterolateral fragment	Lateral zone of comminution	Central zone of comminution	Medial shoulder zone of comminution
Trauma surgeons	84.9	65.7	64.9	65	60.9	57.1
Other surgeons	79.5	58.1	54.7	54.2	52.4	40.6
Residents	82.9	60.5	59.3	63.9	50.6	38.2

Table 3
Comparison of CT images and gold standard CT regarding correct fragment and comminution zone identification by surgeon groups. The values were given as percentage.

	Medial malleolus fragment	Anterolateral fragment	Posterolateral fragment	Lateral zone of comminution	Central zone of comminution	Medial shoulder zone of comminution
Trauma surgeons	75.9	78.2	80.9	76.2	81.4	74.9
Other surgeons	65.7	75.9	75.6	70.9	75.7	67.6
Residents	72.2	71.7	83.1	78.9	79.5	70

Table 4
Treatment recommendations according to imaging modalities.

	Traction radiographs n (%)	CT images n (%)	p
Conservative treatment	3 (1.2%)	0 (0%)	0.089
ORIF	215 (89.6%)	224 (93.4%)	0.316
External fixation	14 (5.9%)	11 (4.6%)	0.732
Percutaneous screw fixation	5 (2.1%)	3 (1.2%)	0.857
Tibiotalar arthrodesis	3 (1.2%)	2 (0.8%)	0.962
Total	240 (100%)	240 (100%)	

Table 5
Surgical approach recommendations according to imaging modalities.

	Traction radiographs n (%)	CT images n (%)	p
Medial	9 (3.7%)	6 (2.5%)	0.787
Anterolateral	31 (13%)	28 (11.7%)	0.318
Posterolateral	3 (1.2%)	1 (0.4%)	0.098
Posteromedial	1 (0.4%)	0 (0%)	0.712
Combined	196 (81.7%)	205 (85.4%)	0.498
Total	240 (100%)	240 (100%)	

recommendations on the operative management and surgical approach based on traction radiographs and CT images only, without knowledge of the soft tissue situation that may affect the operative and surgical approach decisions. In clinical practice, some patients may still have a poor soft tissue envelope when definitive treatment is performed. Also, a variety of medical problems may complicate the definitive strategy, and any decision will need to consider the individual patient.

CT imaging provides detailed information about fracture lines, fragment features, comminution zones, additional pathologies, and any requirement for combined reduction and stabilization techniques [6,12,20–22]. Theoretically, it is superior to traction radiographs. Tornetta and Gorup noted a 64% change in the operative plan when the additional information obtained from CT scans was taken into consideration. They recommended the routine use of CT scanning for all pilon fractures to help the surgeon understand the fracture pattern and to serve as a guide for operative intervention [12]. In our study, better fracture fragment and comminution zone identification was confirmed for the evaluation with CT. This did however not influence the observers' recommendation on the surgical approach and the treatment to a substantial degree. Reflection of these results may vary. We recommend to study how the clinical outcomes differ between patients treated based on CT versus traction radiographs.

Using specific fragment and comminution zone data and a standardized fracture classification to select patients, implementing two randomizations, not providing information on the final treatment to limit the bias of observers, using the gold standard imaging technique as the reference, and using orthopedic surgeons with widely varying experience levels as observers were the strengths of this study.

There are some limitations to this study. First, our sample size was relatively small. Secondly, there were only comminuted articular fractures. Thirdly, treatment options and surgical approaches were not detailed. The similar treatment option and surgical approach recommendations may be associated with the limited choice surgeons had.

Conclusion

In conclusion, while CT evaluation proved superior to traction radiographs in the identification of fracture fragments and comminution zones in OTA/AO 43C3 type fractures, both assessment methods resulted in similar treatment and surgical approach recommendations. Therefore, traction radiographs may be a useful alternative to CT imaging in the preoperative planning in settings where (ultra-low-dose) CT is not available, too costly or high radiation doses are a concern. Prospective controlled clinical studies assessing the link between our results and clinical outcomes are needed.

Conflict of interest

Abdulhamit Misir, Turan Bilge Kizkapan, Kadir Ilker Yildiz, Erdal Uzun and Mustafa Ozcamdalli declare that they have no conflict of interest.

References

[1] Aneja A., Luo TD, Liu B, Domingo 4th M, Danelson K, Halvorson JJ, et al. Anterolateral distal tibia locking plate osteosynthesis and their ability to capture OTAC3 pilon fragments. Injury 2018;49(2):409–13, doi:http://dx.doi.org/10.1016/j.injury.2017.12.015.

[2] Tomás-Hernández J. High-energy pilon fractures management: state of the art. EFORT Open Rev 2017;1(10):354–61, doi:http://dx.doi.org/10.1302/2058-5241.1.000016.

[3] Jacob N, Amin A, Giotakis N, Narayan B, Nayagam S, Trompeter AJ. Management of high-energy tibial pilon fractures. Strategies Trauma Limb Reconstr 2015;10(3):137–47, doi:http://dx.doi.org/10.1007/s11751-015-0231-5.

[4] Marsh J, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium-2007: orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma 2007;21(10 Suppl) S1–S133.

[5] Ruedi TP, Allgower M. The operative treatment of intraarticular fractures of the lower end of the tibia. Clin Orthop Relat Res 1979;138:105–10.

[6] Leonetti D, Tigani D. Pilon fractures: a new classification system based on CT-scan. Injury 2017;48(10):2311–7, doi:http://dx.doi.org/10.1016/j.injury.2017.07.026.

[7] Topliss CJ, Jackson M, Atkins RM. Anatomy of pilon fractures of the distal tibia. J Bone Joint Surg Br 2005;87(5), doi:http://dx.doi.org/10.1302/0301-620X.87B5.15982 692–7.

[8] Mak MF, Tay GT, Stern R, Assal M. Dual-incision approach for repair of peroneal tendon dislocation associated with fractures of the calcaneus. Orthopedics 2014;37(2):96–100.

[9] Crim J, Enslow M, Smith J. CT assessment of the prevalence of retinacular injuries associated with hindfoot fractures. Skeletal Radiol 2013;42(4):487–92, doi:http://dx.doi.org/10.1007/s00256-012-1530-2.

[10] Fokin Jr A, Huntley SR, Summers SH, Lawrie CM, Miranda AD, Caban-Martinez AJ, et al. Computed tomography assessment of peroneal tendon displacement and posteromedial structure entrapment in pilon fractures. J Orthop Trauma 2016;30(11):627–33, doi:http://dx.doi.org/10.1097/BOT.0000000000000658.

[11] Barlett CS, Hahn JC, Hall JS, Duffy R. Fractures of the tibia pilon. In Browner BD, Jupiter JB, Krettek C, Anderson PA, editors. *Skeletal Trauma: Basic Science, Management, and Reconstruction*. 5th ed. Philadelphia: Elsevier Saunders; 2015, p. 2119-2188.

[12] Tornetta 3rd P, Gorup J. Axial computed tomography of pilon fractures. Clin Orthop 1996;(323):273–6.

[13] Konda SR, Goch AM, Haglin J, Egol KA. Ultralow-dose CT (REDUCTION protocol) for extremity fracture evaluation is as safe and effective as conventional CT: an evaluation of quality outcomes. J Orthop Trauma 2018;32(5):216–22, doi:http://dx.doi.org/10.1097/BOT.0000000000001137.

[14] Konda SR, Goch AM, Leucht P, Christiano A, Gyftopoulos S, Yoeli G, et al. The use of ultra-low-dose CT scans for the evaluation of limb fractures: is the reduced effective dose using ct in orthopaedic injury (REDUCTION) protocol effective? Bone Joint J 2016;98-B(12):1668–73, doi:http://dx.doi.org/10.1302/0301-620X.98B12.BJJ-2016-0336.R1.

[15] Cole PA, Mehrle RK, Bhandari M, Zlowodzki M. The pilon map: fracture lines and comminution zones in OTA/AO type 43C3 pilon fractures. J Orthop Trauma 2013;27(7):e152–156, doi:http://dx.doi.org/10.1097/BOT.0b013e318288a7e9.

[16] Sirkin MS. Plating of tibial pilon fractures. Am J Orthop 2007;36(Suppl 12):13–7.

[17] Heim U, Naser M. Operative treatment of distal tibial fractures. Technique of osteosynthesis and results in 128 patients (author's transl). Arch Orthop Unfallchir 1976;86(3):341–56.

[18] Penny P, Swords M, Heisler J, Cien A, Sands A, Cole P. Ability of modern distal tibia plates to stabilize comminuted pilon fracture fragments: is dual plate fixation necessary? Injury 2016;47(8):1761–9, doi:http://dx.doi.org/10.1016/j.injury.2016.05.026.

[19] Bhattacharyya T, Crichlow R, Gobezie R, Kim E, Vrahas MS. Complications associated with the posterolateral approach for pilon fractures. J Orthop Trauma 2006;20(2):104–7, doi:http://dx.doi.org/10.1097/01.bot.0000201084.48037.5d.

[20] Chan DS, Balthrop PM, White B, Glassman D, Sanders RW. Does a Staged Posterior Approach Have a Negative Effect on OTA 43C Fracture Outcomes? J Orthop Trauma 2017;31(2):90–4, doi:http://dx.doi.org/10.1097/BOT.0000000000000728.).

[21] Liporace FA, Yoon RS. An adjunct to percutaneous plate insertion to obtain optimal sagittal plane alignment in the treatment of pilon fractures. J Foot Ankle Surg 2012;51(2):275–7, doi:http://dx.doi.org/10.1053/j.jfas.2011.11.008.

[22] Kim GB, Shon OJ, Park CH. Treatment of AO/OTA type c pilon fractures through the anterolateral approach combined with the medial mipo technique. Foot Ankle Int 2018;39(4):426–32, doi:http://dx.doi.org/10.1177/1071100717746628.