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Review

Open reduction and internal fixation versus closed reduction and percutaneous fixation in the treatment of Bennett fractures: A systematic review

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ABSTRACT

Purpose: Open reduction and internal fixation (ORIF) of Bennett fractures is increasingly preferred over closed reduction and percutaneous fixation (CRIF) in an attempt to prevent the development of post-traumatic arthrosis. The aim of this systematic review was to determine whether the preference for ORIF is justified based on the available literature regarding functional outcome and complications after surgery.

Methods: A systematic review was performed in Medline, Embase, Cochrane CENTRAL, Web of science, and Google scholar. Duplicates were removed and title and abstract were screened after which full text articles were analysed. The reference lists of selected articles were screened for additional relevant studies. Study characteristics were recorded and methodological qualities were assessed after which data was extracted from the included articles. The Eaton-Littler score for post-traumatic arthrosis (primary outcome) on follow-up X-rays was used as primary outcome. Secondary outcomes were Grip strength, Pinch strength, persistent pain, fixation failure, functional impairment, infection and surgery time.

Results: Ten studies were included; three retrospective comparative studies and seven retrospective case series. Of the 215 patients in these studies, 138 had been treated using an open technique and 77 by a closed percutaneous technique. The pooled rate of post-traumatic arthrosis was 57.5% (26.6–85.5) in the ORIF group versus 26.1% (3.9–59.0) in the CRIF group. Mean surgical operation time was 71.9 min for ORIF and 30.2 min for percutaneous patients. Fixation failure was significantly more often seen in the ORIF patients, 8.2% (0.7–22.8) vs. 2.9% (0.8–9.1), Risk Ratio 1.132 (0.01–176.745); p = 0.048. Infection was only seen in 5 CRIF patients. Persistent pain was seen in 32.9% (0.6–83.1) in ORIF patients versus 22.3% (8.1–41.1) in the CRIF patients. The pooled means Grip strength was 48.3 kg (95% CI; 39.7–56.9) versus 43.4 kg (95% CI; 22.9–63.8) for ORIF and CRPF, respectively. Functional impairment was similar between the two groups, 1.4% (0.1–4.4) vs 1.8% (0.1–5.7) respectively.

Conclusion: The analysed data do not confirm ORIF to prevent post-traumatic arthrosis, secondly more fixation failure and pain was seen in the ORIF group. The pooled data show percutaneous fixation to be preferable over ORIF in the surgical treatment of Bennett fractures.

Contents

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Introduction

Ever since the 1950's there has been an ongoing debate regarding the best treatment of Bennett fractures. [1–5] Together with the introduction of new techniques recent research has reported on outcome after several types of surgical treatment [6–10]. Closed reduction and percutaneous fixation (CRIF) give good clinical results, although complications such as pintract infections and secondary dislocation have been reported. [4,11] Open reduction and internal fixation (ORIF) has also been reported to provide good results and has the advantage of anatomical reduction of the fracture under direct visualisation [3,12,13]. Anatomical fracture reduction aims to prevent the development of post-traumatic arthrosis [14]. Secondly, the advantage of open reduction and internal fixation is the possibility of early mobilisation [15]. One of the reasons for the ongoing debate is the quality of the evidence in hand surgery in general and more specific the lack of randomized controlled trials regarding this topic [16,17].

Part of the discussion is the suggestion that an anatomical reduction might prevent the development of post-traumatic arthrosis. Some authors found a relationship while others were not able to correlate accuracy of fracture reduction with post-traumatic arthrosis. [3,4,14,18] To improve anatomical reduction arthroscopically assisted percutaneous techniques have been introduced to combine visualisation of anatomical reduction with minimally invasive techniques [6,19].

There is lack of consensus because most studies only describe one surgical technique or only a small sample of patients. [16] This paucity in evidence stresses the importance to evaluate open and closed techniques in a systemic review [20,21]. Combining results from multiple studies might provide additional insight into the pros and cons for each treatment type.

Therefore, this systematic review aimed to determine the functional outcome and post-operative complications for both techniques in the treatment of Bennett fractures.

Materials and methods

A systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, including [1] a systematic search of the literature [2], selection of studies [3], recording of study characteristics [4], assessment of methodological quality of studies, and [5] extraction and comparison of clinical outcomes (22, 23).

Search strategy

The literature search was conducted on April 6, 2018. The search strategies were developed by a medical librarian and included combinations of different terms and synonyms for Bennett fractures and its surgical treatment. The searches were performed in Medline, Embase, Cochrane central, Web of science, and Google scholar. The detailed search strategies are described in the "Appendix".

Selection of studies

After removal of duplicate studies, the title and abstract of the remaining studies were screened to evaluate if they met the following criteria: [1] Language: English [2]. Study design: trial (randomized) or observational (case series or cohort, prospective or retrospective) [3]. Population: Humans with Bennett fractures with no additional injury [4]. Intervention: ORIF and/or Percutaneous K-wire fixation [5]. Outcome: post-traumatic arthrosis, hand function, consolidation, or complications [6]. Period: Publication after 2000 (24).

Following screening of title and abstract, the full text articles were screened using the same inclusion criteria. The reference lists of selected articles were screened for additional relevant studies which had not been identified during the search process (25).

Recording of study characteristics

The following study characteristics were extracted from the selected articles: author, title, publication year, country of origin, study design, number of participants, type of surgical treatment and follow-up period. All corresponding authors of the included articles were contacted by email for additional data.

Assessment of methodological quality

The risk of bias was assessed following the instructions by Spindler et al. within and between studies and the level of evidence of the selected studies was assessed. [26]

Data extraction

As primary outcome, post-traumatic arthrosis was scored by radiological evaluation using the Eaton-Littler classification. [2,27] Secondary outcomes were surgical time, fixation failure, infection, Grip strength, Pinch strength, persistent pain, functional impairment. Two researchers (APAG and JVG) performed steps 2–6 independently. During step 2, disagreement about selection of studies for full text analysis was resolved by inclusion of the study for full text reading. This way no disputed article was excluded on title and abstract alone. Disagreement during steps 3–5 was resolved by discussion.

Statistical analysis

Meta-analysis of the collected data for either ORIF or percutaneous treatment was performed using MedCalc for Windows, version 16.4.3 (MedCalc Software bvba, Ostend, Belgium; https://medcalc.org;2016 MedCalc). The pooled risk ratios are reported with their 95% confidence intervals (CI) and p-value. Heterogeneity was quantified with Cochran's Q test and I^2 statistic, a fixed effects model was used when the I^2 was < 40%. A random effects model was used for the pooled analysis when the I^2 was ≥ 40%. A p-value

Since many studies did not provide a mean with standard deviation for continuous outcome measures (which would be needed for a formal meta-analysis), a weighted average was also calculated for the two treatment options. The sample size was used as weighting factor.

Results

Study selection

The search identified a total of 809 articles in Medline, Embase, Cochrane CENTRAL, Web of science and Google scholar (Fig. 1). After removing 273 duplicate studies, the title and abstract of the remaining 536 articles were screened. Ten articles were included in the systematic review. The corresponding author of one study replied to an email and provided additional information (*i.e.*, Pinch and Grip strength in kilograms instead of % of uninjured side). (28)

Risk of bias and level of evidence

The graded evidence of the included studies is described in Table 1. [26] All included articles were retrospective studies [3,4,6,8–10,15,28–30]. Three of the included articles were retrospective comparative studies [6,10,29]. The remaining seven studies were retrospective case series, four studies on open reduction and internal fixation (ORIF) and three studies on closed reduction and percutaneous fixation (CRIF) [3,4,8,9,15,28,30].

Study characteristics

No multicentre randomized studies were found (Tables 2 and 3). One article reported on a mixed group of patients who had been treated with open reduction after which some were fixed with K-wires and others with internal fixation. In order to prevent contamination only the patients who had primarily been treated with ORIF were included in this systematic review. [8] The ten articles included a total of 215 patients. ORIF was performed in 138 patients and CRIF was performed in 77 patients. Open surgery consisted of open reduction and internal fixation using screw, plate fixation or tension band wiring (Table 2).

One comparative study compared ORIF with an arthroscopically assisted percutaneous fixation (Table 3). [6] Closed reduction and percutaneous fixation consisted of percutaneous K-wire fixation according to Iselin, parallel K-wire fixation according to Van Niekerk et al. or leverage pinning using Wagner's technique [2,28,30].

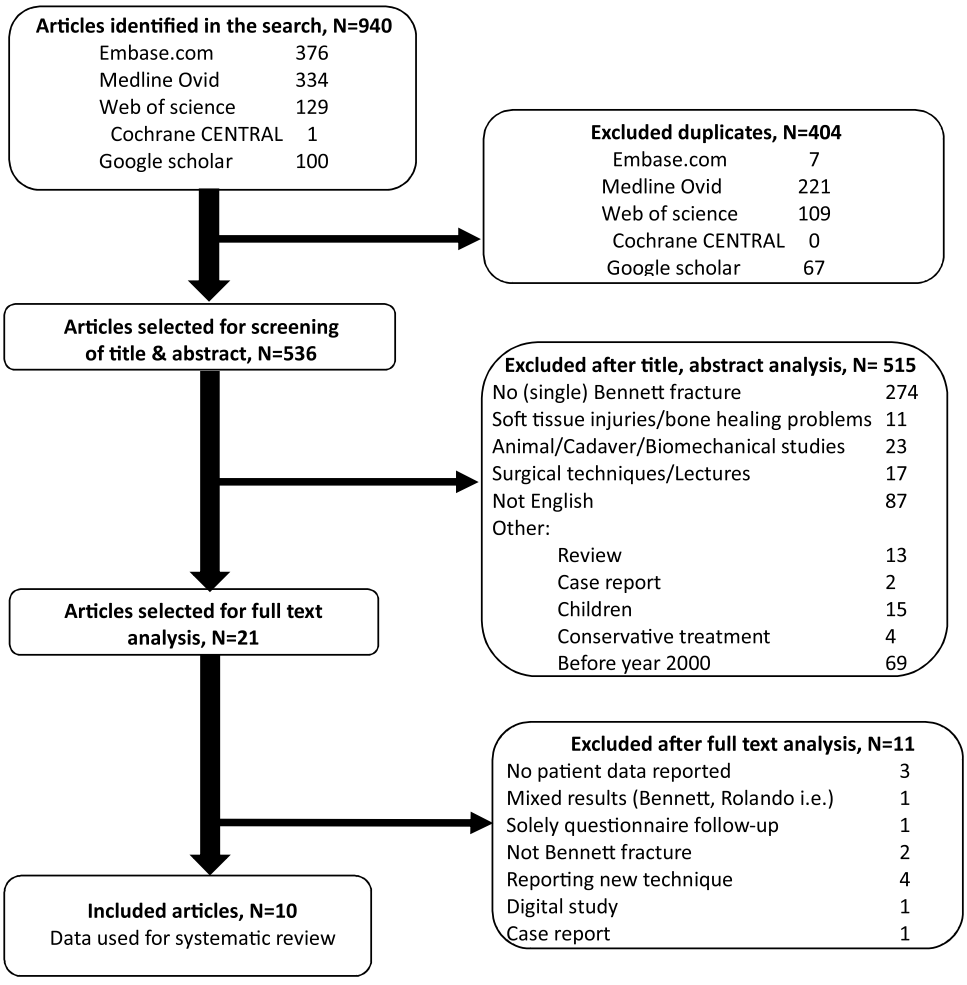

Fig. 1. Flowchart of selected articles.

Table 1
Characteristics of included articles.

Nr.	Study	Year	Country	Design	Fixation	No. of patients	Follow-up (months)	Level of Evidence
1	Fischborn et al. [8][a]	2018	Germany	Retrospective cohort	ORIF	3	41.9 (30.5–74.9)	IV
2	Levy et al. [9]	2018	Argentina	Retrospective cohort	ORIF	21	8 (3–10)	IV
3	Pomares et al. [6]	2016	France	Retrospective cohort	ORIF vs CRIF	21 (10 vs 11)	33 vs 27	III
4	Uludag et al. [15]	2015	Turkey	Retrospective cohort	ORIF	9	14 (10–24)	IV
5	Adi et al. [28]	2014	France	Retrospective cohort	CRIF	7	14 (9–22)	IV
6	Greeven et al. [4]	2012	Netherlands	Retrospective cohort	CRIF	7	24	IV
7	Leclerc et al. [3]	2012	France	Retrospective cohort	ORIF	24	83 (54–154)	IV
8	Zhang et al. [10]	2012	China	Retrospective cohort	ORIF vs CRIF	79 (56 vs 23)	39 (21–47) vs 35 (31-41)	III
9	Sawaizumi et al. [30]	2005	Japan	Retrospective cohort	CRIF	12	26 (8–54)	IV
10	Lutz et al. [29]	2003	Austria	Retrospective cohort	ORIF vs CRIF Total	32 (15 vs 17) 215 (138 vs 77)	84 (36–216)	III

ORIF = Open Reduction and Internal Fixation.
CRIF = Closed Reduction and Percutaneous Fixation.
[a] 3 patients included who had been treated by Open Reduction and Internal Fixation.

Table 2
Data collected from comparative studies (Open vs Percutaneous).

Studies	*Pomares et al.* (6)		*Zhang et al.* [10]		*Lutz et al.* (29)	
	10 x ORIF	11 x CRIF + Arthroscopy	56 × ORIF	23 × CRIF	15 × ORIF	17 × CRIF
Mean age (years)	30	37	32 (19–51)	35 (21–47)	37	28
Follow-up (months)	33 (28–36)	28 (24–31)	39 (36–42)	35 (31–41)	84 (36–204)	84 (36–204)
Fracture classification	>30% joint	>30% joint	Gedda I	Gedda I	Gedda I	Gedda I
Fixation type	Screw(s)	Screw(s)	Tension band wiring	K-wire	Screw	Wagner method
Surgery time (minutes)	56.6 (45-64)	42.6 (26-70)	–	–	–	–
Immobilization (weeks)	7.1	3.9	0.2	5 (4-6)	4	6
Pain (VAS)	–	–	0 (0-2)	0 (0-5)	–	–
Persistent Pain	6/10 (60%)	1/11 (9%)	1/56 (2%)	1/23 (4%)	4/15 (27%)	2/17 (12%)
Grip (% of contralateral)	52 kg (-)	48.7 kg (-)	43 (22–48) kg	39 (21–45) kg	89 kPa[c]	87 kPa[c]
Pinch (% of contralateral)	10.7 kg (-)	9.3 kg (-)	7.4 (3.9–8.2) kg	5.8 (3.1–7.5) kg	42 kPa[c]	40 kPa[c]
(Quick) DASH	9.5	3.1	–	–	–	–
Consolidation time (weeks)	–	–	4 (3-6)	4 (3-5)	–	–
Arthritis Stage 1/2/3/4[b]	–	–	–	–	4/9/3/0	5/10/0/0
Additional information/ Complications	1 loss of strength 1 mal-union 1 paraesthesia 4 screw migration 2 inadequate reduction	1 × CRPS	100% 2nd operation for removal of tension band at 8 months	3 pain + reoperation 2 patients excluded after loss of reduction in percutaneous group were re-operated[a]		

Results are presented as mean (range).
- = Not reported.
ORIF = Open Reduction and Internal Fixation.
CRIF = Closed Reduction and Percutaneous Fixation.
CRPS = Complex Regional Pain Syndrome.
[a] = excluded from follow-up.
[b] = Eaton Littler classification [2].
[c] = Balloon Dynamometer.

Primary outcome: post-traumatic radiographic arthrosis

For 79 patients, post-traumatic arthrosis was scored using the Eaton Littler score. Post-traumatic arthrosis (Eaton-Littler score 2 and higher) was more common in patients treated with ORIF (pooled mean 52.8%; CI 30.0–75.0) than in patients treated with CRIF (pooled mean 28.0%; 95% CI 2.9–65.7) (Table 4).

Secondary outcomes: Surgical time, Fixation failure, Infection, Pain, Grip, Pinch, and Functional impairment (results of the weighted and pooled analyses are shown in Table 4. The associated forest plots are shown in Supplemental Table S1)

Operation time was reported in 37 ORIF patients and 25 CRIF patients. A weighted average could be calculated of 71.9 min for the ORIF patients and 30.2 min for the CRIF patients (Table 4).

Fixation failure (i.e. screw migration, inadequate reduction and loss of reduction) could be pooled and analysed in 206 patients. Statistical analysis showed a pooled proportion for ORIF patients was 8.2% (0.7–22.8) versus 2.9% (0.8–9.1), which was statistically significant (p = 0.048).

Post-operative infections could be pooled and analysed in 129 ORIF patients and 77 CRPF patients. Infection only occurred in 5 CRIF patients. The pooled proportion for ORIF patients was 1.0% (0.1–3.3) versus 7.0% (0.80–18.7) for CRIF patients.

Pain was scored using the Visual Analogue Score (VAS) in 75 ORIF patients and 60 CRIF patients. A VAS of 2 and more was seen in 12 ORIF patients and 11 CRIF patients. The weighted average of a VAS of 2 and more within each group was 32.9% (0.6–83.1) vs 22.3% (8.1–41.1) respectively and was not statistically significant (p = 0.627).

Grip strength could be pooled and analysed in 167 patients. Statistical analysis showed pooled mean for ORIF patients was 43.4 kg (95% CI; 22.9–63.8) versus 48.3 kg (95% CI; 39.7–56.9) for CRIF patient, a difference of 0.70 kg.

Pinch strength was reported in 37 ORIF treated patients and 25 CRIF patients. The weighted average was 10.35 kg vs 8.76 kg

Table 3
Data collected from single treatment studies.

Studies	*Fischborn et al.*(8)	*Levy et al.* (9)	*Uludag et al.* (15)	*Adi et al.* (28)	*Greeven et al.* (4)	*Leclerc et al.* (3)	*Sawaizumi et al.* (30)
	3 x ORIF[a]	21 × ORIF	9 × ORIF	7 × CRIF	7 × CRIF	24 × ORIF	12 × CRIF
Age (years)	38 (27-47)	32 (22-52)	33 (16-56)	31 (16-60)	31 (16-49)	40 (24-64)	36 (18-79)
Follow-up (months)	41.9 (30.5-74.9)	8 (3-10)	14 (10-24)	14 (9-22)	24	83 (54-154)	26 (8-54)
Fracture classification	–	Gedda I / II	–	2 Gedda I 5 Gedda II	–	10 Gedda I 14 Gedda II	9 x Gedda I 3 × Gedda III
Fixation type	Screws	Pins or screws	8 × Screw / 1× Plate	K-wire, Iselin + connector	K-wire parallel	Screws	K-wire, leverage pinning
Surgery time (minutes)	67 (52-82)	–	–	29 (16–40)	12 (6–20)	79	–
Immobilization (weeks)	–	5	1.4	0	4	2	–
Pain (VAS)	2	0 (1–1.5)	1.2 (0–3)	0 (0–3)	2 (0–4)	1.4 (1.0–1.8)	–
Persistent Pain (%)	–	–	5/9 (56%)	2/7 (29%)	4/7 (57%)	–	3/12 (25%)
Grip (kg)	48.5	30.8 (12–45)	–	–	56.6 (51–62)	48.6	40 (29–44)
Pinch (kg)	27.3	–	–	–	8.3 (7.0–10.5)	10.2	–
(Quick) DASH	1.7 (0–38)	15	12 (10–12)	4.5 (0–13.6)	–	–	–
Arthritis Stage 1/2/3/4	–	–	–	7/0/0/0	4/1/0/0[b]	14/9/1/0	10/2/0/0
Additional information /Complications	–	1 secondary dislocation and re-operation	–	2 mal-union no secondary dislocation	3 pintract infection 1 cosmetic deformity 2 cast immobilization	1 secondary dislocation and re-operation	2 pin-tract infection 1 arthroplasty 1 hyperaesthesia

Results are presented as mean (range).
[a] = 3 of 8 patients with Bennett fracture included who have had open reduction and internal fixation.
[b] = 2 patients lost to follow-up.

Table 4
Post-traumatic arthrosis, Fixation failure, Infection, Grip strength and pain.

	Post-traumatic arthrosis		Fixation failure		Infection		Pain		Grip (kg)	
Author	ORIF	CRIF	ORIF	CRIF	ORIF	CRIF	ORIF	CRIF	ORIF	CRIF
Fischborn et al. (2018)	–	–	0/3 (0%)	–	0/3 (0%)	–	–	–	45.80 (-, n = 3)	–
Levy et al. (2018)	–	–	1/21 (5%)	–	0/21 (0%)	–	–	–	30.80 (9.38, n = 21)	–
Pomares et al. (2016)	–	–	6/10 (60%)	0/11 (0%)	0/10 (0%)	0/11 (0%)	6/10 (60%)	1/11 (9%)	52.00 (2.30, n = 10)	48.70 (3.50, n = 11)
Uludag et al. (2015)	–	–	–	–	–	–	4/7 (57%)	–	–	–
Adi et al. (2014)	–	0/7 (0%)	–	0/7 (0%)	–	0/7 (0%)	–	2/7 (29%)	–	–
Greeven et al. (2012)	–	1/5 (20%)	–	0/7 (0%)	–	3/7 (43%)	–	4/7 (57%)	–	56.60 (4.00, n = 7)
Leclerc et al. (2012)	10/24 (42%)	–	1/24 (4%)	–	0/24 (0%)	–	–	–	48.60 (-, n = 24)	–
Zhang et al. (2012)	–	–	0/56 (0%)	2/23 (9%)	0/56 (0%)	0/23 (0%)	1/56 (2%)	1/23 (4%)	43.00 (-, n = 56)	39.00 (-, n = 23)
Sawaizumi et al. (2005)	–	2/12 (17%)	–	0/12 (0%)	–	2/12 (17%)	–	3/12 (25%)	–	39.70 (5.00, n = 12)
Lutz et al. (2003)	10/15 (67%)	12/16 (75%)	0/15 (0%)	0/17 (0%)	0/15 (0%)	0/17 (0%)	–	–	–	–
Weighted average	20/39 (51.3%)	15/40 (37.5%)	8/129 (6.2%)	2/77 (2.6%)	0/129 (0%)	5/77 (6.5%)	12/75 (16.0%)	11/60 (18.3%)	4279 (n = 114)	43.50 (n = 53)
Pooled proportion (95% CI)	52.8% (30.0–75.0)	28.0% (2.9-65.7)	8.2% (0.7–22.8)	2.9% (0.8–9.1)	1.0% (0.1–3.3)	7.0% (0.80–18.7)	32.9% (0.6–83.1)	22.3% (8.1–41.1)	43.4 (22.9–63.8%)	48.3 (39.7–56.9)
Risk Ratio	N.A.		1.132 (0.01–176.745)		N.A.		1.956 (0.130-29.375)		0.70 kg difference	
p-value			p = 0.048				p = 0.627			

* = in kilograms.
SD = Standard deviation.
n = number of patients.
#= Visual Analogue Score of 2 or higher.
95% CI = 95% confidence interval.
N.A. = Not available.
‡ = forest plots for these analyses are shown in Supplemental Table S1.

Table 5
Overall complications and reoperations for all included patients.

	ORIF (n = 138)		CRIF (n = 77)	
	No. with complications	No. with reoperations	No. with complications	No. with reoperations
Delayed Union	0	0	0	0
Fixation failure	8 (5.8%)[a]	2 (1.4%)	2 (4%)[b]	2 (4%)[b]
Functional impairment	1 (0.7%)	0	0	0
CRPS	0	0	1 (2%)	0
Infection	0	0	5 (7%)	0
Pain	16 (11.6%)	0	11 (14%)	0
Cosmetic deformity	0	0	1 (1%)	0
New fracture	0	0	0	0
Planned removal	0	56 (69%)	0	0

ORIF = Open Reduction and Internal Fixation.
CRIF = Closed Reduction and Percutaneous Fixation.
[a] = fixation failure: screw migration and inadequate reduction.
[b] = loss of reduction in percutaneous group were all re-operated.

respectively. For 27 of the ORIF patients the standard deviation (SD) was not reported. No further statistical analysis could therefore be performed.

Functional impairment data was pooled for 108 ORIF treated patients and 77 CRIF patients. One ORIF patients was reported with functional impairment versus no patients in the CRPF group. Statistical analysis showed a pooled proportion of 1.4% (0.1–4.4) for ORIF patients and 1.8% (0.1–5.7) for CRIF patients.

Overall complications and reoperations for all patients

An overview of all complications and reoperations is reported separately (Table 5). Reoperations in ORIF patients was 1.4% and 3.9% in the CRIF patients. An additional 56 (69%) patients were re-operated in the ORIF group for planned hardware removal.

Discussion

The difference in primary outcome between the two groups of patients is the most important finding in this systematic review. A higher percentage of post-traumatic arthrosis was seen in the ORIF patients compared to CRIF patients, 52.8% vs 28.0% respectively.

In this systematic review, the follow-up period of the included studies was long enough for post-traumatic arthrosis to develop. [3,29] Especially in the comparative studies with a follow-up period of 36–204 months no advantage of ORIF over CRIF in preventing post-traumatic arthrosis was found. (6, 10, 29)

The pooled data in this systematic review do not warrant the choice for ORIF in the surgical treatment of Bennett fractures because doing so reduces the chance of post-traumatic arthrosis. [13,14,31] On the contrary, the current evidence seems to confirm the opposite. Possibly, a step and/or gap of 2 mm after reduction and fixation can be accepted, therefore not requiring exploration of the fracture site per se. (2, 4)

The second important finding is the significant difference in fixation failure. Failure occurred in 8.2% ORIF patients versus 2.9% CRIF patients. The additional findings in similar Grip strength, more frequently reported pain and longer surgical time suggest ORIF to be the less preferable technique in treating Bennett fractures.

Infections were more frequently seen in the CRIF group. These pin-tract infections are reported to have been successfully treated with antibiotics and removal of K-wires after consolidation. No additional effect of these infections has been reported. Pain was more frequently seen in the open treated patients, 33% versus 22%, respectively. Finally, a closed percutaneous technique was found to take shorter surgical operation time.

It can be debated if a planned implant removal should be seen as a re-operation. Advocates of ORIF might state that implant removal is integral part of the initial treatment. However, any second operation exposes the patient for a second time to risks such as infection, wound healing difficulties, additional adhesion formation, and a possible set back in function. The potential risks of such a second operation should be compensated by a clear functional benefit from the open technique in comparison with a closed percutaneous technique. In the reported results from all ten included articles no such advantage in outcome for patients treated by open technique was found. Possibly, such a benefit does exist for other intra-articular first metacarpal base fractures (i.e. Rolando, comminuted fractures).

This systematic review of literature has several limitations. Unfortunately, only retrospective studies, mostly case series rather than comparative studies could be included.

Secondly, considerable heterogeneity in subtypes of Bennett fractures (Table 3), surgical techniques as well as in choice of outcome measures and follow-up duration was present across the studies included. Because of these limitations a detailed subgroup analysis was not possible.

Another limitation is that data presentation per study was often incomplete; e.g. the lack of standard deviation hampered the possibilities for a formal meta-analysis and to present the results in forest plots for all outcomes. Unfortunately, the authors of the included studies were unresponsive to a request for additional data.

For the three comparative studies a selection bias might be considered. Because all included patients were treated for the same Bennett fracture subtype (i.e. Gedda type I corresponds with an involvement of > 30% of the joint surface) comparison of these three studies is possible. (6, 10, 29)

Secondly, within the ORIF and CRIF groups different surgical techniques were used. The low number of patients per surgical technique limits the possibility to perform a detailed subgroup analysis. In general, less invasive techniques have less failure of fixation without the additional risk of pain as seen after open surgery.

These findings suggest that closed percutaneous technique should be a first choice of treatment. Only when no acceptable closed reduction and percutaneous fixation can be reached, an open technique is warranted. However, the current results should be interpreted with some caution because of the Level of Evidence (III and IV) of the included articles and the limitations mentioned above. Future research should focus on the comparison between ORIF and percutaneous fixation for Bennett fractures, preferably in a prospective randomized setting.

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Compliance with ethical requirements

This research was performed in compliance with ethical requirements.

Declaration of Competing Interest

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Appendix A. Search strategies

Embase.com

('bennett fracture'/de OR ((((('fracture'/de OR 'intraarticular fracture'/de OR 'joint fracture'/de) AND ('metacarpal bone'/de)) OR 'metacarpal bone fracture'/de) AND ('thumb'/de OR 'thumb injury'/de)) OR ((bennet* NEAR/3 fracture*) OR (fracture* NEAR/10 (metacarp* OR bas*-joint*) NEAR/10 (thumb* OR first))):ab,ti) AND ('surgery'/exp OR surgery:lnk OR 'orthopedic fixation device'/exp OR (surg* OR operative* OR fixat* OR wire* OR orif OR screw* OR plate* OR ((close* OR open) NEAR/3 reduc*) OR osteosynthes* OR approach* OR repair*):ab,ti)

Medline Ovid

(((((Fractures, Bone[mh] OR Intra-Articular Fractures[mh]) AND (Metacarpal Bones[mh] OR Metacarpus[mh]))) AND (thumb[mh])) OR ((bennet*[tiab] AND fracture*[tiab]) OR (fracture*[tiab] AND (metacarp*[tiab] OR base-joint*[tiab] OR basal-joint*[tiab]) AND (thumb*[tiab] OR first[tiab])))) AND (Surgical Procedures, Operative[mh] OR surgery[sh] OR Orthopedic Fixation Devices[mh] OR (surg*[tiab] OR operative*[tiab] OR fixat*[tiab] OR wire*[tiab] OR orif[tiab] OR screw*[tiab] OR plate*[tiab] OR ((close*[tiab] OR open[tiab]) AND reduc*[tiab]) OR osteosynthes*[tiab] OR approach*[tiab] OR repair*[tiab]))

Cochrane CENTRAL

(((bennet* NEAR/3 fracture*) OR (fracture* NEAR/10 (metacarp* OR bas*-joint*) NEAR/10 (thumb* OR first))):ab,ti) AND ((surg* OR operative* OR fixat* OR wire* OR orif OR screw* OR plate* OR ((close* OR open) NEAR/3 reduc*) OR osteosynthes* OR approach* OR repair*):ab,ti)

Web of science

TS=((((bennet* NEAR/2 fracture*) OR (fracture* NEAR/10 (metacarp* OR bas*-joint*) NEAR/10 (thumb* OR first)))) AND ((surg* OR operative* OR fixat* OR wire* OR orif OR screw* OR plate* OR ((close* OR open) NEAR/2 reduc*) OR osteosynthes* OR approach* OR repair*)))

Google scholar

"bennet|bennett fracture|fractures"|"bennet|bennett*fracture|fractures" surgery|surgical|operative|fixation|"closed|open reduction"|osteosynthesis|repair

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.06.027.

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