The added value of routine radiographs in wrist and ankle fractures

Gerven, P. van

2

The value of radiography in the follow-up of extremity fractures. A systematic review

P. van Gerven
S.M. Rubinstein
C. Nederpelt
M.F. Termaat
P. Krijnen
M.W. van Tulder
I.B. Schipper

Archives of Orthopaedic and Trauma Surgery. 2018;138:1659–69

ABSTRACT

Background

The added value of routine radiography during the follow-up of extremity fractures is unclear. The aim of the present systematic review was to create an overview of radiography use in extremity fracture care and the consequences of these radiographs for the treatment of patients with these fractures.

Methods

Studies were included if they reported on the use of radiography during the follow-up of extremity fractures and on its influence on the treatment strategy, clinical outcome, or complications. A comprehensive search of electronic databases (i.e., PubMed, Embase, and Cochrane) was performed to identify relevant studies. Methodological quality was assessed with the Newcastle-Ottawa scale for cohort studies. Level of evidence was assessed with use of GRADE. The search, quality appraisal, and data extraction were performed independently by 2 researchers.

Results

Eleven studies were included. All studies were retrospective cohorts. Of these, only 2 used a comparative design. Two of the included studies described fractures of both the upper and lower extremities, 4 studies concerned fractures of the lower extremity only, and 5 studies focused on fractures of the upper extremity. Pooling of data was not performed because of clinical heterogeneity. Eight studies reported on a change in the treatment strategy related to radiography. Percentages ranged from 0 to 2.6%. The overall results indicated that radiographs made during the follow-up of extremity fractures seldom alter the treatment strategy, that the vast majority of follow-up radiographs are made without a clinical indication and that detection of a complication on a radiograph, in the absence of clinical symptoms, is unlikely. All included studies were regarded of a 'very low' level when scored with GRADE.

Conclusions

Based on current literature, the added value of routine radiography during the follow-up of extremity fractures seems limited. Results, however, should be interpreted with care, considering that available evidence is of a low level.

INTRODUCTION

Traumatic skeletal fractures are commonly encountered in healthcare and present a large medical and socio-economic burden.[1, 2] The majority of fractures occur in either the upper or lower extremity. For example, fractures of the wrist, hand and ankle represent roughly 50% of all skeletal fractures.[3] Because of the aging population, the incidence of extremity fractures is expected to increase in the coming decades.[4] Current national and international protocols recommend frequent outpatient clinic visits at which radiographs of the fractured extremity are made. These radiographs can be used to check for (secondary) dislocation, assess bone-healing and provide early detection of complications.[5-8] Other reasons for radiographic imaging include resident education, reassurance of patients, and medicolegal protection.[9] The costs and cost-effectiveness of diagnostic imaging for traumatic skeletal fractures are becoming increasingly important factors in clinical decision-making.[10] Recent studies have assessed routine radiography use in patients with distal radius and ankle fractures. These studies suggested that radiographs made without a clinical indication do not lead to changes in the treatment strategy whilst adding to treatment cost.[11-13] The added value of radiographs for other fractures of the extremities and their consequences for the treatment strategies are still unclear. Therefore, the aim of this review was to analyze studies that examine the influence of follow-up radiography for extremity fractures on the treatment strategy. Specifically, we focused on whether omission of these more or less routine radiographs is associated with a delayed detection of complications and subsequently a possible deteriorated functional outcome.

METHODS

The present systematic review was conducted adhering to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.[14] Our methods include a comprehensive search of the literature, independent selection of studies, as well as assessment of the methodologic quality of these studies and extraction of the clinical outcomes by 2 of the authors.

Search Strategy

A comprehensive literature search was conducted in multiple databases (i.e., PubMed, Embase, and the Cochrane library) on October 9, 2017. The search strategies were developed with the guidance of a trained medical librarian and included combinations of different terms and synonyms for effectiveness, radiographs, and both upper and lower extremity fractures. In addition, the reference lists of the selected articles were screened for any other relevant studies not identified in the electronic search. The search was limited to studies published in the English or Dutch language and was aimed at studies on adult, human subjects. The detailed search strategy is presented in Appendix 1.

The search was repeated on July 10, 2018. In total, 385 additional articles were identified and added to the screening process. No additional relevant studies were found, and thus, none were added to the analysis.

Inclusion Criteria

We included studies that described radiographic imaging during the follow-up of fractures of the upper and/or lower extremities. One of the outcome measures had to be either the influence of radiographic imaging on a change in the treatment strategy, the association between radiographic imaging and complications (i.e., a lower number of complications detected, or a delayed detection of a complication because of the omission of radiographs) or a possible relation between the omission of radiographs and clinical outcomes (i.e., because of a possible missed complication) such as: range of motion, a functional outcome score (on a validated test/questionnaire), quality of life (with use of a validated questionnaire), or pain (with use of a validated instrument). Both randomized controlled trials and observational studies were eligible for inclusion. Case reports and small case series (<20 subjects) were not included, as well as studies mainly describing patients with pathologic fractures, open fractures (Gustilo grade II/III), severely injured patients (ISS >16), studies not reporting on the use of radiography in a follow-up setting (but rather in a diagnostic setting), and studies reporting the use of intra-operative control radiographs or their directly post-operative equivalents.

Selection of Studies

After removal of duplicate records, the titles and abstracts of the remaining studies were independently screened by 2 authors with use of the online systematic review tool "Covidence" (www.covidence.org, Veritas Health Innovation Ltd.) Articles selected based on title and abstract were evaluated fully. If it was unclear whether a study met the inclusion criteria or if no abstract was available, but the title suggested relevance, the full text of the article was assessed for eligibility as well. In the case of a dispute, consensus between the 2 reviewers was reached by discussion or by consulting an arbiter, if necessary.

Assessment of Methodological Quality

Methodological quality of the included studies was assessed with the Newcastle-Ottawa scale (NOS) by 2 authors independently. In the case of inconsistent results, consensus between the 2 reviewers was reached by discussion. The Newcastle-Ottawa scale is a frequently used assessment tool for the methodological quality of nonrandomized studies.[15] Separate scales are available for case-control and cohort studies. For the present systematic review, we used the scale that evaluates cohort studies, as none of the included studies were randomized or had a case-control design.

The Newcastle-Ottawa scale assesses the methodological quality of studies on 8 different criteria distributed over 3 domains: selection, comparability, and outcome. It is designed to measure the risk of selection bias, information bias, and confounding. Scoring is performed by allocating points when the criteria are met. A total of 9 points equals a perfect score. The scale for cohort studies is presented in Appendix 2.

Data Extraction and Management

The following study characteristics were extracted: study design, country of origin, fracture location and/or type, number of participants, inclusion and exclusion criteria, participant demographics and study setting, number of (routine) radiographs, outcomes (including changes in the treatment strategy, the number of complications detected on a radiograph, radiographic changes compared with previous imaging or differences in clinical outcome), duration of follow-up, and results. Data extraction was performed by 2 authors independently. In the case of a dispute, consensus between the 2 reviewers was reached by discussion.

Analysis of Results

If the identified studies were clinically homogeneous, a meta-analysis was performed. If the studies were too heterogeneous to pool the data, we performed a descriptive review.

Assessment of Level of Evidence

The GRADE method was used to evaluate the overall quality of the evidence and weigh the recommendations.[16] In GRADE, the levels of evidence are stratified high, moderate, low, and very low. Observational studies are primarily labelled 'low'. A study can gain a 'level' if a large (e.g., RR <0.5) or very large (RR <0.2) effect was found, if there is evidence of a dose-response effect (although this is not applicable to the present systematic review), or if plausible residual bias or confounding would only result in study findings being more distinct. On the other hand, a study might drop a 'level' if there were limitations in the study design and execution and if there was inconsistency, indirectness, imprecision, or publication bias.

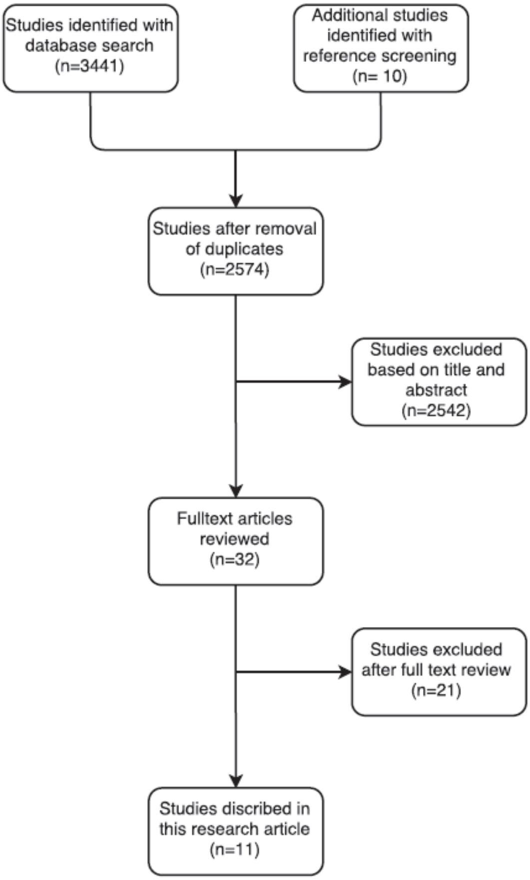

Fig. 1. Flowchart of the article selection process

RESULTS

Search Results

The literature search yielded 2564 unique references. Of these studies, 9 were included. Manual screening of reference lists yielded 2 additional studies. This resulted in 11 unique studies, totaling 4873 participants. The selection process is illustrated in Fig. 1. All studies excluded after full-text review and the reason for exclusion are listed in the Appendix.

Study Characteristics and Overall Results

Two of the included studies described fractures of both the upper and lower extremities.[17, 18] 4 studies concerned fractures of the lower extremity only.[19-22] The remaining 5 studies focused on fractures of the upper extremity.[23-27] The extracted characteristics per study are listed in Table I.

All the included studies used a retrospective cohort design, were conducted in a hospital setting, and evaluated the use of plain radiographs. Two studies compared outcomes between 2 groups (i.e., 1 group with a complete set of radiographs as per protocol, and another group, where some radiographs were omitted). Three of the included studies reported on the number of routine radiographs. Ghattas et al.[18] (92.5%), Weil et al.[23] (86%), and Huffaker et al.[25] (94%) all reported that a large majority of follow-up radiographs is not made for a clinical indication. Three studies mainly focused on complications. They concluded that the detection rate of a complication on a radiograph not made for a clinical indication was low. Similarly, detection rate of complications was not reduced by the omission of routine radiographs. Mean follow-up length within the studies ranged from 9 days to 64 months. For all studies, this was regarded adequate to evaluate the used outcome measures. The outcome measures that were studied and results of the included studies are reported in Table II.

The included articles were clinically too heterogeneous for pooling of data to be meaningful. We therefore chose to describe the results of the individual studies.

Methodological Quality

On the Newcastle-Ottawa scale the included studies earned a total number of 3 to 6 points out of a maximum of 9. For the selection domain, the maximum achieved score was 3 points out of a maximum of 4. As we identified only retrospective studies, none of the studies got a point for item 4: 'demonstration that the outcome of interest was not present at the start of the study'. Schuld et al.,[17] McDonald et al.,[19] and Eastley et al.[26] scored 3 points in the selection domain.

All other studies, with the exception of Robertson et al.,[22] scored 2 points, as there was no nonexposed cohort. None of the studies fulfilled the criteria for comparability, given that none controlled for baseline factors. 6 studies (i.e., McDonald et al.,[19] Ovaska et al.,[20] Kempegowda et al.,[21] Weil et al.,[23] Stone et al.,[24] and Huffaker et al.[25]) scored the maximum number of 3 points for the outcome domain. All other studies scored 2 points, mainly because no statement was made on the adequacy of follow-up. (Table III).

Table I. Characteristics of the studies included in the systematic review

Author	Year	Country	Fracture location and type	No. of participants	Inclusion / Exclusion	Length of follow-up mean (range)	Compared groups
de Beaux	1992	Scotland	Elbow joint	31	incl: patients without a fracture, but with a positive fat pad sign on ED radiographs excl: no FU radiographs, no-show on 2w visit	2 weeks	-
Eastley	2012	UK	Conservatively treated, extra articular, distal radius fracture	138	Incl: hand therapy, grip strength + ROM. excl age <16. Goyrand-Smith fracture, Open fracture. NV symptoms, other ER, no initial or follow-up radiographs, instability/pain at follow-up.	until discharge from physiotherapy	Short (1^{st} x > 2w, n=77) vs Long (1^{st} x <2w, n=61)
Ghattas	2013	USA	All: pelvis, acetabulum, tibia, ankle, clavicle, elbow, hip, wrist, foot, knee, femur, forearm, humerus, scapula.	171 (200 fractures)	incl: acute fracture age<18, time to surgery>2weeks, surgical fixation with implants, radiograph at 1st post-op visit. excl: spine and skull fractures.	24 days (7-61)	-
Huffaker	2014	USA	Distal radius fracture, AO type-A	158 (446 radiographs)	incl: patients with volar locking plate surgery, excl: open fracture, both bone forearm#, skeletal immature, severely injured patients (ISS>16)	4.2 months (1.5-48)	-
Kempegowda	2016	USA	Healed intertrochanteric fracture	465	incl: clinical and radiological consolidation, FU >1Y excl: age<60, pathological fracture, periprosthetic fracture, sec. dislocation, nonunion	81.2 weeks (52-368)	-
McDonald	2014	USA	Operatively treated ankle fracture	1411	incl :surgical fixation excl: open fracture, incomplete charts, no radiography between T+7 and T+120 days	until discharge from clinic	Early (x w 1-3 n=889) vs. Late (x >3w, n=522)

Table I. Characteristics of the studies included in the systematic review (continued)

Author	Year	Country	Fracture location and type	No. of participants	Inclusion / Exclusion	Length of follow-up mean (range)	Compared groups
Ovaska	2016	Finland	Operatively treated ankle fracture	878	incl: age 16+ ORIF of the fracture	64 months	-
Robertson	2000	Scotland	Isolated, closed tibial shaft fracture	53 (343 radiographs)	incl: treated with intramedullary nailing,	no statement. time to union: 24 weeks (10 to 73)	-
Schuld	2016	USA	Non-displaced fracture of hand, wrist, ankle or foot	265 (27 post-splinting X, 179 repeat X at FU)	incl: non-dislocated fracture, plaster immobilization. excl: brace immobilization	9 days (1-135)	-
Stone	2015	USA	Operatively treated distal radius fracture	261 (268 fractures)	excl: skeletal immaturity, absent 2-week radiograph, less than 3 sets of radiographs	12 weeks	-
Weil	2017	NL	Both operatively and conservatively treated distal radius fractures	1042	incl: age >18 excl: absence of FU data, pathologic fracture, open fracture, >1simultaneous fracture of the extremities	no statement	-

Legend for Table I
AO: Arbeitsgemeinschaft für Osteosynthesefragen
ROM: Range Of Motion
FU: Follow-Up
ISS: Injury severity score
ER: Emergency room
ORIF: Open Reduction, Internal Fixation
SD: Standard Deviation

Table II. Measured outcomes and results of included studies outcomes

Author	Relevant measured outcome(s)	Changes in management	Results
de Beaux	change in treatment strategy	0/31 (0%)	6% fractures observed (2 patients), no changes treatment strategy
Eastley	Grip strength, ROM, conversion to operative care	0/61 (0%)	Grip strength / ROM: no difference. no conversion to operative care based on late radiographs.
Ghattas	No. of radiographs per patient, changes from normal postoperative management	3/200 (1.5%)	3/200 changes from normal postoperative management
Huffaker	% clinical findings (changes from expected normal FU), % radiographic findings(hardware or fracture complications), re-intervention, complications	-	0% radiographic complications.
Kempegowda	changes on radiographs obtained after radiological healing had been established. no. of radiographs and clinic visits, complications, costs	-	No. of clinic visits: 2.8, no. of X-rays: 2.6. 98% no changes, 0.7% AVN 0.7% osteoarthritis 0.7% heterotopic ossification
McDonald	complications	-	Complications: early: 62/889 (7.0%) late 31/522(5.9%) $p = 0.45$
Ovaska	change in treatment strategy	3/878 (0.3%)	3/878 changes in treatment strategy based merely on radiographs (0.3%)
Robertson	changes in treatment strategy.	9/343 (2,6%)	9/343 (2,6%) of follow-up radiographs --> change in treatment strategy
Schuld	dislocation on post-splinting radiographs. secondary displacement on repeat radiographs, change in treatment strategy.	0/27 (0%)	no change in treatment strategy based on post-splinting radiographs. 7.8% sec. dislocation. No change in treatment strategy based on repeat radiographs
Stone	change from normal postoperative management, unplanned re-intervention	3/261 (1.1%)	1% unexpected changes in postoperative management (3pt) (secondary dislocation/hardware failure --> re-intervention (all after new trauma)
Weil	changes in treatment strategy.	11/720 (1.5%)	Change in treatment strategy: 22/841radiographs (2.6%). Changes based on routine radiographs: 11/720 (1.5%). 9/11 (1.2%)prolonged cast immobilization, 2/11 (0.2%) conversion to surgery

Legend for Table II
w: weeks
x: Radiograph
ROM: Range Of Motion
FU: Follow-Up

Table III. Scores per category on the Newcastle-Ottawa scale for methodological quality

Author	Selection (max 4 ★)	Comparability (max 2 ★)	Outcome (max 3 ★)
De Beaux	★ ★	-	★ ★
Eastley	★ ★ ★	-	★ ★
Ghattas	★ ★	-	★ ★
Huffaker	★ ★	-	★ ★ ★
Kempegowda	★ ★	-	★ ★ ★
McDonald	★ ★ ★	-	★ ★ ★
Ovaska	★ ★	-	★ ★ ★
Robertson	★	-	★ ★
Schuld	★ ★ ★	-	★ ★
Stone	★ ★	-	★ ★ ★
Weil	★ ★	-	★ ★ ★

Results on Outcome Measures from Individual Studies

Fractures of both the upper and lower extremities

Two studies found no changes in the treatment strategy for post-splinting and post-operative radiographs of both the upper and lower extremities.

Schuld et al.[17] (NOS 5/9) examined the effect of imaging on the treatment of 265 nondisplaced fractures of the hand, wrist, ankle, or foot. They examined the number of dislocations during the splinting procedure on post-splinting radiographs (n=27) and the number of secondary dislocations in patients with follow-up radiographs made at the outpatient clinic (n=179). No changes in management based on post-splinting radiographs were identified. Secondary dislocation was observed in of 7.8% of participants (n=14). The treatment strategy was unaltered in all these patients. Based on these findings, post-splinting radiographs were labelled "likely unnecessary", and the authors stated that repeat imaging in this patient group should be discouraged.

Ghattas et al.[18] (NOS 4/9) assessed the influence of radiographs on the treatment strategy of extremity fractures that were treated with surgical fixation in a retrospective, 2-year cohort. In total, 200 fractures in 171 patients were included. All changes to normal post-operative management (i.e., all procedures or interventions not typically used in the aftercare of that specific fracture) at the initial outpatient clinic visit were identified. Over a mean follow-up period of 24 days (range 7 to 61 days) 3 out of 200 fractures had a change in the treatment strategy. All 3 changes were based on clinical symptoms, rather than on the radiographs. The authors concluded that radiographs at the initial post-operative outpatient clinic visit do not alter the treatment strategy but do pose a financial burden.

Fractures of the lower extremity:

Four studies showed that radiographs of the lower extremity do not change the treatment strategy, do not have an impact on complications, and should not be made if there are no clinical signs of a complication.

McDonald et al.[19] (NOS 6/9) studied the number of complications in relation to the timing of the first post-operative radiograph in a retrospective cohort of 1411 operatively treated ankle fractures. They divided this cohort in 2 groups. The first group had their initial follow-up radiograph taken in the first 3 weeks following surgery; the second received their initial follow-up radiograph more than 3 weeks after the intervention. They observed 62 complications in 889 patients with 'early' radiographs (7.0%), and 31 complications in 522 patients with radiographs solely made more than 3 weeks after surgery (5.9%). This difference was not significant. The researchers concluded that obtaining early routine radiographs (i.e., in the first 3 weeks following surgery) for all patients with an ankle fracture is of questionable benefit.

Ovaska et al.[20] (NOS 5/9) evaluated the number of changes in the treatment strategy based on radiographs made at the first scheduled outpatient clinic visit in a retrospective cohort of 878 patients with an operatively treated ankle fracture. In 3 out of 878 patients (0.3%), a change in the treatment strategy was observed solely based on a routine radiograph. All these changes were adjustments in weight bearing regimen, either after an initially undiagnosed medial malleolus fracture, or after subtle secondary dislocation. The authors concluded that routine radiographs should probably not be made at the first outpatient clinic visit if no clinical signs of a complication are present.

Kempegowda et al.[21] (NOS 5/9) assessed a cohort of 465 patients with healed intertrochanteric fractures with a mean follow-up period of 81 weeks. The main outcome measure was a radiologic change on radiographs made after clinical and radiologic union had already been demonstrated earlier on. On average, patients had 2.8 outpatient clinic visits, and 2.6 radiographs after union had been confirmed. Of these radiographs, 98% did not reveal changes when compared with previous imaging. Three images (0.7%) showed signs of avascular necrosis of the femoral head, 3 showed osteoarthritis of the hip, and 3 revealed heterotopic ossification. The authors concluded that there is a negligible role for radiographs and clinic visits when evidence of clinical and radiographic healing with acceptable alignment of an intertrochanteric fracture is available.

Robertson et al.[22] (NOS 3/9) retrospectively evaluated 53 patients with an isolated tibial shaft fracture that were treated with an intramedullary nail. Out of 343 radiographs made during follow-up, 9 (3%) directly led to a change in clinical management. In 2 patients, radiographs showed union, and the nail was removed. The remaining 7 patients showed signs of delayed union, which gave rise to nail exchange procedures. The authors concluded that serial radiographs are not justified, and that radiographs prior to 10 weeks follow-up should only be made when there is a clinical suspicion of a complication.

Fractures of the upper extremity

Five studies showed that follow-up radiographs of the upper extremity seldom influenced the treatment strategy, should only be made for a clinical indication and that routine radiography can probably be omitted.

Weil et al.[23] (NOS 5/9) evaluated the use of routine radiographs, and the changes in the treatment strategy based on these radiographs, taken after more than 3 weeks of follow-up in a multi-center cohort of 1042 patients with a distal radius fracture. A radiograph was labelled routine if no clinical indication for obtaining it was registered in the medical records. Of the 720 radiographs that complied with these requirements, 11 (1.5%) led to a change in the treatment strategy. In 9 instances, cast immobilization was prolonged, and in 2 instances, the patient was converted to operative treatment. The conclusion of the authors was that routine radiographs after the initial 3 weeks follow-up period seldom influence clinical decision making.

Stone et al.[24] (NOS 5/9) studied radiographs taken 2 weeks after open reduction and internal fixation of distal radius fractures in a retrospective cohort of 261 patients with 268 fractures. They evaluated the number of changes in the treatment strategy as well as the number of re-interventions. At 2 weeks follow-up, 3 changes in management were recorded (1.1%). All these cases involved patients with a loss of reduction or hardware failure after a consecutive trauma to the injured wrist. The authors concluded that for low-energetic, noncomminuted fractures, routine radiographs at 2 weeks could be omitted.

Huffaker et al.[25] (NOS 5/9) evaluated the value of routine postoperative radiographs in AO type A[28] distal radius fractures treated with volar locking plates. They identified 446 post-operative radiographs in a cohort of 158 patients. During follow-up (mean 4.2 months), none of the radiographs showed nonunion, loss of fixation, or a change in alignment. For patients presenting with symptoms (such as neuropathy, signs of infection, pain, or crepitation), radiography was not associated with a higher likelihood of operative intervention. The authors concluded that radiographs, apart from the primary direct post-operative radiograph, should only be made for a clinical indication.

Eastley et al.[26] (NOS 5/9) assessed 137 patients with extra-articular distal radius fractures that were treated nonoperatively. They investigated whether grip strength, clinical deformity, and range of motion were associated with obtaining radiographs after more than 2 weeks of follow-up. The cohort was divided into 2 groups. One that had radiographs taken only in the first 2 weeks ('early' n=77), and another group that had follow-up radiographs beyond this term as well ('late' n=61). No significant differences in grip strength, mean flexion, dorsiflexion, radial deviation, and ulnar deviation were found. There was no conversion to operative care based on late radiographs. The authors concluded that omission of late radiographs in this patient category may have no adverse effects on clinical outcome whilst providing financial benefits.

De Beaux et al.[27] (NOS 4/9) evaluated a retrospective cohort of 45 patients with a suspected fracture of the elbow region (depicted by a positive fat pad sign, but the absence of a fracture line on the initial emergency room radiographs). The main research question was if repeat radiography after 2 weeks altered the treatment strategy. At the follow-up moment after 2 weeks, 11 patients failed to attend and 3 had no repeat radiographs made. Of the remaining 31 patients, 29 had normal radiographs, and 2 patients were diagnosed with a nondisplaced fracture of the radial head. No changes were made to the treatment of any participant. The authors concluded that routine follow-up radiography is unnecessary in this patient category.

Level of Evidence

All the included studies are observational, and therefore, the initial level of evidence should be considered 'low'. As the studies are retrospective in nature, the risk of bias was regarded high. As a result, the level of evidence was downgraded to 'very low' for all included studies.

DISCUSSION

In total, we identified 11 retrospective studies that examined the possible relation between radiographic imaging and the treatment strategy. Several studies also described the influence of the omission of radiographs on functional outcome or detection of complications. Unfortunately, these studies were clinically so diverse that it was not possible to pool the data. Based upon the descriptive analysis, it appears that all studies come to essentially the same conclusion. They all suggest that omitting some, or even all, follow-up radiographs of extremity fractures does not have important clinical consequences, such as changes in the treatment strategy, a deterioration of clinical outcomes, or missed complications. From the studies we included in the present systematic review, no distinction could be made between different fracture locations or fracture types. However, all conclusions were based upon retrospective studies, introducing a high risk of bias and confounding. The level of evidence was low, indicating that these results should be interpreted with caution. We did not identify any prospective studies. As a result, studies included in this review should be regarded as the best available evidence at present.

For other indications, such as low back pain,[29] knee osteoarthritis,[30] or following paediatric spinal surgery[31] the added value of routine radiographs are being questioned as well. Apparently, for other indications than extremity fractures, radiographs are also made routinely and without great impact on the treatment strategies. In addition, for direct post-operative check radiographs of, for instance, hip fractures, multiple retrospective studies exist that debate their usefulness or discourage their use.[32-35] A randomized study investigating the usefulness of direct post-operative control radiographs for operatively treated wrist and ankle fractures is currently being conducted by Oehme et al.[36] Routine radiographs might resemble low-value care, and omitting them might lead to increased efficiency for the healthcare system. The American College of Foot and Ankle Surgeons released a consensus statement discouraging the use of routine radiographs to monitor fracture, osteotomy, and arthrodesis healing without a clinical indication in the foot and ankle.[37] However, to date, prospective evidence to support this claim is lacking.

In all studies included in this review, the number of changes in the treatment strategy based on radiography was low. As depicted in Table II, it ranged from 0 to 2.6%. The number of complications detected on a routine radiograph, in the absence of clinical symptoms, was similarly low. Both patients and physicians tend to ascertain value to radiographic confirmation of a favourable recovery. However, this review suggests that findings on a routine radiograph that require a change in the treatment strategy, in the absence of clinical symptoms, are rare. The presence of clinical symptoms could be a good predictor of an unfavorable outcome and might justify the use of radiography to rule out a complication. In the randomized controlled trial, we are currently conducting,[38] reasons to obtain radiographs include: a score higher than 6 on a 0-to-10-points visual analogue scale for pain, a loss in range of motion, neurovascular symptoms, or a successive trauma to the injured limb.

It is clear from our overview that interest in this topic is growing. All but 2 studies were published in the last 6 years, and quality and precision of the studies improved over time.

For example, the older 2 studies contributed just 2% to the total number of participants and scored poorly on the Newcastle-Ottawa scale (3 and 4 points out of 9, respectively). The more recent studies included more participants and, on average, scored higher on the Newcastle-Ottawa scale.

Limitations and Strengths

All studies included in this review had a retrospective design and several other limitations in their study design on the Newcastle-Ottawa scale. All studies but 2 had a non-comparative design, and no statistical testing of outcomes was performed. The risk of bias was high, confounding was likely, and the external validity was limited. This resulted in a 'very low' level of evidence according to GRADE.

Conclusions in systematic reviews are dependent on the quality and design of studies included. The fact that only retrospective studies were identified, and the level of evidence was very low hinders us in making strong recommendations. A second potential limitation was the tool used for assessment of the methodological quality of the included studies. The Newcastle-Ottawa scale is best suited for comparative and prospective nonrandomized studies; therefore, this tool might not deliver the best assessment of risk of bias in the current setup. Finally, we limited our search to English and Dutch; therefore, language bias may affect our conclusions. However, no studies in Dutch were identified by the search strategy, and manual screening of the reference lists of included studies did not yield any references in a language other than English. Consequentially, the chance that language bias played a substantial role in the selection process of the systematic review was deemed low.

A strength of the present study is fact that the percentage of included studies was very low (0.4%). This indicates that our initial search was broad, and as a result, the risk that important publications were missed was low.

CONCLUSION

The added value of routine radiography in extremity fractures appears limited, whilst making these radiographs involves effort and cost. Although this conclusion is based upon results of retrospective studies with all concomitant limitations, some reservation in use of follow-up radiographs for extremity fractures seems justified. We urge physicians to be reticent in ordering follow-up radiographs of lower and upper extremity fractures in the absence of a clear clinical indication. Future research in this topic should focus on the conception of prospective randomized studies. These studies should evaluate the impact of routine radiographic imaging on the treatment strategy and the treatment outcomes of patients with extremity fractures. Conducting such a trial seems feasible and might provide a more solid substantiation of our conclusion.

REFERENCES

1. Polinder S, Haagsma J, Panneman M, Scholten A, Brugmans M, Van Beeck E. The economic burden of injury: Health care and productivity costs of injuries in the Netherlands. Accident; analysis and prevention. 2016 Aug;93:92-100. Epub 2016/05/14.
2. Leslie WD, Lix LM, Finlayson GS, Metge CJ, Morin SN, Majumdar SR. Direct healthcare costs for 5 years post-fracture in Canada: a long-term population-based assessment. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2013 May;24(5):1697-705. Epub 2013/01/24.
3. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. Injury. 2006 Aug;37(8):691-7. Epub 2006/07/04.
4. (CBS) SN. Population prognosis in the Netherlands. Statistics Netherlands (CBS) 2015 [May 1, 2017]; Available from: http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83225ned&D1=0&D2=a&D3=0,131-133&D4=0,4,9,14,19,24,29,34,39,l&VW=T.
5. Koehler S, Eiff P. Overview of ankle fractures in adults. UpToDate2016 [cited 2017 23-06-2017]; Available from: https://www.uptodate.com/contents/overview-of-ankle-fractures-in-adults.
6. Petron DJ. Distal radius fractures in adults. UpToDate: Petron, D.J.; 2016 [cited 2017 23-06-2017]; Available from: https://www.uptodate.com/contents/distal-radius-fractures-in-adults.
7. Schipper IB, Termaat MF, Rhemrev S, Meylaerts SAG, Bartlema K, Stichter W, et al. Richtlijnen voor behandeling van letsels van het steun en bewegingsapparaat (Clinical guidelines for the treatment of trauma to the musculoskeletal system). Rotterdam: Optima grafische communicatie; 2016.
8. info-med. Traumaprotocol. info-med; 2015 [26-04-2017]; Available from: http://www.info-med.nl/Traumatologie.htm.
9. Chaudhry S, DelSole EM, Egol KA. Post-splinting radiographs of minimally displaced fractures: good medicine or medicolegal protection? The Journal of bone and joint surgery American volume. 2012 Sep 05;94(17):e128(1)-(5). Epub 2012/09/21.
10. Mushlin AI. Challenges and opportunities in economic evaluations of diagnostic tests and procedures. Academic radiology. 1999 Jan;6 Suppl 1:S128-31. Epub 1999/01/19.
11. Ghattas TN, Dart BR, Pollock AG, Hinkin S, Pham A, Jones TL. Effect of initial postoperative visit radiographs on treatment plans. J Bone Joint Surg Am. 2013 5/1/2013;95 e57(9):1-4.
12. Eastley N, Aujla R, Khan Z. Radiographs late in the follow up of uncomplicated distal radius fractures: are they worth it? Clinical outcome and financial implications. Orthopedic reviews. 2012 May 09;4(e20):88-90. Epub 2012/07/18.
13. Harish S, Vince AS, Patel AD. Routine radiography following ankle fracture fixation: a case for limiting its use. Injury. 1999 Dec;30(10):699-701.
14. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. International journal of surgery (London, England). 2010;8(5):336-41. Epub 2010/02/23.
15. GA Wells, B Shea, D O'Connell, J Peterson, V Welch, M Losos, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. [13-07-2017]; Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
16. GRADE-working-group. GRADE. Available from: http://www.gradeworkinggroup.org/.

17. Schuld JC, Volker ML, Anderson SA, Zwank MD. Postsplinting x-rays of nondisplaced hand, wrist, ankle, and foot fractures are unnecessary. The American journal of emergency medicine. 2016 Aug;34(8):1625-6. Epub 2016/05/30.
18. Ghattas TN, Dart BR, Pollock AGA, Hinkin S, Pham A, Jones TL. Effect of initial postoperative visit radiographs on treatment plans. Journal of Bone and Joint Surgery - Series A. 2013;95(9):e571-e4.
19. McDonald MR, Bulka CM, Thakore RV, Obremskey WT, Ehrenfeld JM, Jahangir AA, et al. Ankle radiographs in the early postoperative period: do they matter? Journal of orthopaedic trauma. 2014 Sep;28(9):538-41. Epub 2014/01/01.
20. Ovaska MT, Nuutinen T, Madanat R, Makinen TJ, Soderlund T. The role of outpatient visit after operative treatment of ankle fractures. Injury. 2016 Nov;47(11):2575-8. Epub 2016/11/05.
21. Kempegowda H, Richard R, Borade A, Tawari A, Howenstein AM, Kubiak EN, et al. The Role of Radiographs and Office Visits in the Follow-Up of Healed Intertrochanteric Hip Fractures: An Economic Analysis. J Orthop Trauma. 2016 Dec;30(12):687-90. Epub 2016/10/21.
22. Robertson A, Sutherland M, Keating JF. Intramedullary nailing of tibial fractures: how often are post-operative radiographs needed? J R Coll Surg Edinb. 2000 Aug;45(4):220-2. Epub 2000/12/29.
23. Weil NL, El Moumni M, Rubinstein SM, Krijnen P, Termaat MF, Schipper IB. Routine follow-up radiographs for distal radius fractures are seldom clinically substantiated. Archives of orthopaedic and trauma surgery. 2017;137(9):1187-91.
24. Stone JD, Vaccaro LM, Brabender RC, Hess AV. Utility and cost analysis of radiographs taken 2 weeks following plate fixation of distal radius fractures. The Journal of hand surgery. 2015 Jun;40(6):1106-9. Epub 2015/04/05.
25. Huffaker S, Earp BE, Blazar PE. The value of post-operative radiographs in clinical management of AO type A distal radius fractures. J Hand Surg Eur Vol. 2015 Oct;40(8):790-5. Epub 2014/12/18.
26. Eastley N, Aujla R, Khan Z. Radiographs late in the follow up of uncomplicated distal radius fractures: are they worth it? Clinical outcome and financial implications. Orthopedic reviews. 2012 May 9;4(2):e20. Epub 2012/07/18.
27. de Beaux AC, Beattie T, Gilbert F. Elbow fat pad sign: implications for clinical management. J R Coll Surg Edinb. 1992 Jun;37(3):205-6. Epub 1992/06/01.
28. AO foundation. Available from: www.aofoundation.org.
29. Chou R, Fu R, Carrino JA, Deyo RA. Imaging strategies for low-back pain: systematic review and meta-analysis. Lancet (London, England). 2009 Feb 7;373(9662):463-72. Epub 2009/02/10.
30. Skou ST, Thomsen H, Simonsen OH. The value of routine radiography in patients with knee osteoarthritis consulting primary health care: a study of agreement. The European journal of general practice. 2014 Mar;20(1):10-6. Epub 2013/09/03.
31. Garg S, Kipper E, LaGreca J, Carry P, Erickson M. Are routine postoperative radiographs necessary during the first year after posterior spinal fusion for idiopathic scoliosis? A retrospective cohort analysis of implant failure and surgery revision rates. Journal of pediatric orthopedics. 2015 Jan;35(1):33-8. Epub 2014/05/21.
32. Kurup HV, Michael ALR, Beaumont AR. The need for routine postoperative radiographs in hip fracture fixation: An audit-based approach. European Journal of Orthopaedic Surgery and Traumatology. 2008;18(4):265-7.
33. Westerterp M, Emous M, Vermeulen MC, Eerenberg JP, van Geloven AA. No additional value of routine check X-rays after internal fixation of hip fractures. Eur J Trauma Emerg Surg. 2013 Apr;39(2):163-5. Epub 2013/04/01.
34. Mohanty K, Gupta SK, Evans RM. Check radiography after fixation of hip fractures: is it necessary? J R Coll Surg Edinb. 2000 Dec;45(6):398-9. Epub 2001/01/12.

35. Teo T, Schaeffer E, Cooper A, Mulpuri K. Do Immediate Postoperative Radiographs Change Patient Management After Fracture Fixation? A Systematic Review. Journal of orthopaedic trauma. 2018 May;32(5):211-5. Epub 2018/03/10.
36. Oehme F, Ruhle A, Muhlhausser J, Fourie L, Link BC, Babst R, et al. Are Routine Radiographs Needed the Day After Open Reduction and Internal Fixation Surgery for Distal Radius and Ankle Fractures: Study Protocol for a Prospective, Open Label, Randomized Controlled Trial. JMIR research protocols. 2017 Aug 16;6(8):e159. Epub 2017/08/18.
37. Meyr AJ, Mirmiran R, Naldo J, Sachs BD, Shibuya N. American College of Foot and Ankle Surgeons((R)) Clinical Consensus Statement: Perioperative Management. The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons. 2017 Mar - Apr;56(2):336-56. Epub 2017/02/25.
38. Weil NL, Termaat MF, Rubinstein SM, El Moumni M, Zuidema WP, Derksen RJ, et al. WARRIOR-trial - is routine radiography following the 2-week initial follow-up in trauma patients with wrist and ankle fractures necessary: study protocol for a randomized controlled trial. Trials. 2015 Feb 27;16:66. Epub 2015/04/16.

APPENDICES

Appendix 1: search strategy

PubMed/Cochrane

#1 Reduce frequency Radiography

"Radiography"[Mesh] OR "Radiation"[Mesh] OR Diagnostic X-Ray*[tiab] OR Roentgenograph*[tiab] OR Roentgenogram*[tiab] OR X-Ray Radiolog*[tiab] OR reduced imaging[tiab] OR radiograph*[tiab] OR "diagnostic imaging"[Subheading] OR radiation[tiab] OR (Imaging[tiab] AND (protocol*[tiab] OR "standards"[Subheading] OR standards[tiab] OR guideline*[tiab] OR criteria*[tiab] OR practice*)) **AND** ("Diagnostic Tests, Routine"[Mesh] OR "Unnecessary Procedures/economics"[Mesh] OR "Unnecessary Procedures/epidemiology"[Mesh] OR Reducing[tiab] OR omitt*[tiab] OR omission[tiab] OR frequenc*[tiab] OR decreas*[tiab] OR lessen[tiab] OR restrict*[tiab] OR cut down[tiab] OR routine*[tiab])

#2a bones of upperextremity

(("Upper Extremity"[Mesh] OR Upper Extremit*[tiab] OR Membrum superius[tiab] OR Upper Limb*[tiab] OR "Bones of Upper Extremity"[Mesh] OR arm[tiab] OR arms[tiab] OR brachium*[tiab] OR shoulder[tiab] OR clavic*[tiab] OR collar bone*[tiab] OR scapula*[tiab] OR shoulder blade*[tiab] OR acromion*[tiab] OR coracoid*[tiab] OR glenoid[tiab] OR humerus[tiab] OR humeral[tiab] OR Tuberc*[tiab] OR tuberosity*[tiab] OR trochlea*[tiab] OR epicondy*[tiab] OR condy*[tiab] OR elbow*[tiab] OR ulna*[tiab] OR olecran*[tiab] OR radius[tiab] OR radial[tiab] OR coranoid*[tiab] OR forearm*[tiab] OR Antebrachi*[tiab] OR wrist*[tiab] OR hand[tiab] OR hands[tiab] OR finger*[tiab] OR thumb*[tiab] OR carpus[tiab] OR carpal[tiab] OR scaphoid*[tiab] OR navicular*[tiab] OR triquetra*[tiab] OR Metacarp*[tiab] OR phalanges[tiab] OR phalanx[tiab]) AND ("Fractures, Bone"[Mesh:NoExp] OR "Fracture Healing"[Mesh] OR fracture*[tiab] OR broken bone*[tiab]))

Specific types of upper extremity fractures

"Shoulder Fractures"[Mesh] OR "Humeral Fractures"[Mesh] OR "Ulna Fractures"[Mesh] OR Monteggia*[tiab] OR galeazz*[tiab] OR "essex lopresti"[tiab] OR "Radius Fractures"[Mesh] OR Colles*[tiab] OR boxers fracture*[tiab] OR boxer's fracture*[tiab] OR bankart[tiab] OR hill-sachs[tiab] OR Bennett*[tiab] OR Rolando*[tiab] OR smith's fracture*[tiab] OR Goyrand-Smith's[tiab]

#2b bones of lower extremity

(("Lower Extremity"[Mesh] OR Lower Extremit*[tiab] OR lower limb[tiab] OR membrum inferius[tiab] OR "Bones of Lower Extremity"[Mesh] OR leg bone*[tiab] OR hip fracture*[tiab] OR fracture of the hip[tiab] OR fractures of the hip[tiab] OR Femur*[tiab] OR femoral*[tiab] OR trochanter*[tiab] OR intertrochanter*[tiab] OR subtrochanter*[tiab] OR patella*[tiab] OR knee[tiab] OR knees[tiab] OR kneecap*[tiab] OR tibia*[tiab] OR fibula*[tiab] OR foot bone*[tiab] OR feet bone*[tiab] OR Tarsal*[tiab] OR ankle*[tiab] OR cuneiform*[tiab] OR cuboid*[tiab] OR calcaneus*[tiab] OR heel bone*[tiab] OR metatarsal*[tiab] OR toe bone*[tiab] OR toes bone*[tiab] OR hallux*[tiab] OR hallic*[tiab] OR malleol*[tiab] OR trimall*[tiab] OR bimall*[tiab]) AND ("Fractures, Bone"[Mesh:NoExp] OR "Fracture Healing"[Mesh] OR fracture*[tiab] OR broken bone*[tiab]))

Specific types of lower extremity fractures

"Femoral Fractures"[Mesh] OR "Tibial Fractures"[Mesh] OR "Ankle Fractures"[Mesh] OR maisonneuve*[tiab] OR lisfranc*[tiab] OR segond*[tiab] OR tillaux*[tiab]

#3 QoL/ outcome measurements

"Health Status"[mesh] OR "Quality of Life"[mesh] OR "Treatment Outcome"[mesh] OR "Outcome Assessment (Health Care)"[Mesh] OR "Recovery of Function"[Mesh] OR "Clinical Decision-Making"[Mesh] OR clinical indicat*[tiab] OR clinical impact*[tiab] OR treatment strategy[tiab] OR therapeutic polic*[tiab] OR patient management[tiab] OR management policy[tiab] OR clinical management[tiab] OR recovery[tiab] OR "Health Status"[tiab] OR "Quality of Life"[tiab] OR clinical Outcome*[tiab] OR value[tiab] OR "clinical decision making"[tiab] OR "Quality-Adjusted Life Years"[Mesh] OR (("Life years"[tiab]) AND ("Quality adjusted"[tiab] OR adjusted[tiab] OR Gained [tiab])) OR "QUALY"[tiab] OR "LYG" [tiab] OR "Quality adjusted"[tiab] OR ((change*[tiab] OR changing[tiab]) AND management*[tiab])

#4 Adults only

NOT (("Adolescent"[Mesh] OR "Child"[Mesh] OR "Infant"[Mesh] OR adolescen*[tiab] OR child*[tiab] OR schoolchild*[tiab] OR infant*[tiab] OR girl*[tiab] OR boy*[tiab] OR teen[tiab] OR teens[tiab] OR teenager*[tiab] OR youth*[tiab] OR pediatr*[tiab] OR paediatr*[tiab] OR puber*[tiab]) NOT ("Adult"[Mesh] OR adult*[tiab] OR man[tiab] OR men[tiab] OR woman[tiab] OR women[tiab]))

#5 Publication types/ humans

NOT ("addresses"[Publication Type] OR "biography"[Publication Type] OR "Case Reports" [Publication Type] OR "comment"[Publication Type] OR "directory"[Publication Type] OR "editorial"[Publication Type] OR "festschrift"[Publication Type] OR "interview"[Publication Type] OR "lectures"[Publication Type] OR "legal cases"[Publication Type] OR "legislation"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type] OR "patient education handout"[Publication Type] OR "popular works"[Publication Type] OR "congresses"[Publication Type] OR "consensus development conference"[Publication Type] OR "consensus development conference, nih"[Publication Type] OR "practice guideline"[Publication Type]) NOT ("animals"[MeSH Terms] NOT "humans"[MeSH Terms])

EMBASE.com

#1 Reduce frequency Radiography

'radiography'/exp OR 'radiation'/exp OR Diagnostic X-Ray*:ti,ab OR Roentgenograph*:ti,ab OR Roentgenogram*:ti,ab OR X-Ray Radiolog*:ti,ab OR 'reduced imaging':ti,ab OR radiograph*:ti,ab OR 'diagnostic imaging':ti,ab OR radiation:ti,ab OR (Imaging:ti,ab AND (protocol*:ti,ab OR standards:ti,ab OR guideline*:ti,ab OR criteria*:ti,ab OR practice*)) AND ('diagnostic test'/exp OR 'unnecessary procedure'/exp OR Reducing:ti,ab OR omitt*:ti,ab OR omission:ti,ab OR frequenc*:ti,ab OR decreas*:ti,ab OR lessen:ti,ab OR restrict*:ti,ab OR 'cut down':ti,ab OR routine*:ti,ab)

#2a bones of upperextremity

(('upper limb'/exp OR 'Upper Extremit*':ti,ab OR 'Membrum superius':ti,ab OR 'Upper Limb*':ti,ab OR 'bones of the arm and hand'/exp OR arm:ti,ab OR arms:ti,ab OR brachium*:ti,ab OR shoulder:ti,ab OR clavic*:ti,ab OR 'collar bone*':ti,ab OR scapula*:ti,ab OR 'shoulder blade*':ti,ab OR acromion*:ti,ab OR coracoid*:ti,ab OR glenoid:ti,ab OR humerus:ti,ab OR humeral:ti,ab OR Tuberc*:ti,ab OR tuberosity*:ti,ab OR trochlea*:ti,ab OR epicondy*:ti,ab OR condy*:ti,ab OR elbow*:ti,ab OR ulna*:ti,ab OR olecran*:ti,ab OR radius:ti,ab OR radial:ti,ab OR coranoid*:ti,ab OR forearm*:ti,ab OR Antebrachi*:ti,ab OR wrist*:ti,ab OR hand:ti,ab OR hands:ti,ab OR finger*:ti,ab OR thumb*:ti,ab OR carpus:ti,ab OR carpal:ti,ab OR scaphoid*:ti,ab OR navicular*:ti,ab OR triquetra*:ti,ab OR Metacarp*:ti,ab OR phalanges:ti,ab OR phalanx:ti,ab) AND ('fracture'/de OR 'fracture healing'/exp OR fracture*:ti,ab OR 'broken bone*':ti,ab))

Specific types of upper extremity fractures

'shoulder fracture'/exp OR 'humerus fracture'/exp OR 'ulna fracture'/exp OR Monteggia*:ti,ab OR galeazz*:ti,ab OR 'essex lopresti':ti,ab OR 'radius fracture'/exp OR Colles*:ti,ab OR 'boxers fracture*':ti,ab OR 'boxers fracture*':ti,ab OR bankart:ti,ab OR 'hill-sachs':ti,ab OR Bennett*:ti,ab OR Rolando*:ti,ab OR 'smiths fracture*':ti,ab OR 'Goyrand-Smith*':ti,ab

#2b bones of lower extremity

(('lower limb'/exp OR 'Lower Extremit*':ti,ab OR 'lower limb':ti,ab OR 'membrum inferius':ti,ab OR 'bones of the leg and foot'/exp OR 'leg bone*':ti,ab OR 'hip fracture*':ti,ab OR 'fracture of the hip':ti,ab OR 'fractures of the hip':ti,ab OR Femur*:ti,ab OR femoral*:ti,ab OR trochanter*:ti,ab OR intertrochanter*:ti,ab OR subtrochanter*:ti,ab OR patella*:ti,ab OR knee:ti,ab OR knees:ti,ab OR kneecap*:ti,ab OR tibia*:ti,ab OR fibula*:ti,ab OR 'foot bone*':ti,ab OR 'feet bone*':ti,ab OR Tarsal*:ti,ab OR ankle*:ti,ab OR cuneiform*:ti,ab OR cuboid*:ti,ab OR calcaneus*:ti,ab OR heel bone*:ti,ab OR metatarsal*:ti,ab OR 'toe bone*':ti,ab OR 'toes bone*':ti,ab OR hallux*:ti,ab OR hallic*:ti,ab OR malleol*:ti,ab OR trimall*:ti,ab OR bimall*:ti,ab) AND ('fracture'/de OR 'fracture healing'/exp OR fracture*:ti,ab OR 'broken bone*':ti,ab))

Specific types of lower extremity fractures

'femur fracture'/exp OR 'tibia fracture'/exp OR 'ankle fracture'/exp OR maisonneuve*:ti,ab OR lisfranc*:ti,ab OR segond*:ti,ab OR tillaux*:ti,ab

#3 QoL/ outcome measurements

'health status'/exp OR 'quality of life'/exp OR 'treatment outcome'/exp OR 'outcome assessment'/exp OR 'convalescence'/exp OR 'clinical decision making'/exp OR 'clinical indicat*':ti,ab OR 'clinical impact*':ti,ab OR 'treatment strategy':ti,ab OR 'therapeutic polic*':ti,ab OR 'patient management':ti,ab OR 'management policy':ti,ab OR 'clinical management':ti,ab OR recovery:ti,ab OR 'Health Status':ti,ab OR 'Quality of Life':ti,ab OR 'clinical Outcome*':ti,ab OR value:ti,ab OR 'clinical decision making':ti,ab OR 'quality adjusted life year'/exp OR (('Life years':ti,ab) AND ('Quality adjusted':ti,ab OR adjusted:ti,ab OR gained:ti,ab)) OR 'QUALY':ti,ab OR 'LYG':ti,ab OR 'Quality adjusted':ti,ab OR ((change*:ti,ab OR changing:ti,ab) AND management*:ti,ab)

#4 Adults only

NOT (('juvenile'/exp OR'embryo'/exp OR'fetus'/exp OR adolescen*:ti,ab OR child*:ti,ab OR schoolchild*:ti,ab OR infant*:ti,ab OR girl*:ti,ab OR boy*:ti,ab OR teen:ti,ab OR teens:ti,ab OR teenager*:ti,ab OR youth*:ti,ab OR pediatr*:ti,ab OR paediatr*:ti,ab OR puber*:ti,ab) NOT ('adult'/exp OR adult*:ti,ab OR man:ti,ab OR men:ti,ab OR woman:ti,ab OR women:ti,ab))

#5 Publication types/ humans

PT use EMBASE filters

NOT ('animal'/exp] NOT 'human'/exp)

Appendix 2: Newcastle Ottawa Scale

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE
COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability

Selection

1) Representativeness of the exposed cohort
   a) truly representative of the average _______________ (describe) in the community ✱
   b) somewhat representative of the average ______________ in the community ✱
   c) selected group of users eg nurses, volunteers
   d) no description of the derivation of the cohort

2) Selection of the non exposed cohort
   a) drawn from the same community as the exposed cohort ✱
   b) drawn from a different source
   c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure
   a) secure record (eg surgical records) ✱
   b) structured interview ✱
   c) written self report
   d) no description

4) Demonstration that outcome of interest was not present at start of study
   a) yes ✱
   b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for _____________ (select the most important factor) ✱
   b) study controls for any additional factor ✱ (This criteria could be modified to indicate specific control for a second important factor.)

Outcome

1) Assessment of outcome
   a) independent blind assessment ✱
   b) record linkage ✱
   c) self report
   d) no description

2) Was follow-up long enough for outcomes to occur
   a) yes (select an adequate follow up period for outcome of interest) ✱
   b) no

3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for ✱
   b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost) ✱
   c) follow up rate < ____% (select an adequate %) and no description of those lost
   d) no statement

Appendix 3: Excluded articles

Author	Year	Journal	Reason for exclusion
Archdeacon	2015	J Orthop Trauma	Study describing direct postoperative 'check radiography'
Bessette	2017	J Arthroplasty	Study describing patients with an artroplasty, not a fracture
Bhattacharyya	2017	Injury	Study describing a reduction in outpatient clinic visit, not radiography
Chakravarthy	2007	Int J Clin Pract	Study describing direct postoperative 'check radiography'
Chaudhry	2012	J Bone Joint Surg Am	Study describing direct postprocedural 'check radiography'
Ferguson	2015	Injury	Study describing a reduction in outpatient clinic visit, not radiography
Harish	1999	Injury	Study describing direct postprocedural 'check radiography'
Jain	2008	Ann R Coll Surg Engl	Study not reporting on any of the required outcome measures
Johnson	2016	Plast Reconstr Surg	Study describing direct postoperative 'check radiography'
Kurup	2008	Eur J Orthop Surg Traumatol	Study describing direct postoperative 'check radiography'
Michelson	1995	J Trauma	Study not reporting on any of the required outcome measures
Miniaci-Coxhead	2015	Foot Ankle Int	Study describing direct postoperative 'check radiography'
Mohanti	2000	J R Coll Surg Edinb	Study describing direct postoperative 'check radiography'
Moody	2016	J Orthop Trauma	Study not reporting on any of the required outcome measures
Morewood	1987	Br. Med J (Clin Res Ed)	Study with a large percentage (26%) of pediatric patients
O'Shea	2006	J Orthop Surg (Hong Kong)	Study describing direct postoperative 'check radiography'
Pannell	2016	Hand (N Y)	Study without "clinical" cases, solely imaging.
Quinton	1987	J Bone Joint Surg Br	Study describing patients without a fracture.
Stott	2017	J Orthop Trauma	Study describing direct postoperative 'check radiography'
Welsh	1987	Br Med J (Clin Res Ed)	Correspondence with comment on a research article (Morewood 1987)
Westerterp	2013	Eur J Trauma Emerg Surg	Study describing direct postoperative 'check radiography'