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Title: Outcomes of total hip replacement as a salvage procedure following failed internal fixation of intracapsular neck of femur fractures: A systematic review and meta-analysis

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Abstract

The management of intracapsular femoral neck fractures in independently mobile patients remains controversial. Successful fixation obviates the limitations of arthroplasty for this group of patients, however with fixation failure rates as high as 30%, the outcome of revision surgery to salvage total hip replacement (THR) must be considered. We carried out this review to determine the outcome of salvage THR and how this compares to primary THR for fracture. We performed a PRISMA compliant systematic review using the PubMed, EMBASE and Cochrane libraries databases. A meta-analysis was performed when possible and a narrative synthesis when a meta-analysis was not possible. Our analysis revealed a significantly increased risk of complications including deep infection, early dislocation and peri-prosthetic fracture when salvage THR was compared with primary THR for an intracapsular femoral neck fracture (overall risk ratio of 3.15). Functional outcomes assessment using EQ5D were not significantly different (p=0.3).

Introduction

The ideal treatment of displaced intracapsular neck of femur fractures (ICNOF) in independently mobile patients remains controversial. This category of patients constituted 8.8% of the total femoral neck fracture cohort in the United Kingdom (UK) in 2013[1]. The incidence of ICNOF in this group of patients is steadily rising and with femoral neck fracture management reaching an annual cost of two billion pounds limited by fiscal resources, treatment must be based on good patient outcomes and cost-effectiveness[1,2].

In physically demanding adults, arthroplasty has its limitations as there is a high risk of wear with resultant aseptic loosening and early revision[3]. Whilst successful reduction and fixation of these fractures obviates these limitations, the reported failure rate of fixation and risk of revision to total hip replacement (THR) is as high as 30%[4]. As a result, consideration of the outcome of THR for failed osteosynthesis (salvage THR) must form part of the decision making process when considering how best to treat displaced ICNOF in this group of patients.

The aim of this systematic review was to present the outcome of salvage THR in terms of complication rate and functional outcome.

Materials and Methods

Search Strategy

A PRISMA compliant systematic review was undertaken[5]. We searched the published online databases PubMed, EMBASE and The Cochrane Library from inception to March 2015. Online available conference proceedings from 2004 to March 2015 were reviewed to identify relevant abstracts. These included the British Orthopaedic Association (BOA), British Hip Society (BHS), American Academy of Orthopaedic Surgeons (AAOS), American Association of Hip and Knee Surgeons (AAHKS) and International Society for Technology in Arthroplasty (ISTA). The UK National Hip Fracture Database (NHFD) 2013 and 2014 reports were also considered for further information[1].

The MeSH terms used included “Hip”, “Neck of Femur”, “Femur”, “Femoral” AND “Fracture”, “Intracapsular” AND “Intra-articular”, “Internal” AND “Fixation”, “Hip”, “Arthroplasty”, “Replacement” AND “Prosthesis”. The reference lists of included articles were reviewed for additional records.

Eligibility Criteria

All studies investigating the outcomes of THR following failed fixation of an ICNOF were eligible. Translation was sought for non–English language published material. Included studies were limited to level I – III studies assessing radiological and/or clinical outcomes in human subjects aged 20 years or older (to exclude physeal injuries). The titles and abstracts of eligible studies were independently reviewed by two authors (SSSM, EOP). The same two reviewers independently reviewed the full texts of all potentially relevant titles and abstracts to assess overall eligibility. Any disagreement was resolved by discussion and adjudication by a third reviewer (CBH).

Critical Appraisal

Each study was appraised independently by two reviewers (SSSM, EOP) using the Critical Appraisal Skills Program (CASP) checklist[6]. Any disagreements were resolved by discussion or adjudicated by a third reviewer (CBH).

Data Extraction

Extracted data included patient demographics, degree of fracture displacement at presentation (Garden classification), time interval between the injury and operative fixation, fixation technique, time interval between operative fixation and salvage THR, surgical approach for salvage THR, implants used for salvage THR, outcomes and complications. Data was extracted independently by two reviewers (SSSM, EOP) into an agreed data extraction table for the analysis.

Data Analysis

Clinical heterogeneity was assessed by visual assessment of the data extraction tables. A meta-analysis was appropriate where there was clinical homogeneity between the studies. A narrative review of the evidence was undertaken when there were insufficient data to pool or where there was evidence of significant clinical heterogeneity in population characteristics, intervention or outcome assessment methods.

Statistical heterogeneity between studies was assessed using I-squared and Chi-squared tests. When I-squared was equal to or above 30% and Chi-squared equated to $p \leq 0.01$, a random-effect statistical model of risk ratio was undertaken. When I-squared was less than 30% and Chi-squared equated to $p>0.01$, a fixed-effect statistical model of risk ratio (RR) was undertaken. Data were pooled to determine the relative risk of overall and specific complications for the three meta-analyses. The a priori planned analyses were outcomes of salvage THR following failed osteosynthesis versus primary THR for ICNOF versus, salvage THR following failed osteosynthesis versus outcomes of primary THR for osteoarthritis and avascular necrosis (AVN), salvage THR following failed osteosynthesis alone. All meta-analyses were undertaken by one review author (TS) using Review Manager (RevMan) Version 5.2. Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration, 2012.

Results

Search Results

The results of the search strategy are presented in Figure 1. The electronic database search yielded 165 results (MedLine 80 records, EMBASE 82 records, Cochrane Library three records). Conference proceeding searches produced three relevant abstracts. On initial screening 24 papers were deemed potentially eligible. Of these, 11 studies published between 1989 and 2013 met the final eligibility criteria and were included in the review. Seven were case controlled studies comparing salvage THR with primary THR [7,8,9,10,11,12,13] and four were case series reporting the post-operative outcome of salvage THR[14,15,16,17] (Table 1). The NHFD 2013 report presented reoperation rates within 30 days without distinction between intracapsular and extracapsular fractures and therefore was not suitable for data extraction.

Methodological Quality

Nine of the studies were of moderate quality. Strengths were that the studies had a focused research question, recruited the appropriate population in an acceptable way, they were unbiased regarding exposure and outcome reporting, they had adequately reported potential confounding factors specially regarding the method of initial fixation and previous mobility and reported precise satisfactory results. Two included studies had a less rigorous retrospective design. All studies but one had a minimum follow–up period of six months[17].

Characteristics of Included Studies

Five hundred and fifty-eight patients (568 ICNOF) with age range of 30 to 96 years were included in the eligible studies[8,12]. Seven studies recorded patient gender and the male to female ratio was 1:2.6[7,8,9,10,12,15,17]. The cohort of patients were followed up for a minimum of six months (range: six to 78 months)[17].

Initial fracture displacement was not mentioned in six of the included studies[10,11,12,13,14,16]. From the studies that documented displacement, 259 were displaced (Garden III or IV) and four were undisplaced (Garden I or II). Screw fixation was the preferred method of fixation in most studies (Table 2).

The mean time to fixation failure varied from 5.5 to 31.2 months[9,12]. Cause of fixation failure was only reported in 434 cases, 48% failed due to non-union, 42% due to AVN and 10% due to post-traumatic osteoarthritis. Recording of the time to salvage THR was variable: the mean interval between fracture and fixation failure ranged from 5.5 to 31.2 months while the interval between internal fixation and salvage THR ranged from 5.5 to 37 months.[7,11,15,17]

Surgical approach for the salvage THR was variable. The posterior approach to the hip joint was favoured by most authors.[7,10,13,15,17] The modified Hardinge approach was used in one study and the direct lateral approach was used in another study.[8,11] Four studies did not record the approach used.[9,12,14,16]

None of the studies specified patient age as a selection criterion for implant type. Cemented fixation was used in most cases (88%) in contrast to cementless (10%) and hybrid (2%) techniques. THR implants used at the time of the salvage procedure varied in relation to the age of the study. The Lubinus and Howse-Arden were used in studies between 1989 and 1994 (181 and two respectively).[13,15] Over the next two decades, Charnley and Exeter systems were the preferred cemented implants. One study did not specify the THR implant used[14] (Table 2).

Several different scoring systems were adopted to assess post-operative functional outcome. The Harris Hip score (HHS) was the most widely used (four studies)[14,15,17,19] but other scoring systems included the Merle d'Aubigne hip score, Nottingham Health Profile (NHP), Charnley Hip Score and the Health Related Quality of Life EQ-5D score.[1,12,16] McKinley et al[7] used independent functional outcomes (pain, mobility and social dependence) to investigate postoperative function.

Outcomes

Salvage THR versus primary THR or hemiarthroplasty for ICNOF

Complications: Three studies (182 patients) compared primary THR for ICNOF to salvage THR for failed fixation[7,8,9]. Homogeneity of studies permitted a meta-analysis of complications and outcomes. This revealed a significantly increased overall risk of complications in the salvage THR group (Relative risk, RR 3.15, 95% Confidence Interval (CI) 1.39 to 7.11, p=0.006). The risk of deep infection was significantly higher in the salvage THR group (RR 7.05, 95% CI 2.08 to 23.86, p=0.002), as was early dislocation (RR 1.46, 95% CI 1.46 to 10.25, p=0.006) and peri–prosthetic fracture (RR 5.55, 95% CI 1.53 to 20.23, p=0.009) (Figures 2,3,4,5 respectively). Ozturkmen et al[9] noted that complications resulted in a significantly increased reoperation rate in the salvage THR group ($p<0.05$).

Function: Functional outcome was reported differently by the studies and so results could not be pooled. McKinley et al[7] reported severe pain in 25/99 patients following salvage THR versus 4/99 patients following primary THR for ICNOF ($p<0.05$). While 81/99 patients were fully mobile without walking aids following primary THR for ICNOF, only 57/99 of the salvage group achieved the same level of mobility ($p<0.05$). Regarding independent mobility and discharge to private residence, this was achieved in 73/99 patients following salvage THR in contrast to 82/99 patients after primary THR for ICNOF ($P<0.05$).[7] Blomfeldt et al[8] reported a mean Charnley hip score of 15 following primary THR for ICNOF and a mean score of 13 after salvage THR and this difference was statistically significant ($P<0.001$).[8] Studies reporting the EQ-5D did not show a statistically significant difference between primary THR for ICNOF and salvage THR.[8,18,19] The mean EQ-5D scores were 0.7 and 0.68 following primary THR and salvage THR respectively ($p=0.3$). Ozturkmen et al.[9] reported better Merle d'Aubigne hip scores for pain, mobility and walking in the primary THR group. In their study 27 of 34 primary THR patients were independently mobile using a single stick (79.4%) versus 19 of 34 (55.9%) in the salvage THR group ($p<0.05$). Four patients (11.8%) used crutches and walked with pain after primary THR versus nine (26.5%) after salvage THR ($p<0.05$).

When compared to primary hemiarthroplasty for ICNOF, salvage THR provided significantly better mean mobility and social scores on the NHP (34 versus 54, $p=0.05$ and 16 versus 37, $p=0.003$ respectively)[13,20].

Salvage THR versus primary THR for osteoarthritis and AVN

Complications: Heterogeneity of data between studies precluded a statistical meta-analysis and results were therefore pooled and reported narratively. Ninety-eight patients were included in this assessment. The complications of salvage THR included four dislocations (4%), four infections (4%) (three deep and one superficial), two peri–prosthetic fractures (2%), two cases of prosthetic loosening (2%) and a single case of post–operative myocardial infarction (1%). Franzen et al[10] showed a 2.5 times higher risk of prosthetic failure in salvage THR compared to primary THR for osteoarthritis for patients aged 70 years or older (p=0.012). Winemaker et al[11] found that the mean operative time for salvage THR was significantly longer than for primary THR (95 versus 77 minutes, p=0.015). They also reported greater intra–operative blood loss and a longer hospital stay following salvage THR, but these differences were not statistically significant (p=0.06, p=0.358 respectively). Zhang et al[12] reported an increased risk of intra-operative fractures when salvage THR specifically for AVN was compared to THR for idiopathic AVN (P<0.05).

Function: Zhang et al[12] reported no significant difference in mean HHS when salvage THR for AVN was compared with THR for non-traumatic AVN (p>0.05). Similarly, Winemaker et al[11] found no significant difference in range of movement or mean HHS when primary THR for OA was compared with salvage THR [mean range of movement 195.2 (±SD18.1) versus 191 (±SD31.1), mean HHS 80.9 (±SD12.5) versus 79.3 (±SD11.7) respectively, p>0.05].

Salvage THR

Complications: From a cohort of 168 THRs (167 patients) pooled from four studies, seven (4%) had early post–operative superficial wound complications (five haematomas and two discharging wounds), three had deep infections (2%), 11 had a dislocation (7%), one had a post–operative peri–prosthetic fracture (1%) and one a pulmonary embolism (1%)[14,15,16,17].

Neander et al[17] used computed tomography (CT) scans to investigate the postoperative changes of bone and muscle mass. They demonstrated that bone mass lost before salvage THR could not be regained up to six months after the index procedure. Only 20% improvement of muscle mass was gained through the same time interval.

Function: Two out of three cohort studies reported a mean HHS of 81 at the time of latest follow–up.[14,16] Nilsson et al[15] reported an improvement in overall hip function and mobility following salvage THR.

Discussion

The management of displaced intracapsular femoral neck fractures in independently mobile patients remains the subject of debate. Physically demanding patients including those who would like to return to impact activities may opt for internal fixation as the only sensible treatment option that will allow them to do so without the risk of wear and aseptic loosening associated with arthroplasty. However it is important that both patients and treating physicians are aware of the implications of this choice of treatment. Studies have shown that up to 30% of internally fixed fractures will fail requiring salvage THR and so the outcome of salvage THR must play a part in the decision-making process.

This review suggests that the functional outcome of salvage THR may be similar to primary THR for femoral neck fracture. There was no statistically significant demonstrable difference using the EQ–5D score[8]. Four studies reporting the Harris Hip score reported average scores of 79.4[12], 81[16], 81.8[14], 79.3[11] and these scores compare favourably with those of THR for non-traumatic AVN 84.2[12] and THR for OA 80.9[11]. Two comparative studies reported a statistically significant difference in functional outcome using a recognised scoring system. Blomfeldt et al[8] found a statistically significant difference in mean Charnley hip score in favour of THR for ICNOF over salvage THR. There was a two-point difference between both groups (maximum total of 18) and while this difference was statistically significant, it is of questionable clinical significance. Moreover it is important to note that the Charnley Hip Score scores pain, hip movement, and walking separately on a scale of 0-6 and the individual scores are not meant to be combined to obtain a total score[21] and so this result is also of questionable validity. Nevertheless, Ozturkmen et al[9] used the Merle d'Aubigne hip score to quantify the functional outcomes of salvage THR against primary THR for ICNOF. They were able to demonstrate favorable outcomes of primary THR for ICNOF over salvage THR with respect to pain and postoperative mobility. This was supported by the results of McKinley et al[7] who showed clinically and statistically significant inferior functional outcomes of salvage THR in comparison to THR for ICNOF in age-matched patients, however the use of the authors' own functional outcome measures does not allow for comparison across studies.

We intended to analyse factors that potentially influenced functional outcome including age, degree of fracture displacement, reason for salvage THR and time to salvage THR. For example, outcome may differ depending on the mode of failure: a patient living with a symptomatic non-union over a lengthy period of time is likely to experience pain and poor mobility which would result in disuse osteopenia and muscle wasting and this could have an impact on functional outcome[17]. A patient whose fracture unites but then develops AVN or OA may have a period of reasonable function and mobility before salvage THR and therefore a better functional outcome after salvage THR. One study showed no difference in functional outcome when salvage THR specifically for AVN was compared with that of primary THR for non-traumatic AVN[12]. We were unable to pool data to address this due to study heterogeneity.

The evidence therefore suggests that patients may obtain a similar functional outcome to primary THR if they opt for fixation first and it fails requiring revision to salvage THR. However, failed initial treatment has a major psychological impact on patients[22]. In addition, this review demonstrates that patients undergoing salvage THR are at a significantly greater risk of complications (RR: 3.15) including deep infection, periprosthetic fracture, early dislocation and prosthetic failure with significant implications for the patient and for healthcare resources. Deep infection following arthroplasty has been estimated to cost £70,000 per patient to treat [23]. Salvage THR is technically challenging and is associated with a longer operative time and a tendency towards higher blood loss and longer hospital stay[11]. Exposure is more difficult and the combination of stiffness and osteoporosis in many patients increases the risks of periprosthetic fracture. Cement pressurization is more difficult to achieve due to the presence of screw holes in the femur and this has implications for the longevity of the implant reflected in a statistically significant lower five and 10 year implant survival when salvage THR was compared with primary THR for ICNOF[7] and a higher risk of implant failure in patients aged 70 or older[10]. There is an argument that operations such as salvage THR should only be done in specialist units with an appropriate critical mass[23] in order to decrease the risk of complication and improve outcomes. Data from the National Joint Registry of England, Wales and Northern Ireland (NJR) has shown that the incidence of complications is significantly reduced when patients are treated in specialist centres[23]. It is therefore possible that by ensuring patients are treated by surgeons with the appropriate expertise in specialist centres, the incidence of complications following salvage THR could be greatly reduced. This was supported by Mabry et al’s study that reported up to twenty years implant survival in 76% of THR performed for nonunion of ICNOF. Additionally, 96% of their cohort reported no pain at the end of follow up period of at least two years[24]. In one of the papers demonstrating statistically and clinically significant poorer outcomes with salvage THR, the authors pointed out that the operations were supervised (but not necessarily performed) by one of eight senior orthopaedic trauma surgeons who were not specialist joint arthroplasty surgeons and that the dislocation rates seen in their series were relatively high[7]. However, some authors still recommend primary THR for displaced ICNOF particularly in patients with pre-existing hip osteoarthritis[25].

A limitation of this review is the inclusion of retrospective cohort studies. This was unavoidable as all identified studies investigating the outcome of salvage THR were retrospective and reported relatively small numbers. As such our study shares the limitations of all retrospective studies including investigator bias and uncontrolled possible confounding factors. Further work is still needed to provide a definitive answer on how best to treat displaced NOF in independently mobile and physically demanding patients in terms of health economics and patient outcomes. This would require a prospective multi-centre adequately powered randomised trial as it is unlikely that analysis of hip fracture databases will provide an answer unless the appropriate data is collected prospectively.

Conclusion

This systematic review has shown a similar functional outcome when comparing primary THR to salvage THR for ICNOF but an increased incidence of complications following salvage THR. Our review suggests that patients can be offered either internal fixation or THR but should be counselled regarding the risk of complications with salvage THR if internal fixation fails. Counselling with regards to complications of primary THR including risks of dislocation, infection and significant wear requiring further revision should also be stressed. Robust prospective studies with a large sample size investigating the outcome of salvage THR in comparison to primary THR for ICNOF are still required to determine how best to treat independently mobile patients.

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Table 1: Eligible studies including numbers of patients, follow up intervals, approaches and outcome measures assessed.

THR (Total Hip Replacement); IF (Internal Fixation); NOF (Neck Of Femur); AVN (Avascular Necrosis); EC (Extracapsular); IC (Intracapsular); OA (Osteoarthritis)

Author	Year	Study Design	N	Age range	M: F	Implant	Follow up	Outcome measures
McKinley et al.[7]	2002	**Case-Control** Salvage THR following failed IF Vs. Primary THR for NOF	107	73 (60-80) years	22:85	Charnley: Exeter 90:17	Median 6.5 (2-12) years	Functional outcome at 1year and final follow up: Pain, Mobility and Social dependence Complications: Superficial infection Dislocation Revision beyond 1 year 5 and 10 year Prosthetic survival rate
Zhang X et al.[12]	2010	**Case-Control** Salvage THR Vs. THR for Non-traumatic AVN	83	58.3 years (range 45-75 years)	56:27		3.4 (2 – 5) years	Functional outcomes: Harris Hip Score Complications: Intra-operative fracture Operative time Blood loss and need for blood transfusion Infection Dislocation Thigh pain
Archibeck MJ et al.[14]	2013	**Retrospective** Review of results of Salvage THR	63	70 (30-96) years	N/A	Huge mixture of implants	3.2 (2 – 18) years	Functional outcomes: Harris Hip Score Complications: Periprosthetic Fractures Haematoma Infection
Winemaker M et al.[11]	2006	**Retrospective Case-Control** Salvage THR Vs. Primary THR for OA	14 (of 36)	71 (+/-12.5) years	N/A	24 cementless, 1 cemented, 11 Hybrid.	1 year.	Functional outcomes: Range of Movement Harris Hip Score Complications: Technical difficulty Intra-operative fracture Operative time Blood loss Need for further surgical interference
Neander G et al.[17]	1999	Prospective Radiological Study (No Functional Outcomes)	16	Mean age 73 (48 – 86) years	1:15		3 and 6 months	Post-operative change of Muscle mass Post-operative Change of Bone Mineral Density
Nilsson LT et al.[15]	1989	**Prospective Cohort** Report of the outcomes of salvage THR	74 Pat. (With 75 hips)	Mean age 77 (51 – 93)	14:60		3.7 (0.7 – 6.6) years.	Length of Stay Complications: Post-operative mortality Dislocation Additional surgery Deep infection Peri-prosthetic fracture
Nilsson LT et al. [13]	1994	**Retrospective Case-Control** Outcomes of 1ry Hemi Vs. Salvage THR	28 (with 37 hips)	75 (45 – 93) years	N/A	Lubinus prosthesis (26), Charnley (2)	Min. 5 years	Functional Outcomes: Nottingham Health Profile (NHP)
Franzen H et al.[10]	1990	**Retrospective Case-control** Outcomes of Savage THR Vs. 1ry THR	84	Mean age 75 years (45 – 93)	17:66	Lubinus (81), Charnley (2), Howse-Arden (1)	Min 5 years	Complications: Dislocation Deep infection Prosthetic Loosening

		for OA						
Mehlhoff et al.[16]	1991	**Retrospective** Analysis of the outcomes of Salvage THR	14	65 (range, 35 – 90) years	N/A		Min. 2ys. Mean 34 months.	Functional Outcomes: Harris Hip Score Leg-length discrepancy Complications: Technical difficulty at time of surgery Blood loss Operative time Deep infection
Ozturkmen Y.[9]	2006	**Case Control** Salvage THR for failed IF Vs. 1ry THR for NOF	34	68 (60 – 75) years	8:26	Uncemented	5.2 (2 – 7) years.	Functional Outcomes: Merle D'Aubigne hip scores Complications: Pain Reoperation rate
Blomfeldt et al.[8]	2006	**Case Control** Salvage THR Vs. 1ry THR for NOF	41	80 (74.7 – 85.3) ys.	3:38	Anterolateral (Modified Hardinge) approach. Cemented Exeter stem and OGEE acetabular component.	2 years.	Functional Outcomes: Charnley Hip score Health Related Quality of Life (HRQoL) using the EQ-5D index score. Katz ADL index Complications: General medical complications Nerve palsy

Table 2: Fractures and procedures in different cohorts.

AVN (Avascular Necrosis); NU (Nonunion); OA (Osteoarthritis); IC NOF (Intracapsular Neck of Femur); EC NOF (Extracapsular Neck of Femur); THR (Total Hip Replacement)

Paper	Initial Fracture	IF method	Mean Duration to fixation failure	Cause of Failure	Time to THR	THR implant
Archibeck et al.[14]	N/A	-3 or 4 Cannulated screws (42) -Solid threaded pins (21)	N/A	AVN (24), NU (7), Post traumatic OA (24), Early fixation failure (8)	Not mentioned	Didn't differentiate implants applied for failed IC NOF from implants applied for EC NOF. -Approach: N/A -Acetabular component: All Cementless [Titanium with screws and spiked Trilogy Zimmer]. -Femoral component: Cementless, Calcar replacement systems, Cemented.
McKinley et al.[7]	Displaced (Garden 3-4)	-3 Cannulated screws (107)	5.5 months	NU or fixation failure (89), AVN (18)	Mean 5.5 (0.5–4) months after the fracture	-Posterior approach. -Cemented (Using Second Generation techniques) Charnley (90), Exeter (17)
Blomfeldt et al.[8]	Displaced (Garden 3-4)	Not mentioned	Not mentioned	NU (29), AVN (12)	11 (0 – 41) months	-Modified Hardinge approach -Cemented THR (Exeter stem and OGEE acetabulum)
Ozturkmen et al.[9]	Displaced (Garden 3-4)	-DHS (6) -Cannulated Screws (28)	6.5 months	Fixation failure (18) NU (10) AVN (4) Segmental collapse (2)	Not mentioned	-Uncemented THR Acetabular component: (CLS cup, Protek AG, Bern, Sweden) (Rimcup, Biomet, Avrupa) Femoral components: (Protasul-100, Protek AG, Bern, Sweden) Hydroxyapatite coated with collar press-fit stem (F 40 ergosystem, Biomet, Avrupa)
Franzen et al.[10]	Not mentioned	-Four flanged nail.	Not mentioned	Not mentioned	Not mentioned	-Posterior approach

		-Two hook pins.				-All cemented: Lubinus (81), Charnley (2), Howse-Arden(1)
Winemaker et al.[11]	Not mentioned	Pin and plate (22) Cannulated Screws (14)	Not mentioned	-Secondary OA (19) -AVN (17)	97.2 months	-Direct Lateral Approach -Cementless (23) -Cemented (4) -Hybrid (9)
Zhang et al.[12]	Not mentioned	Not mentioned	31.2 months	AVN (83)	31.2 (12 – 20) months	-Cemented
Nilsson et al 94 Jarth.[13]	Not mentioned	-Four flanged nail. -Two hook pins.	Not mentioned	Not mentioned	Fracture to THR: 14 (1 – 32) months	-Posterior approach -All cemented: Lubinus (81), Charnley (2), Howse-Arden(1)
Nilsson et al 89 JBJS.[15]	-Displaced (71) -Undisplaced (4)	-Four flanged nail -Hook pins	7 months.	-NU (66) -Segmental collapse (9)	IF to THR: 10 (0.4 – 68) months.	-Posterolateral approach -Cemented Lubinus (74) -Moore Hemi (1)
Mehlhoff et al.[16]	Not mentioned	Not mentioned	Not mentioned	-AVN (10) -Loss of fixation (Fixation failure) (1) -NU (6) -Joint penetration by the nail (4)	IF to THR: Mean: 31 months	Cemented Cementless Hybrid Implant manufacturer: Not mentioned
Neander G et al.[17]	-Displaced (Garden 3-4) (16)	2 parallel Olmed screws	Not mentioned	-AVN (16)	Initial fracture to THR: Mean 37 (12-144) months.	-Posterior approach -Cemented THR

Figure a: PRISMA Flowchart showing identification, screening and inclusion of studies for review.

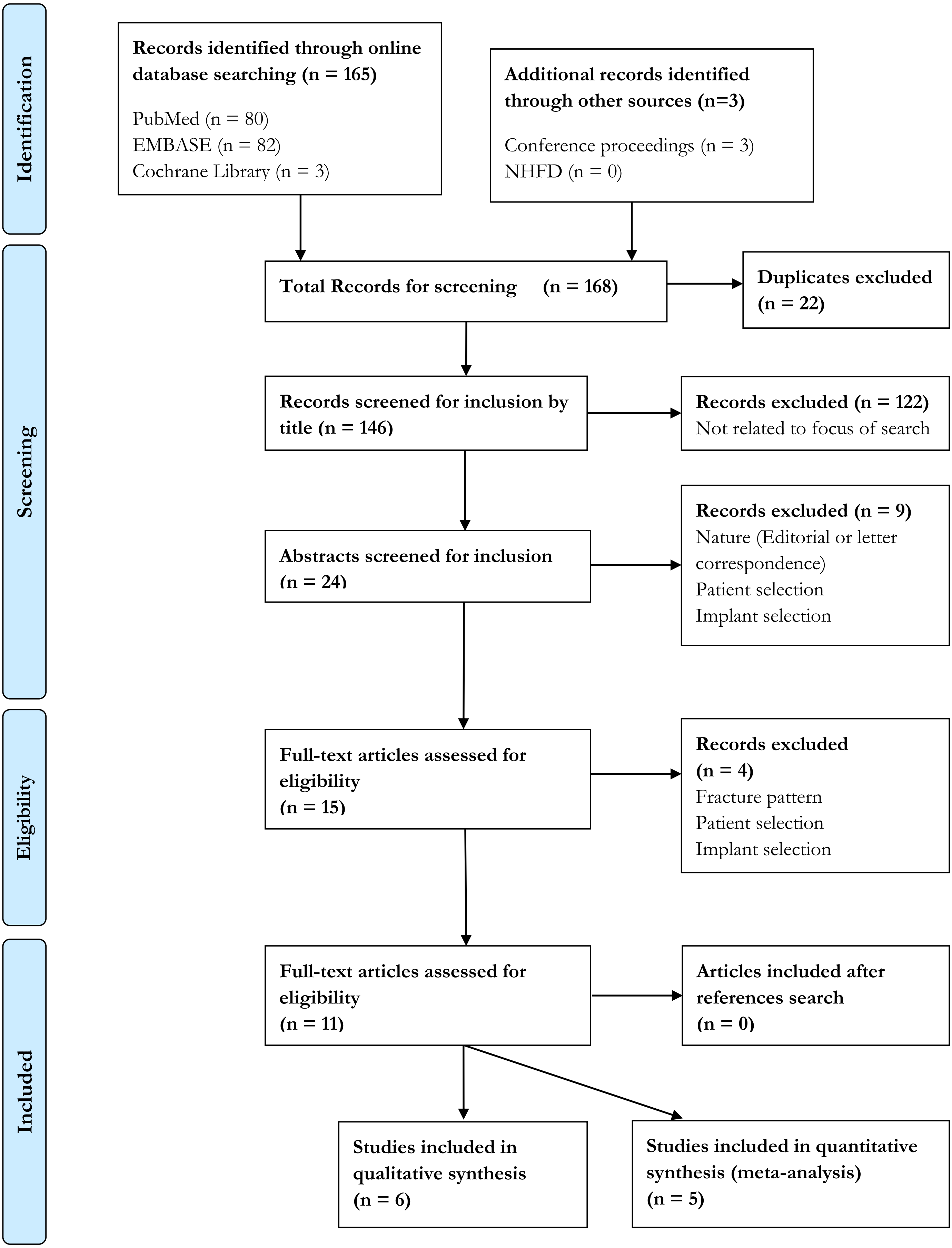

Fig. b: Meta-analysis of the overall risk of complications.

Study or Subgroup	Salvage THA Events	Salvage THA Total	Primary THA Events	Primary THA Total	Weight	Risk Ratio M-H, Random, 95% CI
Blomfeldt 2006	5	41	4	43	23.1%	1.31 [0.38, 4.54]
McKinley 2002	52	107	22	258	43.5%	5.70 [3.65, 8.89]
Ozturkmen 2006	16	34	6	34	33.5%	2.67 [1.19, 5.99]
Total (95% CI)		**182**		**335**	**100.0%**	**3.15 [1.39, 7.11]**
Total events	73		32			

Heterogeneity: Tau² = 0.35; Chi² = 6.40, df = 2 (P = 0.04); I² = 69%
Test for overall effect: Z = 2.76 (P = 0.006)

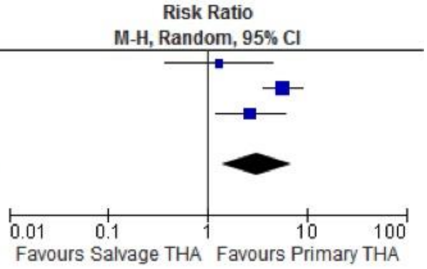

Fig. c: Meta-analysis of the risk of deep infection

Study or Subgroup	Salvage THA Events	Salvage THA Total	Primary THA Events	Primary THA Total	Weight	Risk Ratio M-H, Fixed, 95% CI
McKinley 2002	8	107	2	258	54.0%	9.64 [2.08, 44.68]
Ozturkmen 2006	4	34	1	34	46.0%	4.00 [0.47, 33.97]
Total (95% CI)		**141**		**292**	**100.0%**	**7.05 [2.08, 23.86]**
Total events	12		3			

Heterogeneity: Chi² = 0.43, df = 1 (P = 0.51); I² = 0%
Test for overall effect: Z = 3.14 (P = 0.002)

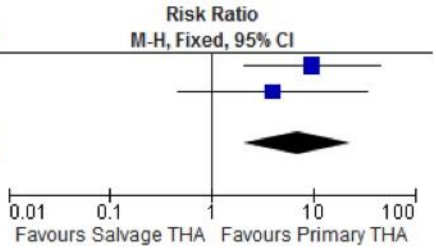

Fig. d: Meta-analysis of the risk of early dislocation.

Study or Subgroup	Salvage THA Events	Salvage THA Total	Primary THA Events	Primary THA Total	Weight	Risk Ratio M-H, Random, 95% CI
McKinley 2002	21	107	9	258	63.8%	5.63 [2.66, 11.88]
Ozturkmen 2006	6	34	3	34	36.2%	2.00 [0.54, 7.35]
Total (95% CI)		**141**		**292**	**100.0%**	**3.87 [1.46, 10.25]**
Total events	27		12			

Heterogeneity: Tau² = 0.24; Chi² = 1.82, df = 1 (P = 0.18); I² = 45%
Test for overall effect: Z = 2.72 (P = 0.006)

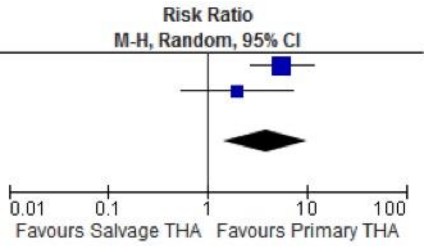

Fig. e: Meta-analysis of the risk of peri-prosthetic fracture

Study or Subgroup	Salvage THA Events	Salvage THA Total	Primary THA Events	Primary THA Total	Weight	Risk Ratio M-H, Fixed, 95% CI
McKinley 2002	5	107	2	258	54.0%	6.03 [1.19, 30.59]
Ozturkmen 2006	5	34	1	34	46.0%	5.00 [0.62, 40.58]
Total (95% CI)		**141**		**292**	**100.0%**	**5.55 [1.53, 20.23]**
Total events	10		3			

Heterogeneity: Chi² = 0.02, df = 1 (P = 0.89); I² = 0%
Test for overall effect: Z = 2.60 (P = 0.009)