

Dynamic and static external fixation for distal radius fractures—A systematic review

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ARTICLE INFO

Article history:

Accepted 16 February 2010

Keywords:

Distal radius fractures
Wrist injuries
External fixators
Treatment outcome
Systematic review

ABSTRACT

Introduction: External fixation of distal radius fractures may be static (wrist-bridging) or dynamic (wrist-bridging with mobile hinge or non-bridging). The aim of this systematic review is to investigate the effectiveness of different methods of external fixation for unstable distal radius fractures.

Methods: A Medline database search was performed with strict eligibility criteria to obtain the highest quality evidence from meta-analyses, RCTs and comparative studies. Eligible studies were critically appraised using levels of evidence and RCTs were further appraised using a validated scoring tool.

Results: Fifty-four studies were identified of which eight were included. There were six RCTs and two retrospective comparative studies. Three RCTs compared non-bridging with static wrist-bridging fixation. Two RCTs compared dynamic wrist-bridging with static wrist-bridging fixation. One study compared dynamic wrist-bridging with non-bridging fixation. The RCTs varied in quality and scored between 12 and 23 out of a maximum of 33 points.

The evidence suggests that there are no functional or radiological benefits for a dynamic wrist-bridging external fixator with a mobile hinge joint over a static wrist-bridging external fixator. The evidence also suggests that there are no benefits for non-bridging over static wrist-bridging external fixation in older patients but there do appear to be clear benefits both functionally and radiologically when considering patients of all ages.

Conclusion: Dynamic and static external fixators both achieve good outcomes for patients with unstable distal radius fractures with comparable complication rates. Non-bridging fixation may result in better functional and radiological results than static wrist-bridging fixation when considering patients of all ages with earlier return of function. This benefit does not seem apparent when considering older patients. Although a benefit was not seen in this group, the technique may have practical advantages over wrist-bridging fixation by allowing increased mobility and use of the limb during the fixation period and enabling such patients to maintain their independence. Cost effective analyses are required to assess whether this would be an economically viable option for this group of patients.

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Introduction

Distal radius fractures may be managed non-operatively or operatively with both methods resulting in good reliable results when appropriately used.^{8,11,13} The operative methods for displaced unstable fractures include closed reduction with percutaneous pinning, open reduction with internal fixation, external fixation, combinations of percutaneous pinning with internal and external fixation, arthroscopically assisted reduction and bone grafting and cementing techniques.

External fixation of distal radius fractures may be static or dynamic. Static fixation involves a wrist-bridging (WB) external

fixator with no possibility of wrist mobilisation during the treatment period. Dynamic fixation allows wrist mobilisation whilst the fixator is in place. This may be achieved with a WB fixator with a mobile hinge joint or by a non-bridging (NB) fixator with pins being inserted into the distal end of the radius.

The goal of treatment is to restore wrist mobility and function and to prevent the development of secondary osteoarthritis.¹⁵ Previous studies have shown that this is achieved by accurate reduction of normal radial inclination (23°), radial height (12 mm) and volar tilt (11°) and a radial articular step <2 mm with reduction of the distal radioulnar joint in intra-articular fractures.^{13,15} Furthermore, early mobilisation of the wrist is thought to result in an earlier return to function with reduced complications² and also has practical advantages for the patient. Dynamic external fixation has a theoretical advantage over static fixation by enabling accurate fracture reduction and earlier mobilisation of the wrist joint whilst maintaining stability.

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The aim of this systematic review is to decide, with the best available evidence, whether dynamic external fixation results in better functional and radiological outcomes, an earlier return to function and fewer complications when compared to static external fixation achieved with either bridging or non-bridging techniques for fractures of the distal aspect of the radius.

Methods

Manuscript retrieval

A Medline database search was undertaken using the Ovid Medline internet search engine to look at citations that have been published using the following MeSH (Medline/Pub Med's Subject Headings) terms:

1. exp radius fractures/ or exp wrist injuries/ or exp wrist joint/
2. exp external fixators/
3. exp "Outcome Assessment (Health Care)"/ or exp treatment outcome/ or exp "Range of Motion, Articular"/
4. 1 and 2 and 3
5. limit 4 to (humans and English language and (clinical trial or comparative study or meta-analysis or randomised controlled trial or "review"))

Search dated: 1950 to August Week 4 2009.

Criteria for eligibility

Studies selected were original articles that compared different external fixation methods for displaced unstable distal radius fractures. Only English language publications were included. Data had to be presented in the same format for all included articles in order to compare statistics. The criteria for eligibility were as shown below with studies using any of the outcomes included within the review.

Studies:	Randomised controlled trial; comparative study; clinical trial; meta-analysis; systematic review.
Patients:	Adults patients with displaced and unstable distal radius fractures (AO classification).
Intervention:	Dynamic external fixation (wrist-bridging and non-bridging).
Comparison:	Static external fixation or other combinations.
Outcomes:	Functional—disease specific and general health measurements. Range of movement (ROM), grip and pinch strength. Return to work and other activities of daily living (ADL). Complications.

Extraction of data

The resultant abstracts were assessed for their suitability to be reviewed in further detail. Studies that did not involve the management of distal radius fractures were excluded from the review at this stage. A hand search of core clinical journals and a Cochrane library search were also performed to ensure that no relevant studies were missed after the database search. All relevant studies were independently reviewed by two reviewers (C.S.M. and K.H.) with any disagreements being resolved by a third

reviewer (C.D.M.). The studies were systematically reviewed using a data extraction proforma with results being summarised in tabulated form and graded according to their level of evidence.¹²

The RCTs were then further appraised using a scoring system devised by the Cochrane Musculoskeletal Injuries Group which was modified for fractures of the distal radius by Handoll and Madhok.⁴ The checklist assesses a study against 11 aspects of trial validity with a maximum score of 33 points for a study.

Results

Literature search

The Medline literature search revealed 54 studies within the limitations described above. There were no further studies identified from the hand search of core clinical journals and the Cochrane database search. Eight studies were identified as meeting the inclusion criteria for this review and 46 were excluded for the reasons shown in Fig. 1. Of the eight studies that met the inclusion criteria six were RCTs^{1,6,7,9,10,14} and two were retrospective studies.^{5,16} The details and results of these has been summarised in Table 1. The RCTs were studied in further detail and their trial validity scores are shown in Table 2.

Randomised controlled trials

Dynamic (non-bridging) vs. static (wrist-bridging)

*Atroshi et al.*¹. This RCT compared dynamic NB (Hoffmann II Compact – Stryker) with static WB (Hoffmann – Stryker) external fixation. Thirty-eight patients (males >60 years; females >50 years) with acute unstable intra- and extra-articular distal radius fractures were randomised at a single centre. There were 19 patients in each group with all fixators being removed at 6 weeks followed by physiotherapy rehabilitation with immediate wrist exercises in the NB group. There were 11 type A2/A3 and 8 type C2/C3 fractures in the NB group and 8 type A2/A3 and 11 type C2/C3 fractures in the WB group.

Thirty-six patients (95%) were followed up at 52 weeks. Analysis showed that the DASH (disabilities of the arm, shoulder and hand) scores³ had improved in both groups and almost returned to pre-injury level by 1 year although there were no statistically significant differences. The WB group had significant worsening of the SF-12 (short form 12) score from baseline to 10 weeks ($p = 0.03$) although this difference was not seen at any other time point. There were no significant differences between the groups for pain, patient satisfaction, ROM, grip strength or complications. Radiographic assessment showed no significant differences except that the NB group maintained better radial length at 1 year (ulnar variance (UV): 2.7(2.6) mm WB group vs. 1.0(2.3) mm NB group; $p = 0.04$).

This is a high quality study scoring 23 out of 33 points for trial validity (Table 2) and providing level 1b evidence (Table 1). The authors used computer-generated randomisation with validated outcome measures and independent blinded assessors to reduce bias.

A sample size calculation had, however, not been performed and a type 2 error cannot be excluded. There were also more type A2 (extra-articular) than C2 (complex articular) fractures in the NB group ($n = 11:8$) and more type C2 than A2 fractures in the WB group ($n = 8:11$) which may be a confounder in this study. It is also unclear who recruited and allocated patients to their groups and whether they were independent. The external validity is also limited as the study was performed in a single centre.

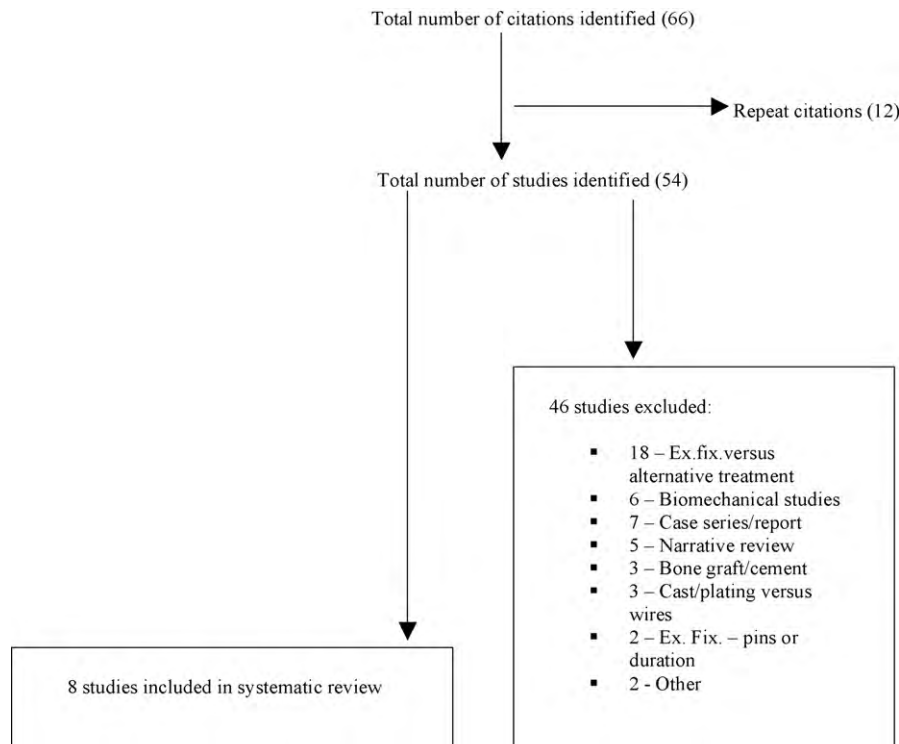


Fig. 1. Summary of data extraction.

Krishnan et al.⁶ This RCT compared NB (Hoffmann II Compact – Stryker) with WB (AO Delta frame) external fixation in 60 adults with a mean age of 56 (18–83) years with intra-articular and complex comminuted distal radius fractures. Thirty patients were allocated to each group with all fixators being removed at 6 weeks followed by physiotherapy rehabilitation with the NB group instructed to commence wrist mobilisation 2 weeks postoperatively. There were 2 type A3, 3 type C1, 6 type C2 and 19 type C3 fractures in the NB group. The WB group included 1 type A3, 1 type B2, 5 type C1, 4 type C2 and 19 type C3 fractures.

The study does not report how many patients completed follow-up to the trial endpoint. There were no significant differences between the groups for pain, grip strength, radiographic measurements or complications. There were no significant differences in ROM except for improved flexion in the NB fixation group at 52 weeks (50° vs. 60°, $p = 0.02$). Although both groups attained similar ADL scores after 12 weeks, the NB group scores were significantly higher in the early period after treatment ($p = 0.034$).

The trial validity score for this study was 15 out of 33 points (Table 2) providing level 2b evidence (Table 1). The patients were randomly allocated to the intervention with a closed envelope method with both study groups well matched for age, fracture type and number of patients, although not for gender as there were more females in the WB group. The radiographic measurements were performed by an independent radiologist. A limitation of this study is the incomplete presentation of data. The flow of patients through the study had not been presented and it was unclear how many patients completed the trial. It was not stated by whom the patients were recruited and allocated to their groups. Unblinded assessors performed the measurements with no comparison to uninjured wrists. Furthermore, there is no mention of a power or sample size calculation and it is therefore difficult to exclude a type 2 error as the reason for a negative result in this study.

McQueen⁹. This RCT compared NB (Pennig fixator – Orthofix) with static WB (Pennig fixator – Orthofix) external fixation. Sixty

patients with a mean age of 61 (31–85) years with unstable extra- and intra-articular distal radius fractures were recruited at a single centre. Thirty patients were allocated to each group with all fixators being removed at 6 weeks followed by physiotherapy rehabilitation as required by the patients. There were 21 type A and 9 type C fractures in the NB group and 25 type A and 5 type C fractures in the WB group.

Fifty-six patients (93%) were followed up at 1 year. Analysis showed significantly better results in the NB group with respect to reduction of dorsal angulation ($p < 0.001$), radial shortening (not significant at 1 year), flexion ($p < 0.05$) and grip strength ($p < 0.001$) at all time periods. There were no significant differences in pain scores or the incidence of complications although there was a 47% malunion in the WB group.

The trial validity score for this study was 18 out of 33 points (Table 2) providing level 2b evidence (Table 1). The eligibility criteria were clearly defined with interventions allocated after closed envelope randomisation. A limitation is that it is not reported by whom the patients were recruited and allocated to their interventions with all procedures being performed by the author in a single centre thus limiting external validity. A sample size or power calculation was not reported and assessors were not blinded. Rehabilitation may have differed between the groups as not all patients had physiotherapy. This may have had a bias effect upon the functional outcome data although probably represents a pragmatic approach.

Dynamic (wrist-bridging) vs. static (wrist-bridging)

McQueen et al.¹⁰. This RCT compared four methods of treatment for redisplaced unstable intra-articular and extra-articular distal radius fractures in 120 patients (30 per group). The four methods were manipulation and cast, open reduction and bone grafting, and WB external fixation (Pennig fixator – Orthofix) statically in group 3 and dynamically in group 4 with mobilisation at a hinge joint at 3 weeks. The fixators were removed at 6 weeks followed by

Table 1
Summary of included studies.

Study	Design	Size	Completed study	Interventions	Eligibility criteria	Outcome measures	Conclusion	Level of evidence ¹²
Atroschi et al. ¹	RCT	38	36	Static bridging vs. non-bridging	Females >50 years; males >60 years; unstable intra- and extra-articular fractures	DASH, SF-12, pain, ROM, grip strength, radiographs, complications	No differences in outcomes at 52 weeks except less radial shortening in non-bridging group ^a	1b
Hayes et al. ⁵	Retrospective	641	588	Static bridging vs. non-bridging	Unstable extra-articular fractures	Radiographs, complications	Risk of dorsal malunion reduced by 6 ^a and shortening by 2.5 times ^a with non-bridging fixation	4
Krishnan et al. ⁶	RCT	60	?	Static bridging vs. non-bridging	Intra-articular fractures	Pain, ROM, grip strength, radiographs, complications	No differences in any outcomes at 52 weeks	2b
Krukhaug et al. ⁷	RCT	75	71	Dynamic bridging vs. non-bridging	Unstable extra-articular fractures	Radiographs, DASH, pain, ROM, complications	No differences in functional or radiographic outcomes	1b
McQueen ⁹	RCT	60	56	Static bridging vs. non-bridging	Unstable intra- and extra-articular fractures	Pain, grip strength, ROM, radiographs, complications	Better functional and radiographic outcomes in non-bridging group ^a	2b
McQueen et al. ¹⁰	RCT	120	109	Dynamic bridging vs. static bridging	Unstable intra- and extra-articular fractures	Pain, grip strength, ROM, radiographs, complications	No differences in functional or radiographic outcomes	2b
Sommerkamp et al. ¹⁴	RCT	73	48	Dynamic bridging vs. static bridging	Unstable intra- and extra-articular fractures	Modified Gartland and Werley Score, ROM, grip and pinch strength, radiographs, complications	Loss of radial length and more complications in dynamic group ^a although function similar	2b
Uchikura et al. ¹⁶	Retrospective	84	?	Static bridging vs. non-bridging	Unstable intra- and extra-articular fractures	Subjective, ROM, grip strength, arthritis, radiographic, complications	Better ROM, grip strength and outcome in non-bridging group	4

^a Significant difference.

physiotherapy rehabilitation as required by the patients. There were 14 type A3, 13 type C2 and 3 type C3 fractures in the static group. The dynamic group included 13 type A3, 13 type C2 and 4 type C3 fractures.

One hundred and nine patients (91%) were followed up at 1 year. There were no significant differences between groups 3 and 4 for radiological measurements, grip strength, ROM or complications. They concluded that mobilising the wrist at 3 weeks with the fixator did not provide any benefit in terms of ROM or hand function.

The trial validity score for this study was 16 out of 33 points (Table 2) providing level 2b evidence. Patients were allocated to their intervention by a closed randomisation method. Accurate radiographic measurements were made by comparing the injured and non-injured sides. Two surgeons performed the procedures thereby increasing the external validity of this study although it was performed in a single specialist centre. A sample size calculation was not reported and assessors were not blinded. Although the treatment protocols were mostly similar, not all patients received physiotherapy and this may have distorted the functional results. Another consideration is that the recruitment periods for this trial overlapped with another trial by the same author⁹ by 10 months and it is therefore possible that the same patients may have been included in both studies thereby increasing the risk of possible bias.

*Sommerkamp et al.*¹⁴ This RCT compared dynamic WB (Clyburn – Zimmer) with static WB (AO/ASIF) external fixation. Seventy-three patients with 75 comminuted unstable intra- and extra-articular distal radius fractures were recruited at a single centre with 37 patients in the dynamic group and 36 in the static group. The fixators were removed at a mean of 9 weeks (6–11) in the static group and a mean of 10 weeks (6–11) in the dynamic group. Patients in the dynamic group were mobilised at a range of 2–6 weeks depending upon the fracture type and surgeon preference. The fractures within this study were not graded according to the AO classification.

Forty-eight patients (66%) were followed up at 12 months. The authors reported significant radial shortening in the dynamic group (4 mm vs. 1 mm, $p < 0.05$). There were no significant differences for other radiological measures, grip and pinch strength and functional scores. ROM was similar except for increased flexion and radial deviation in the static group at 1 year ($p < 0.04$). Although complication rates between the groups were similar, there were five fixator hardware failures in the dynamic group.

This study had the lowest trial validity score of 12 out of 33 points as shown in Table 2. Limitations included the authors using a quasi-randomisation method with odd and even chart numbers. They also included open fractures, bilateral fractures and patients with polytrauma which would have affected the subsequent function. The assessors were not blinded to the interventions at follow-up nor were recruitment or treatment allocation performed independently which may have lead to bias. A sample size or power calculation were not performed. There were significant differences in the treatment protocols. Some patients in each group underwent percutaneous wire fixation, open reduction and internal fixation or bone grafting. Patients within the dynamic group were mobilised at different times ranging from immediately to 8 weeks at the discretion of the authors. The static group were older (mean 39 years vs. 34 years), had more females and fewer severe fractures. These are uncontrolled variables which prevent a scientific comparison being made between the interventions and therefore invalidate some of the conclusions.

Dynamic (wrist-bridging) vs. dynamic (non-bridging)

*Krukhaug et al.*⁷ This RCT compared dynamic WB (Dynamwrist – CMR Prototech) with NB (Hoffmann II Compact – Stryker) external

Table 2
Trial validity scores.

Study	Atroshi et al. ¹	Krukhaug et al. ⁷	Krishnan et al. ⁶	McQueen ⁹	McQueen et al. ¹⁰	Sommerkamp et al. ¹⁴
1. Adequate Concealment?	3	3	3	3	3	0
2. Intention to treat analysis?	3	3	0	1	1	0
3. Outcome assessors blinded?	3	1	0	0	0	0
4. Baseline characteristics reported and comparable?	1	1	1	3	1	0
5. Patients blind to assignment status after allocation?	0	0	0	0	0	0
6. Treatment providers blind to assignment status?	0	0	0	0	0	0
7. Identical treatment protocols?	3	1	3	1	1	0
8. Inclusion/exclusion criteria defined?	3	3	1	3	3	3
9. Outcome measures defined?	3	3	3	3	3	3
10. Accuracy, precision, and observer variation of the outcome measures adequate?	3	3	3	3	3	3
11. Length of follow-up time	1	1	1	1	1	3
Total scores	23	19	15	18	16	12

fixation. Seventy-five patients with a mean age of 62 (20–92) years with unstable extra-articular distal radius fractures with at least 1 cm intact volar cortex in the distal fragment were recruited at two centres. The fixators were removed at a mean time of 43 (33–59) days with follow-up to 1 year. There were 38 type A3 fractures in the WB group and 37 type A3 fractures in the NB group.

Seventy-one patients (95%) were followed up at 1 year although this included two patients that died. There were no significant differences between the groups for radiographic measures, pain scores, functional outcome or complications. Flexion was greater in the dynamic WB group in the early treatment period ($p = 0.001$) but difference was not seen for any other movements or time points.

The trial validity score for this study was 19 points (Table 2) providing level 1b evidence (Table 1). Patients were allocated to their intervention by a closed randomisation method with clear eligibility criteria and treatment protocols. Although a power calculation was reported, it was based upon radial tilt as the primary outcome to ensure a small sample size and an adequately powered study with narrow confidence intervals. This is not, however, a clinically important outcome and a validated functional score may have been more useful. Although the outcome assessor was independent, the level of blinding was not reported and bias cannot be excluded.

Evidence from other studies

Hayes et al.⁵. This retrospective study compared NB (Hoffmann II Compact – Stryker) with WB (Hoffmann – Stryker) with data available for 588 out of 641 patients with unstable intra- and extra-articular distal radius fractures and radiological data available for 546 patients. There were 193 type A3, 105 type C2 and 12 type C3 fractures in the NB group. The WB group included 31 type A3, 62 type C2 and 100 type C3 fractures. Analysis suggested better radiological outcomes in the NB group with respect to restoring volar tilt and carpal alignment ($p < 0.001$) with significantly fewer malunions in the NB group. NB fixation was associated with a significantly higher risk of pin track infection (27% vs. 13%, $p < 0.001$) with other complications occurring similarly between the groups. Most of the procedures were performed by trainees thus also increasing the external validity of the findings.

Uchikura et al.¹⁶. This retrospective study compared NB (Mini Fixator – Medifix Solutions) with WB (Pennig fixator – Orthofix) external fixation in 84 adults with unstable distal radius fractures. There were 8 type A2, 1 type A3, 8 type C1, 12 type C2 and 13 type C3 fractures in the NB group. The WB group included 3 type A2, 4 type A3, 8 type C1, five C2 and 22 type C3 fractures. The subjective evaluation was good or excellent for 100% in the NB group and 90.5% in the WB group. There were small differences in radio-

graphic measures and ROM but greater grip strength and fewer arthritic changes in the NB group.

They concluded that NB fixation achieved more favourable results than WB fixation without the need for bone grafting. There were significant confounders within this study which reduce the validity of its conclusions.

Discussion

The systematic literature search revealed 54 studies of which eight were included in this review. The included studies were six RCTs and two retrospective studies with levels of evidence ranging from 1b to 4 as shown in Table 1. The three RCTs by Atroshi et al.¹, Krishnan et al.⁶ and McQueen⁹ and retrospective studies by Hayes et al.⁵ and Uchikura et al.¹⁶ compared dynamic NB with static WB external fixation. The RCTs by McQueen et al.¹⁰ and Sommerkamp et al.¹⁴ compared dynamic WB fixation with a mobile hinge joint and static WB fixation. The recent RCT by Krukhaug et al.⁷ compared a newer dynamic WB fixator with dynamic NB external fixation.

The RCTs by Atroshi et al.¹ and Krukhaug et al.⁷ were the highest quality studies providing level 1b evidence and scoring 23 and 19 points, respectively. The RCTs by McQueen⁹, McQueen et al.¹⁰, Krishnan et al.⁶ and Sommerkamp et al.¹⁴ provided level 2b evidence with scores ranging from 12 to 18 points.

The best evidence for dynamic NB vs. static WB external fixation for intra- and extra-articular distal radius fractures suggests that there is no functional benefit of one method over another in older patients although NB fixation was better at maintaining radial length.¹ Level 2b evidence (18 points), however, suggests that there are significant functional and radiological benefits for dynamic NB fixation when treating skeletally mature patients of all ages.⁹ Level 4 evidence also suggests that the technique of NB external fixation has good external validity and can be performed by surgeons of varying experience levels with good results.⁵

The best evidence for dynamic WB vs. static WB external fixation for intra- and extra-articular fractures suggests that there are no functional or radiological benefits of one method over another¹⁰ with a risk of losing fracture reduction or hardware failure with some fixators.¹⁴

The best evidence for dynamic WB vs. NB external fixation for extra-articular fractures suggests that there are no functional or radiological benefits of one method over another although some improved ROM was seen after dynamic WB fixation in the early treatment period.⁷

There were no significant differences between the groups in the incidence of complications within the six RCTs. Pin track infection rates ranged from 15% to 39% (mean 25% – 93/366) with an overall reoperation rate for infection of 0.03% and all other infections treated successfully with antibiotic therapy.

Conclusion

The currently available evidence suggests that there is no functional or radiological benefit of a dynamic WB external fixator with a mobile hinge joint over a static WB external fixator¹⁰ for unstable intra- and extra-articular distal radius fractures. Newer designs for dynamic WB external fixators are not as prone to loss of fracture reduction and hardware failure as previous designs with equivocal results to NB fixation methods.^{7,14}

The evidence also suggests that there are no benefits for NB external fixation over static WB fixation for unstable intra- and extra-articular distal radius fractures in older patients¹ but there do appear to be clear functional and radiological benefits including earlier return of function when considering patients of all ages.⁹ Although a benefit was not seen in older patients, the technique was able to achieve excellent clinical results and may have practical advantages over WB fixation for such patients by allowing increased mobility and use of the limb during the fixation period and enabling them to maintain their independence. There are no cost-effectiveness analyses currently available to compare the interventions and whether dynamic NB external fixation is an economically viable option for patients unable to tolerate the practical disadvantages of static WB external fixation.

Further studies comparing these interventions should therefore include a cost-effectiveness analysis and return to work as an outcome measure to aid the decision making process in the treatment of unstable distal radius fractures. Studies should also be performed in multiple centres with multiple operating surgeons to ensure a higher external validity and therefore increasing the likelihood of influencing clinical practice.

The findings from this systematic review confirm that the surgeon has the option of adopting a form of external fixation appropriate to the configuration of the distal radius fracture and the patient, sound in the knowledge that the outcome of treatment is unlikely to be compromised by the choice of external fixation method.

Conflict of interest statement

There have been no financial or personal relationships with other people, or organisations, that could inappropriately influence (bias) this work.

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