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# Long term outcomes of open reduction internal fixation versus external fixation of distal radius fractures: A meta-analysis

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## Abstract

Distal radius fractures are among the most common fractures encountered in the clinical setting. Of these common fractures, it has been said that up to 60% are intra-articular in nature. Intra-articular or unstable and comminuted fractures represent severe and high energy injuries. Despite a large amount of literature, it is surgeon preference which determines the fixation method employed. There are only a few randomised control trials that report 2-year outcomes. There has yet to be a meta-analysis comparing the long-term outcomes of open reduction internal fixation (ORIF) and external fixation (EF). The aim of this meta-analysis is to identify any difference in the outcomes of either fixation method in the long term. We pooled the data of all the available randomised control trials that followed the patients for a minimum of 2 years and compared outcomes of ORIF against EF of distal radius fractures as per PRISMA guidelines from inception of the databases to December 2016. We then performed our meta-analysis using RevMan 5.3 software. Flexion/extension arcs were significantly improved in ORIF, and 7 of the 10 analysed outcomes supported ORIF, although most not to a significant degree. The meta-analysis indicated that there is no difference in outcomes with either form of treatment. Even though the flexion extension arc was statistically better in the ORIF group, the difference is not clinically meaningful.

## Introduction

Distal radius fractures are the most common fracture encountered in the upper limb,<sup>1,2</sup> and are among the most common fractures encountered in the clinical set-

ting.<sup>3,4</sup> Up to 60% are intra-articular in nature.<sup>5-7</sup> Intra-articular, unstable and comminuted fractures represent severe, often high energy injuries. Surgical intervention is indicated for unstable or irreducible fractures to restore the anatomical position of the wrist and the articular surface. This in turn decreases the likelihood of post-traumatic osteoarthritis, increases functional ability, increases range of motion (ROM) and increases strength in the hand and wrist. Malunion has been associated with poor functional outcomes.<sup>8,9</sup> Poor articular reduction; persistent step >2 mm, has been associated with osteoarthritis.<sup>8</sup> Knirk and Jupiter reported significantly better overall results and significantly less radiographic osteoarthritis with restoration of articular congruity.<sup>10</sup> Kreder *et al.* found that with an articular gap >2 mm, there was a 10.4 times higher risk of developing osteoarthritis.<sup>11</sup>

EF relies on the principles of ligamentotaxis to hold the reduction position; it has the benefits of being quick and minimally invasive, however it also has complications; pin sites predispose to local infection, the frame can be cumbersome and needs to be removed.<sup>12</sup> ORIF provides immediate fixation of the fracture most often with plate osteosynthesis.<sup>13</sup> ORIF has become the predominate fixation method,<sup>14,15</sup> particularly the use of the volar locking plate (VLP). Plates may need to be removed under a second anaesthetic or regional block at a later date if symptomatic.<sup>6,16,17</sup>

The most recent Cochrane Review by Handoll and Madhok,<sup>18</sup> was unable to determine which fixation method was superior; Closed Reduction and External Fixation (EF) or Open Reduction and Internal Fixation (ORIF).

Based on four RCT studies; Grewal,<sup>6</sup> Kreder,<sup>11</sup> Kapoor,<sup>19</sup> Leung,<sup>20</sup> the AO Foundation advise that there is no consistent benefit of one treatment over another.<sup>21</sup>

It has been shown that the subjects that have undergone ORIF improve rapidly post operatively in both grip strength and ROM when directly compared with EF, however this difference plateaus and the objective functional outcomes become similar by one year.<sup>11,22-25</sup> This has been attributed to prolonged immobilisation in the case of EF, and conversely early mobilisation and physiotherapy in the case of ORIF. In the study Rozental *et al.*, the authors could only recommend ORIF for those patients who wish to receive “a faster return to function after the injury”.<sup>22</sup> However, despite this trending belief, certain studies have shown that this rapid recovery deficit is independent of immobilisation. Lozano-Calderon *et al.* found that early mobilisation in ORIF did not have any effect on the outcome in ROM

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or functional score.<sup>26</sup> Other studies have inadvertently found this, as although they immobilised their ORIF groups when comparing them with external fixation, they still found a significant difference in the early periods in favour of ORIF.<sup>23,27,28</sup> Given immobilisation does not seem to cause the disparity between ORIF and EF, there must be other influencing factors. Wright *et al.* reports that ROM progresses in its recovery up to four years;<sup>29</sup> a direct disagreement with Kreder *et al.*'s belief that the outcomes at one year are final.<sup>11</sup> We have analysed the long-term outcomes of ORIF and EF interventions.

## Materials and Methods

A comprehensive literature search was carried out, following the PRISMA 27 point checklist,<sup>30</sup> and taking into consideration the guidance offered by the Cochrane Collaboration.<sup>31</sup> We completed a systematic review of PubMed, Embase, Medline and the Cochrane Library, from inception to December 2016. Search terms “distal radius” and “fixation” returned 2687 articles. This is an example of a search strategy used for PubMed: (distal[All Fields] AND (“radius”[MeSH Terms] OR “radius”[All Fields])) AND fixation[All Fields].

After the screening of the title and abstract by two of the authors (CG and MT) 122 articles were deemed to be of relevance. On review we identified four comparison studies and four randomised control

trials. The eligible randomised control trials were Kapoor *et al.*,<sup>19</sup> Xu *et al.*,<sup>32</sup> Landgren *et al.*<sup>33</sup> and Williksen *et al.*<sup>34</sup> A summarised version of this process is presented in Supplementary Figure S1.

### Inclusion and exclusion criteria

Inclusion and exclusion criteria are listed in Table 1.

### Data extraction

Data extraction was done in a systematic and methodical manner as outlined. Demographic data is summarised in Table 2. The outcomes analysed were grip strength, radiographic measurements (palmar tilt, radial inclination, ulnar variance), ROM, subjective functional scoring and complications/re-operations.

### Data analysis

We used Review Manager Software Version 5.3. The continuous data (grip strength, radiographic parameters and ROM) was expressed as mean difference and 95% confidence intervals using the inverse variance method, with random effects model. Confidence intervals were set to 95%. With Student's t-test for statistical significance and  $P < 0.05$  being evaluated

as statistically significant. I-squared tests were used to assess heterogeneity; an I-squared value  $< 25\%$  considered homogenous, an I-squared value between 25 and 50% considered as low heterogeneity, an I-squared value between 50 and 75% considered as moderate heterogeneity and an I-squared value  $> 75\%$  considered as high heterogeneity.

Xu<sup>32</sup> and Williksen<sup>34</sup> presented their data as the range of individual movements from the presumed neutral point as per traditional anatomical position. Standard deviation, standard error or confidence intervals were not provided, except the P-values of the differences between treatments. On the other hand, Landgren *et al.*<sup>33</sup> presented their data as a full arc of movement, with standard deviation and p values given. To compare the values, we combined the individual ROM measures to create arcs of motion for the studies by Xu and Williksen.<sup>32,34</sup> In doing so we combined the given p values with the assumptions of independence and same direction of effects between the individual ROM measures using the online statistical programme MetaP,<sup>35</sup> which utilised Stouffer's z trend test technique to combine probabilities from independent tests with

adjustments for sample sizes and effect directions.<sup>36</sup>

The dichotomous data (complications/re-operations) was expressed as risk ratio. This was calculated by the Mantel-Haenszel method, using random effect model and 95% confidence intervals. Student's t-test was also used and again statistical significance taken to be  $P < 0.05$ . Chi-square and I-squared tests were again used to assess heterogeneity, with the same scale of what was thought to be homogenous and heterogeneous as outlined previously.

A total of 228 subjects were included in the four trials. Of these 84 were male and 144 female. Ages were comparable between the four studies; however, Kapoor provided a mean age of 39 years which included their casting treatment arm, and did not break down the ages any further. Total number of subjects that underwent ORIF was 117, and the total number of subjects that underwent external fixation was 111. All external fixators were bridging, and various methods of ORIF were employed. The fracture patterns and classification systems employed were variable. Mean follow up was over two years as per the inclusion criteria. These results are shown in Table 3.

**Table 1. Inclusion and exclusion criteria.**

Inclusion	Exclusion
Randomised control trials	Open fractures
Methods of fixation that directly compared EF and ORIF	Previous failed operative therapy to the affected side
English translation manuscripts	Non-compliant patients
Adult patients	Paediatric patients
Follow up period $\geq 2$ yrs	Pathological fractures
	Any augmentation of the ORIF group with external fixation
	Previous ipsilateral fracture of the wrist and/or forearm
	Patients suffering with memory disturbance; head injury or dementia

**Table 2. Characteristics of the subjects.**

Study	No.	Age	Gender	Centre No.	ORIF Method (n)	Ex-Fix Method (n)	# Pattern	No, Surgeons	Follow up
Williksen <i>et al.</i>	91	54 (20-84)	13M 78F	Single	Acumed AcuLok (28) Synthes 2 (18) Distal Radius Systems (4) Hand Innovation DVRs (6)	Hoffman II (42) Synthes (2) Bridging ex-fixes	AO A2&3, C1-3	11	66 months
Landgren <i>et al.</i>	50	48 (20-65)	14M 36F	Single	Trimed, VLP	Hoffman type Bridging ex-fix	Frykman I-VII, AO; A1-3 and C1-3, "irreducible"	4	60 months
Xu <i>et al.</i>	30	Ex-fix: 45.3 (35-55) ORIF: 41.8 (21-56)	18M 12F	Single	Variable +/- K wires	Undisclosed	AO-C	1	24 months
Kapoor <i>et al.</i>	57	"Adults"	39M 18F	Single	"T-plate" or K wires	Roger Henderson Bridging ex-fix	Frykman VII & VIII	Unknown	48 months

## Results

Flexion/extension significantly favoured ORIF, as seen in Figure 1,  $P=0.03$ . Pronation/supination and ulnar/radial deviation also favoured ORIF, but neither was statistically significant, Supplementary Figures S2 and S3.

Expressed as the percentage deficit of the contralateral side, grip strength favoured ORIF, as shown in Figure 2, but this was not statistically significant  $P=0.83$ .

The radiographic parameters dorsal tilt, ulnar variance and radial inclination are shown in Supplementary Figures S4-6. Dorsal tilt and ulnar variance favoured ORIF as shown in Supplementary Figures S4 and S5, but neither was statistically significant;  $P=0.31$  and  $0.14$  respectively. Radial inclination however was more improved with external fixation as seen in Supplementary Figure S8, but was not statistically significant either;  $P=0.35$ .

When analysing complications, the results favoured EF, as seen in Figure 3, but this was not statistically significant a P-value of  $P=0.10$ . With regards infection in particular; results suggested there were less in ORIF, as shown in Supplementary Figure S7, and analysing malunion; the result slightly favoured external fixation, as seen in Supplementary Figure S8, but neither were statistically significant. In relation to plate removal; Landgren 12 out of 26 plates removed, Xu 14 out of 16 removed, Williksen 15 out of 29 removed, Kapoor not documented.

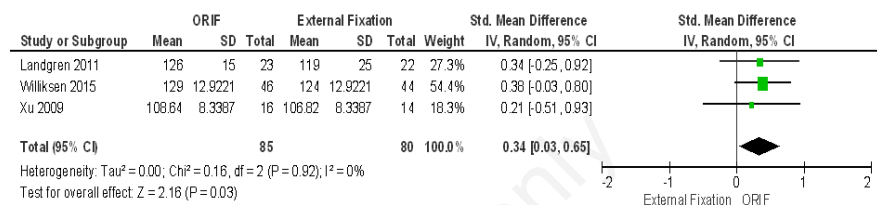
Landgren and Williksen were the only two papers to express their functional scores in the same manner using QuickDASH. The result only slightly favoured ORIF, as seen in Figure 4 but was not statistically significant ( $P=0.59$ ). The two other papers used different subject functional scoring systems; Kapoor used Sarmiento scoring;<sup>19</sup> Xu used two scoring systems: Gartland and Werley,<sup>37</sup> and Green and O'Brien.<sup>38</sup> Kapoor reported; that out of the external fixation group 80% had good or excellent results and 20% had fair or poor results, whereas only 63% of the ORIF group had good or excellent results, 26% fair and 11% poor. Xu found ORIF had better Gartland and Werley and Green and O'Brien results compared to EF, however neither were statistically significant (as reported in the individual papers);  $P=0.88$  and  $0.76$  respectively.

## Discussion

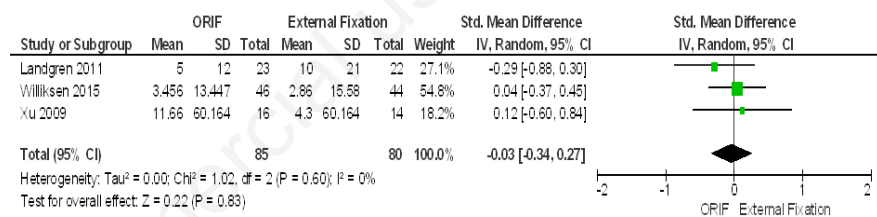
In keeping with prior publications that

**Table 3. Outcome summary.**

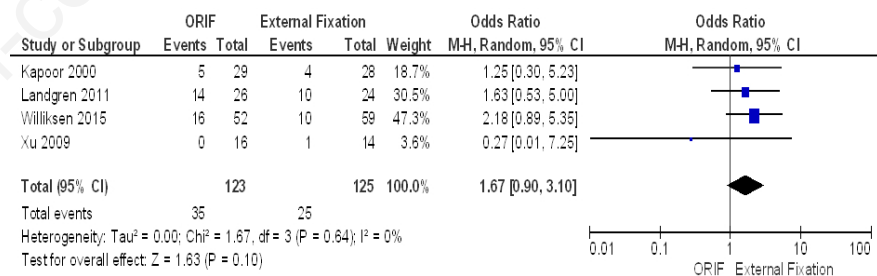
Outcome	Reduction method	P-value
Flexion/Extension Arc	ORIF	0.03
Supination/Pronation Arc	ORIF	0.12
Radial Deviation/Ulnar Deviation Arc	ORIF	0.47
Grip Strength	ORIF	0.83
Dorsal Tilt	ORIF	0.31
Ulnar Variance	ORIF	0.14
Radial Inclination	EF	0.35
Total Complications	EF	0.10
Infection	ORIF	0.34
Mal-union	EF	0.96



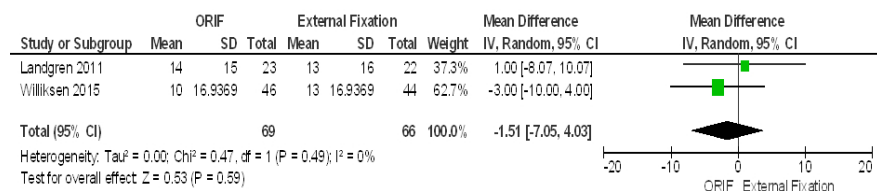
**Figure 1. Table and forest plot illustrating the meta-analysis for flexion/extension arc.**



**Figure 2. Table and forest plot illustrating the meta-analysis for grip strength deficit when compared to the contra-lateral side.**



**Figure 3. Table and forest plot illustrating the meta-analysis for complication rates.**



**Figure 4. Table and forest plot illustrating the meta-analysis for functional scoring QuickDASH.**

document similar outcomes at a year, both EF and ORIF outcomes remain similar in the long term. Thus, it appears that the invasive open approach in the ORIF group does not seem to cause any deleterious effect in the long term. Short term analyses have shown that the EF group initially lags behind due to wrist immobilization, but quickly catches up with the ORIF group by as soon as 3 months after surgery.<sup>39,40</sup> Even though ORIF in this analysis was significantly better for flexion/extension arc, the difference of only 2 degrees is not clinically meaningful.

Grip strength was shown to have no significant difference between the ORIF and EF. It is notable that the Landgren suggested ORIF was superior and Xu and Williksen suggested the opposite; however, within the studies these also were not statistically significant with P-values of 0.3, 0.78 and 0.8 respectively. Previous short term studies have shown initially better grip strength in the subacute period (6 weeks to 3 months) however the grip strength results seem to equilibrate by one year as shown in Wang *et al.*'s meta-analysis.<sup>39</sup> This was believed to demonstrate that the longer immobilisation time the external fixator group has to endure does not have a lasting effect on their objective functional ability. However, to conflict with this, another meta analysis; Cui *et al.*, showed significantly better grip strength in the early period in their external fixator groups almost up to one year. However we note that there are several published papers that immobilised their ORIF subjects and still found improved initial objective measures of functionality; grip strength and ROM.<sup>23,27,28</sup>

Radiographic parameters; dorsal tilt, ulnar variance and radial inclination were all shown to not be of significant difference between the two treatment groups. However dorsal tilt and ulnar variance favoured ORIF, and radial inclination favoured external fixation. The large amount of malunions; five, in the Landgren article may have influenced this result.

Total complications in the long-term studies reveal less in the external fixation group. This was not of statistical significance. It may be more appropriate to look at the more short-term, <2 yr follow up, randomised control trials when reviewing the encountered complications. However, still there is no consensus; the meta analyses of Walenkamp *et al.*, Esposito *et al.*, and Wang *et al.* found no significant difference in overall complication rates between the two treatment modalities.<sup>39,41</sup> Within the analysed studies there seemed to be a high proportion of plate removal; 41 of 71 reported (58%). A meta analysis by Cui *et al.* report-

ed a significant difference in favour of ORIF.<sup>42</sup> When a sub analysis of infection and malunion rates was performed; we found no significant difference between the treatment modalities. Aligned with this; three meta analyses looking at short term outcomes found no statistical difference for malunion.<sup>39,40,42</sup> But this was not the case for infection. Wang *et al.* and Cui *et al.* both found that there was significantly increased infection rates in the external fixation group.<sup>39,42</sup>

When concerned with functional scoring, there was no statistically significant result. However this meta-analysis favoured ORIF (P=0.59). Kapoor and Xu's methods of data reporting was not amenable to meta analysis but Xu found in favour of ORIF, and Kapoor; EF.

We recognise the limitations of this meta analysis due to the small number of papers and the small sample size of 228 subjects. Also, of note is that the follow up times were different for all papers; Xu 2 years, Kapoor 4 years and Williksen and Landgren 5 years, for their final outcome analysis. This contributes a large amount of heterogeneity to our meta analysis. Also within the papers there were a number of fracture types/classes and various methods of ORIF were used, which has been identified in other meta analyses,<sup>16,43</sup> again contributing heterogeneity. The MetaP analyses assume the independence and same direction of effects between individual ROM measures, which, however, cannot be verified without the raw results of the original studies by Xu and Williksen.<sup>32,34</sup> The independence assumption could lead to a smaller P-value (or a smaller standard error); this factor has been taken into account when interpreting the meta analysis results.

The studies in this meta analysis, as with the meta analyses performed on the short-term outcomes, compare multiple different ORIF techniques with various joint bridging external fixation frames. The trend seems to be towards volar locking plates<sup>28</sup>, we would recommend further randomised control trials be undertaken looking at both the short term and long term outcomes of locking volar plate fixation vs external fixation. There have been quite a few short term randomised control trials already but with fairly small sample numbers and some also compared a third method.<sup>22,25,27,28,44-46</sup>

## Conclusions

It appears that in the long term, ORIF provides better range of motion than EF although this difference is not significant,

and there is no significant difference in grip strength, subjective functional outcome or radiographic outcomes.

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