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Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic femoral fracture.

Thesis prepared for the degree of Master of Clinical Science by

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Dedication

To my parents George and Sherrie, thank you from the bottom of my heart for providing me with the foundations which have enabled me to undertake the Master of Clinical Science program and complete my 10th year of tertiary studies.

To my fiancé Dandara Gabriela, thank you for your unconditional love and support during my candidature, I simply could not have done it without you. Beijos.

Preface

This thesis reports on research by way of a systematic review carried out during my Masters of Clinical Science candidature at the University of Adelaide, Adelaide, South Australia from February 2016 to May 2018.

This thesis consists of 4 chapters. Chapter 1 presents the background and context of the review, which develops the foundation for the study aims. Chapter 2 provides a description of the methodology for the systematic review. Chapters 3 presents the results of the study. Finally, Chapter 4 presents an overall discussion of the findings, its clinical implications, summarises the major conclusions and highlights the future directions in research.

Abstract

Hip arthroplasty is a commonly performed orthopaedic intervention employed in the management of various hip pathologies. Australian registry data indicate that over 42,000 primary hip arthroplasties including a stemmed femoral prosthesis were performed during 2016 (Australian Orthopaedic Association 2017). Post-operative peri-prosthetic femur fractures (PFFs) around hip arthroplasties have an incidence around 0.4% to 4% and although infrequent, are a significant complication imparting a heavy burden upon patient, orthopaedic surgeon and the health care system, costing on average around AUD 40,000 per patient, per fracture to manage (Phillips, Boulton et al. 2011). The Vancouver classification system, devised by Brady and colleagues is the most commonly utilised system for classifying PFFs, with Type B fractures occuring at the level of or just below the femoral stem, further subdivided according to stem stability and bone stock, with our study population, type B2 exhibiting an unstable stem with preserved proximal bone stock (Brady, Garbuz et al. 1999). Although revision arthroplasty is currently recommended for management of Vancouver Type B2 PFFs, open reduction internal fixation (ORIF) has been shown in some small studies to yield similar outcomes when compared to revision. If selected Vancouver type B2 fractures were shown to be amenable to ORIF alone rather than revision, it would be beneficial given that much intra-operative risk would be mitigated by way of shorter operative times, and a reduction in skill set demands upon the surgeon, reduce implant costs, and allow for subsequent revision in arthroplasty in younger individuals. The objective of this thesis was to identify the effectiveness of operative interventions for individuals who have undergone a hemi or total hip arthroplasty who sustain a Vancouver type B2 peri-prosthetic femoral fracture or equivalent, by conducting a systematic review. Specifically, the review

investigated open reduction and internal fixation and femoral revision arthroplasty with or without internal fixation.

Unpublished and published studies across PubMed Medline, EMBASE, CINAHL, The Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, ClinicalTrials.gov and Proquest Theses and Dissertations were considered for the systematic review. We assessed both experimental and observational studies written in English from 1990 or later, which reported on five or more Vancouver B2 periprosthetic fractures and assessed at least one outcome of interest, including intra-operative (e.g. surgical time, bleeding), radiographic (e.g. subsidence), clinical (e.g. union, mortality, parker mobility) and patient reported outcomes (e.g. functional status and health-related quality of life). The quality assessment of the papers was performed by two independent reviewers using standardised critical appraisal instruments according to the study design from the Joanna Briggs Institute. The critical appraisal was compared and in case of disagreement a third reviewer's opinion was sought for further discussion. Data was extracted from papers included in the review using the standardised data extraction tool from the JBI-System for the Unified Management, Assessment and Review of Information (SUMARI).
From the electronic searches, 1805 potential articles were found, of which 860 duplicates were removed. In the first screening, 213 studies were selected for full text reading. The reference lists of these articles revealed another 45 articles, and a total of 258 studies were selected for full-text reading. After the evaluation, 37 studies were finally included in the systematic review. There were 27 retrospective case series and 10 retrospective cohort studies, which together evaluated outcomes of 926 Vancouver B2 fracture cases. With regards to the intervention, 25 studies evaluated revision with or without wires, cables or cerclage, while three studies investigated revision plus ORIF with plate. There were three

studies that analysed revision and cortical strut allografts. There were 11 studies that evaluated revision with mixed methods or without specifying the revision technique. Ten studies assessed ORIF with plate. Two studies evaluated ORIF with wires, cerclage or cables. Three studies evaluated ORIF with mixed methods or without specifying ORIF technique. One study evaluated a non-operative intervention. Among the 37 included studies, 24 papers evaluated one intervention of interest, six articles included two interventions, five studies included three interventions and two studies investigated four interventions of interest. Comparative meta-analysis revealed small differences between management strategies across different outcomes. While the surgical time was shorter and the transfusion requirement was less for ORIF with plate vs Revision +/- wires, cerclage and cables, pre and post-operative parker mobility scores, subsidence, union, mortality, dislocation and infection rates were similar. Regarding Revision via any method vs ORIF any method, union, malunion and infection rates were similar, however, mortality rates were lower for ORIF and re-operation rates were lower for revision. Overall, no management strategies have been shown to be consistently superior for the outcomes included in this systematic review and meta-analysis.

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Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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Jamie Raffaele Ianunzio

Date: 8thth of June 2018

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Research Outcomes

Prizes

RJ Bauze Prize for the best paper presentation (podium) at the 2018 Australian Orthopaedic Association SA/NT Branch Scientific Meeting held at The Queen Elizabeth Hospital on Friday, 23 February 2018. Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic fracture: a systematic review and meta-analysis

Publications arising from work contained within this thesis (thus far)

Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic femoral fracture: a systematic review protocol. Ianunzio JR, Munn Z, Mandziak D, Stephenson M, Cain ME**.** *JBI Database System Rev Implement Rep.* 2017 Feb; 15: 245-258. https://www.ncbi.nlm.nih.gov/pubmed/28178018

Conference presentations

National

June 2016

The Australasian Orthopaedic Trauma Society Annual Scientific Meeting, Uluru, Northern Territory. Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic fracture: a systematic review protocol. Ianunzio JR, Munn Z, Mandziak D, Stephenson M, Cain ME.

Regional

February 2018

The Australian Orthopaedic Association SA/NT branch Annual Scientific Meeting, The Queen Elizabeth Hospital, Adelaide, South Australia. Effectiveness of operative interventions

in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic fracture: a systematic review and meta-analysis. Ianunzio JR, Munn Z, Mandziak D, Stephenson M, Cain ME, February 2017

The Australian Orthopaedic Association SA/NT branch Annual Scientific Meeting, Lyell McEwin Hospital, Adelaide, South Australia. Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic fracture: a systematic review protocol.
Ianunzio JR, Munn Z, Mandziak D, Stephenson M, Cain ME
November 2016

The Joanna Briggs Institute (JBI) 20th Anniversary Symposium, Adelaide, South Australia
Effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver B2 peri-prosthetic fracture: a systematic review protocol
Ianunzio JR, Munn Z, Mandziak D, Stephenson M, Cain ME

Chapter 1: Introduction

Preamble

Peri-prosthetic femoral fractures (PFF) around hip arthroplasties may occur intra or post-operatively, and although infrequent, their incidence is rising and are a significant complication imparting a heavy burden upon the patient, orthopaedic surgeon and the health care system (Lindahl 2006 and Phillips et al. 2011). In 1999, Brady and colleagues devised a classification system known as the Vancouver classification in conjunction with the development of a treatment algorithm for post-operatively sustained fractures which is based on location of the fracture, whether or not the stem is loose and the quality of bone stock in the proximal femur (Brady, Garbuz et al. 1999). PFFs where the fracture is at the level of the stemmed femoral prosthesis, where the femoral component is loose and there is uncompromised proximal femoral bone stock are referred to as Vancouver B2 fractures. There is a modest amount of literature assessing the outcomes of management by way of open reduction internal fixation (ORIF) vs femoral revision, with or without internal fixation with some studies suggesting ORIF is a viable alternative to the current gold standard femoral revision.

Review objective

The general aim of this thesis was to identify the effectiveness of operative interventions in individuals with a hemi or total hip arthroplasty who sustain a Vancouver type B2 peri-prosthetic femoral fracture (PFF) or equivalent. Specifically, this thesis aimed to investigate open reduction and internal fixation (ORIF) and femoral revision arthroplasty with or without internal fixation.

Background

Hip arthroplasty

Generally speaking, hip arthroplasty (also known as hip replacement) involves open surgery to the hip joint, resection of the diseased femoral head or defunct femoral head/neck junction, along with implantation of a stemmed femoral prosthesis and prosthetic femoral head, with or without additional acetabular preparation and replacement. Globally, the goals of hip arthroplasty are to restore pre-morbid, stable, pain-free hip joint motion and effective load transfer from pelvis to femur to enable long-term repetitive ambulation. These procedures may be primary interventions, including those performed on a native hip joint without any prior surgery, or revision interventions, where patients have had previous hip arthroplasty procedure(s) and existing implants are replaced (femoral stem, femoral head or neck, acetabular cup or liner) or the construct changed (e.g. conversion of hemi to total hip arthroplasty).

In Australia, hip arthroplasty is a commonly performed orthopaedic intervention employed in the management of various hip pathologies, most commonly, osteoarthritis and fractured neck of femur. (Jones, Beaupre et al. 2005). The Australian national joint registry indicates that from September 1999 to December 2016, over half a million hip arthroplasties in around 430,000 patients were recorded. Furthermore, as at the end of December 2016, in Australia 310,630 living patients had one or more hip prostheses in situ, accounting for 1.27% of the population (ABS data end 2016 population 24,385,600) (Australian Orthopeadic Association 2017).

During 2016, The Australian national joint registry data indicated 47,171 hip arthroplasty procedures were performed including; primary (partial and total) and revision procedures, accounting for 91% (n=41,860) and 9% (n=4,197), respectively. This was an increase by 1,639 (3.7%) compared with 2015 (Australian Orthopeadic Association 2017).

The National Joint Registry for England, Wales, Northern Ireland and the Isle of Man reported over 100,000 hip arthroplasty procedures were performed during 2016 (an increase of 3.5% from 2015), including over 90,000 primary hip replacements and almost 8,000 revision procedures (The National Joint Registry for England, Wales, Northern Ireland and the Isle of Man 2017).

Furthermore, The American joint replacement registry (AJRR) reported 178,362 hip arthroplasty procedures were performed during 2016 including; primary (partial and total) and revision procedures, accounting for 89.6% (n=159,696) and 10.4% (n=18,666), respectively. It should be noted the reporting to the AJRR is voluntary, and 2016 data estimates the registry covers approximately 28% of the estimated annual procedural volume in the US (The American joint replacement registry 2017).

Hip hemi-arthroplasty (HA)

Of the primary hip arthroplasty procedures performed in Australia during 2016, 15% (5,519) were hip hemi-arthroplasty (HA), which incorporates a system where a prosthetic femoral head (attached to a stemmed femoral prosthesis) articulates with the patient's native acetabulum. In over 90% of cases, fractured neck of femur was the principal diagnosis and mean patient age was around 80 to 85 years depending on subcategory of HA system employed. Furthermore, global registry data for partial hip replacement indicates females account for over 70% of the cohort.

Total hip arthroplasty (THA)

Of the primary hip arthroplasty procedures performed in Australia during 2016, 85% (36,341) were total conventional hip arthroplasty (THA) which incorporates the components of a HA with the addition of acetabular replacement, which includes preparation of the acetabular surface and implantation of a cup and liner, resulting in the prosthetic femoral

head articulating with prosthetic liner (Table 1). The two most common indications for primary THR were osteoarthritis and fracture, accounting for 88.8% and 4.3% of cases, respectively. Mean age was 67.7 and around 55% were female (Australian Orthopeadic Association 2017).

Table 1 Summary of hip arthroplasty procedures in 2016 across AOANJRR, NJR, AJRR

2016 Registry	Hip arthroplasty procedures	Revision (n)	Primary (n)	Primary hip arthroplasty	
				Primary partial/HA (n)	Primary THA (n)
AOANJRR	47,171	4,197 (9%)	41,860 (91%)	5,519 (15%)	36,341 (85%)
NJR	101,651	7,938 (7.8%)	93,713 (92%)	N/A	N/A
AJRR*	178,362	18,666 (10.4%)	159,696 (89.6%)	15,672 (9.8%)	144,024 (90.2%)

*Note estimated coverage of 28% joint replacement volume US 2016.

Prostheses

The core prosthetic components that are used in HA are a femoral head and stemmed femoral prosthesis, and additionally an acetabular cup and liner in THA. Given that our review investigates peri-prosthetic femoral fracture (PFF) only, acetabular cup and liner prostheses will not be discussed in further detail.

Femoral stem

The stemmed femoral prosthesis transfers load from the prosthetic femoral head to the native femur and comes in two broad categories, including cemented and press-fit (cementless) stems. Femoral stem prosthesis behaviour within the femoral canal is impacted by many factors including both implant (prosthesis and instrumentation) and patient bone quality. Implant factors include; stem finish (polished or roughened/coated), stem geometry, encompassing shape (straight or anatomical), cross-section (oval or square), collared or collarless, stem tip shape, length of stem, the degree of rounding of edges and preparation of femoral canal. (Scheerlinck and Casteleyn 2006, Khanuja, Vakil et al. 2011). In the case of cemented femoral systems, this load traverses the stem-cement and cement-bone interface.

During 2016, AOANJRR data reports that regarding HA, 35 different types of femoral stem were implanted with over two-thirds of these being *cemented*. Furthermore, regarding THA, 10 different types of femoral stem accounted for over two-thirds of the femoral stems implanted (Australian Orthopeadic Association 2017). In contrast to HA procedures, approximately two thirds of the femoral systems used in primary conventional THA were *cementless*. This Australian registry data indicates there is a substantial variation in the character of hip arthroplasty implants currently in use. It is important to recognise, these characteristics may ultimately impact performance on an 'implant to implant' basis, let alone the consideration of inter-surgeon variability.

Cemented femoral systems

In cemented systems, the stem shape should optimise transmission of axial and torsional forces to cement and to bone without causing damage to either interface and is required to maintain long-term mechanical stability in the face of repetitive loading. The two most common methods to achieve this are 'Loaded-taper' fixation e.g. Exeter and CPT (double taper) and C-stem (triple taper) and 'Composite-beam' fixation concept e.g. Charnley. (Scheerlinck and Casteleyn 2006).

In 'Loaded-taper' fixation the stem shape allows the prosthesis to become wedged in the cement mantel, hoop stresses transmitting force to bone and an air-filled centraliser facilitates subsidence to a stable position without compromising the distal cement mantle. Stem finish is preferably polished for loaded-taper design to allow step-wise subsidence without excessive metal and debris at cement-stem interface.

In 'Composite-beam' fixation the stem needs to be well bound to cement as subsidence or impairment to the SC interface may damage the cement with polymethyl methacrylate (PMMA) and/or metal debris and ultimately implant failure. Roughened stem finish is preferred for composite-beam designs with the intention of increasing cement-stem bonding.

Cementless (Press-fit) femoral systems

Cementless or press-fit stemmed femoral prosthesis rely on the principle of osseointegration, which is the attachment of lamellar bone to implants without intervening fibrous tissue (Albrektsson, Branemark et al. 1981) in order to effectively transfer load from the femoral head prosthesis to the native femur.

Khanuja et al. 2011 (Khanuja, Vakil et al. 2011) described six categories of cementless femoral stems including; type 1 ('Single wedge'), type 2 ('double-wedge'), type 3

(tapered round (3A), spline/cone (3B), tapered rectangle (3C)), type 4 (cylindrical fully coated), type 5 (modular) and type 6 (anatomic).

Complications of hip arthroplasty

Requirement for revision arthroplasty is a significant complication following hip arthroplasty, with fracture being in the top three reasons for revision based on Australian registry data. Where fracture ranks depends on the indication and category and subtype of index procedure e.g. bipolar vs unipolar modular HA for fractured neck of femur, and THA for osteoarthritis of the hip vs neck of femur fracture (Table 2).

Table 2 AOANJRR extract of most common reasons for revision hip arthroplasty based on index indication and category and subtype.

Primary Hip arthroplasty category	**Hip arthroplasty sub-category**	**Proportion of category in registry**	**Index indication**	**Top 3 most common reasons for revision arthroplasty**		
				1st	**2nd**	**3rd**
Partial/HA	Unipolar monoblock	33.7% (n= 28,122)	#NOF	Loosening (43.5%)	Fracture (19.7%)	Prosthesis dislocation (11.3%)
	Unipolar modular	43.3% (n= 36,090)	#NOF	Prosthesis dislocation (19.9%)	Infection (19.1%)	Fracture (16.5%)
	Bipolar	23% (n= 19,163)	#NOF	Fracture (24.9%)	Infection (21%)	Prosthesis dislocation (18.3%)
THA*	Total conventional	100% (n= 383,123)	OA (n=277805) (72.5%)	Loosening (25.6%)	Prosthesis dislocation (21.6%)	Fracture (19.5%)
			#NOF (n=15865) (4.1%)	Prosthesis dislocation (32.9%)	Fracture (27.1%)	Loosening (16.6%)

*Excludes total resurfacing. NOF = Neck of femur fracture. #NOF (4.3%)

Peri-prosthetic femoral fracture (PFF) around hip arthroplasty

Post-operative PFFs usually occur during minor trauma with epidemiological studies revealing a lifetime incidence anywhere between 0.4% to 3.5% for primary THA and around 4% following revision THA (Kavanagh 1992, Berry 1999, Lindahl, Garellick et al. 2006, Abdel, Houdek et al. 2016) being more common in uncemented femoral systems. With regard to HA, incidence of PFF has been estimated between 2 to 4 percent for cementless implants and 0.5 to 1 percent for cemented implants (McGraw, Spence et al. 2013, Phillips, Moran et al. 2013). Alarmingly, PFF rates have been projected in a recent analysis of multiple joint registries to increase by 4.6% every decade over the next 30 years (Pivec, Issa et al. 2015). Intra-operative PFFs usually occur during femoral stem implantation and are classified differently to post-operative PFFs and are therefore not dealt with in our study (Greidanus, Mitchell et al. 2003).

Risk factors for PFF include patient gender, increasing age, osteoporosis, and type of implant; with cementless femoral components having a higher incidence of post-operative PFF (Berend, Smith et al. 2006, Lindahl 2007). Stress risers in femoral cortical bone may occur during broaching intra-operatively, however, they may not fracture until an enticing event such as a simple low energy fall post-operatively. It is important to note intra-operative PFF may go un-noticed, which is a limitation of investigating PPFs.

PFF burden

Mortality risk for PFF varies in the literature. Young and colleagues and Bhattacharyya and colleagues (Bhattacharyya, Chang et al. 2007, Young, Walker et al. 2008) reported an overall 11% increase in risk of death within 12 months of experiencing the complication. Furthermore, Shields et al. 2014 (Shields, Behrend et al. 2014) revealed a 1 year mortality of 18%, with 80% of deaths occurring within the first 3 months. If the

patients do survive, even with surgical treatment, they are four times more likely to require re-admission post-operatively due to complications and are often left with a functional limitation (Carli, Negus et al. 2017).

Economic analysis of PFF management around hip arthroplasties raises an additional challenge for all stakeholders, with an average cost estimate of £23,469 per patient reported in the United Kingdom setting between 1999-2009 (Phillips, Boulton et al. 2011). Furthermore, Shields et al. 2014 (Shields, Behrend et al. 2014) reported an economic analysis on treatment costs for PFF being around $50,000 USD for revision arthroplasty and $25,000 USD for ORIF.

A multi-disciplinary approach is required for management of such fractures with both orthopaedic traumatologists and arthroplasty surgeons fundamental in the planning and execution of surgical intervention. The Vancouver classification system, devised by Brady et al. 1999 (Brady, Garbuz et al. 1999), is the most commonly utilised system for classifying peri-prosthetic fractures around hip arthroplasties. This classification system has been shown to be both reliable and valid (Brady, Garbuz et al. 1999, Brady, Garbuz et al. 2000). The system considers the site of fracture, stability of implant and quality of surrounding bone stock, which are collective pillars for management decision-making. Type A fractures are confined to the greater or lesser trochanter. Type B fractures are diaphyseal, around the prosthesis or immediately distal to it and are further classified into type; B1, B2 and B3, characterised by: a well-fixed stem, an unstable stem with sufficient bone stock and an unstable stem with poor quality bone stock, respectively. Type C is significantly distal to the prosthetic tip.

Vancouver B2 PFF Management

Broadly, goals of PFF are facilitating early weight bearing without compromising fracture healing and return to pain free functional status. The Swedish National Hip Arthroplasty Registry data spanning from 1979-2000 identified 1,049 PFFs, with over half being Vancouver type B2 (52%) (Lindahl, Garellick et al. 2006). Vancouver type B2 fracture management recommendations are currently that of long femoral stem revision arthroplasty, with or without internal fixation, with the aim of re-establishing implant stability and facilitating a fracture healing (Masri, Meek et al. 2004, Abdel, Cottino et al. 2015). In most cases, revision femoral arthroplasty involves open surgical dislocation of the hip, removal of the loose femoral implant and exchange for an uncemented long stem prosthesis which bypasses the fracture site (Abdel, Cottino et al. 2015).

Open reduction and internal fixation (ORIF) for Vancouver B2 fractures has not traditionally been recommended due to the non-union rates, prolonged immobilisation periods and risk of further revision surgery being required for an unstable femoral implant (Lindahl, Garellick et al. 2006, Solomon, Hussenbocus et al. 2015).

In contrast to revision, ORIF strategies generally attract a shorter operative time and involve surgical dissection to directly visualise the fracture site, anatomical reduction and subsequent internal fixation with plates, screws which are temporised with clamping tools and subsequently internally fixed with plate(s), screws or allografts or a combination. Common fixation strategies include locking plates, compression plates, or cables with or without cortical strut allografts (Dehghan, McKee et al. 2014).

Context of the systematic review

At the time of systematic review protocol registration, a modest amount of literature existed assessing the outcomes of Vancouver type B2 fracture management by way of ORIF

and femoral revision with or without internal fixation. Our scoping search revealed approximately 1000 published cases of Vancouver type B2 fracture management in the literature, including case studies, case series and cohort studies.

Although revision arthroplasty is currently recommended for management of Vancouver Type B2 PFFs, open reduction internal fixation (ORIF) has been shown in some small studies to yield similar outcomes when compared to revision (Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016). If selected Vancouver type B2 fractures were shown to be amenable to ORIF alone rather than revision, it would be beneficial given that much intra-operative risk would be mitigated by way of shorter operative times; there is a reduction in skill set demands upon the surgeon, reduced implant costs, and allowance for subsequent revision in arthroplasty in younger individuals.

On the 4th of August 2016, we searched the JBI Database of Systematic Reviews and Implementation Reports, Cochrane Database of Systematic Reviews and PubMed and found no recent systematic review specifically on Vancouver B2 PFF management. Our systematic review protocol was published in February 2017.

Upon writing this thesis the search was repeated including the aforementioned databases on 18th of March 2018 and yielded one result of a systematic review investigating Vancouver B2 and B3 PFF management (Khan, Grindlay et al. 2017). Key differences between our systematic review and that of Khan's are shown in Table 3.

We feel the body of evidence captured by our systematic review and meta-analysis is more expansive than that of Khan's with over 2.5 times a greater number of Vancouver B2 PFF cases included, and captures a larger window of patient care by not excluding papers based on a minimum mean duration of follow-up. Furthermore, our study provides additional evidence to guide practice.

Table 3 Main differences between the systematic reviews.

	(Khan, Grindlay et al. 2017)	Ianunzio
PROSPERO registration	Registration 5/2/2016, completion 7/3/2017	Registration 20/2/2017 and publication protocol Feb 2017 (Ianunzio, Munn et al. 2017)
Databases	Ovid MEDLINE, Embase, and the Cochrane Central Register of Controlled Trials and Database of Systematic Reviews	PubMed Medline, EMBASE, CINAHL, The Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science. And grey literature databases were searched, including; ClinicalTrials.gov and Proquest Theses and Dissertations.
Inclusion criteria	Conducted search on both B2 and/or B3 fractures, studies with 10 or more case	Inclusion criteria and analysis on B2 fractures only, studies with 5 or more B2 PFF
Exclusion criteria	Excluded studies with less than 2-year mean follow-up, no exclusion based on publication date	Did not exclude studies based on follow-up duration, excluded papers published prior to 1990
Number of studies included	Khan included 14 studies including 14 case series	37 studies including 27 retrospective case series and 10 retrospective cohort studies
Number of Vancouver B2 PFF management cases included	n=343	n=926

Evidence synthesis

Given the increasing amount of evidence being generated in orthopaedic research over the past few decades, it has become difficult for clinicians to summarise and assess the quality of the evidence in order to translate research findings into clinical practice (Oxman, Cook et al. 1994, Swingler, Volmink et al. 2003). For this reason, systematic reviews are a powerful tool to facilitate evidence-based healthcare (EBHC) by advising clinical decision making (Murad and Montori 2013). In addition, systematic reviews present several advantages over traditional literature reviews, also known as critical reviews. This is related to the principles of systematic reviews, including rigour, transparency and replication, which may in turn improve the quality of traditional literature reviews in a number of ways. By carrying out systematic searches across multiple databases, systematic reviews may help reduce researcher bias, as it forces the reviewers to look for studies beyond their pre-existing knowledge of the literature on the topic. In addition, systematic reviews may generate a more objective answer to the research question itself, given they mandate specific information on the population of interest, intervention/exposure, group of comparison and outcome, generating a broad yet focused body of evidence.

Justification of Review approach

A systematic review and meta-analysis was chosen to answer our research objective on the effectiveness of management strategies for Vancouver B2 PFF due to a number of reasons. First, this approach allowed us to collate and summarise the best available evidence around our research question to date by adopting a rigorous and transparent search, quality assessment and data synthesis. Second, orthopaedic research is often limited to observational studies, given the ethical and practical barriers to undertaking randomised controlled trials

(RCTs). Specifically, in relation to our objective, randomising exposure allocation would require unanimous support of surgeons within a unit, as well as flexible skill sets, which would enable them to perform either intervention in a reproducible way. In addition, the cost and time burden associated with running such an RCT would not be feasible without significant funding from government and health industry, which has ethical implications. Finally, even if a large, high-quality RCT was conducted, it may still not be enough to guide clinical practice. In light of this, a systematic review and meta-analysis (where heterogeneity allows) is seen as an effective research tool which can be conducted in a timely fashion and generate good quality evidence, which can be rapidly translated into clinical practice.

There are a number of factors that characterise a rigorous systematic review. Firstly, the systematic review should explicitly declare the review questions as well as the eligibility criteria before the search across databases. Globally, the process should follow the guidelines from Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher, Liberati et al. 2009) and be published in the form of a protocol in reliable databases, such as PROSPERO. Furthermore, the search strategy should be tailored to the clinical question and cover multiple databases, ideally including the grey literature, and be subject to dual critical appraisal using an approved checklist, such as the tool provided by the Joanna Briggs Institute. Where heterogeneity allows, meta-analyses should be performed, and forest-plots generated to summarise pooled estimates from single group and comparative studies. Finally, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach should be employed to generate a Summary of Findings Table where appropriate.

Objectives, inclusion criteria and methods were specified in advance and published in a protocol (Ianunzio, Munn et al. 2017) and registration number CRD42017057776 in PROSPERO.

Assumptions and limitations of approach

Although systematic reviews and meta-analysis provide a good level of evidence, the quality of the review is associated with the methodological quality of the included studies themselves. Therefore, the quality of the systematic review cannot be superior to that of the included studies. Unfortunately, orthopaedic research is often of low quality and this limits the findings presented in this current study.

Chapter 2- Methods

Inclusion and exclusion criteria

Types of participants

The review considered studies including individuals with a total hip arthroplasty or hip hemi-arthroplasty, primary or revision, who sustained a Vancouver type B2, or equivalent, PFF. Those who sustained intra-operative fractures were excluded, given the classification system is different. Additionally, studies utilising alternative methods of classification other than Vancouver or equivalent were excluded.

Types of interventions

This review considered studies that evaluate the following:

- ORIF by any method including but not limited to, cable plate, compression plate, locking plates, screws, cerclage wires, cortical strut allografts **or** a combination of methods; **and/or**
- Any form of femoral revision arthroplasty, with or without internal fixation.

The review compared the aforementioned interventions with each other. Studies that have evaluated two or more interventions and studies that have investigated only a single intervention were considered for inclusion. If any of the interventions were compared with a different approach, including non-operative management, these were considered for inclusion.

Types of outcomes

The types of outcomes, their definition, and their example measures are included in Table 4.

Table 4 Outcomes included in the systematic review.

Outcome	Definition
Re-operation	Defined as return to theatre for any surgical intervention required to manage the Vancouver B2 fracture OR complication following initial management strategy
Implant breakage/ migration of screws	Fracture through any hardware component or migration of screws
Femoral loosening	As defined using Harris' criteria (Harris, McCarthy et al. 1982) or other criteria as used by study authors.
Femoral osteolysis	greater than 3mm sized non-linear demarcated lesion (Solomon, Hussenbocus et al. 2015)
Stem subsidence/migration	'Stem subsidence (is) measured using the width of radio-lucent lines present at the s-c interface in Gruen zone 1 parallel to the stem long axis' (Solomon, Hussenbocus et al. 2015) For CCPT femoral stems, <6mm subsidence expected and acceptable (Solomon, Hussenbocus et al. 2015) For other femoral stem systems thresholds for acceptable subsidence were based on relevant literature/expert opinion/product manufacturer guide
Union	Defined clinically as absence of pain at fracture site upon weight-bearing and radiographically as cortical bridging of fracture on three or more sides viewed on antero-posterior and lateral radiograph (Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016)
Delayed union –	Defined as healing taking greater than 3 months from time of surgery (Joestl, Hofbauer et al. 2016)
Non-union	Defined as a lack of progressive signs of healing beyond 6 months post-operatively (Joestl, Hofbauer et al. 2016)
Malunion	Defined as deviation of more than 5 degrees from anatomical norms in the mediolateral or antero-posterior plains (Kaab, Stockle et al. 2006)

Table 4 (cont.) Outcomes included in the systematic review.

Outcome	Definition
Re-fracture	Defined as any new peri-prosthetic fracture or re-fracture through previous fracture site.
Loss of reduction	Defined as any change in fracture alignment (Joestl, Hofbauer et al. 2016)
Dislocation of prosthesis	Loss of anatomical reduction at hip articulation
Neurovascular injury	Defined as any neurological or vascular deficit, permanent or temporary, attributed directly to management intervention as documented by surgical team (excluding effects of regional anesthesia)
Prosthetic joint infection defined as	Sinus tract to prosthesis; OR Culture pathogen from 2+ samples; OR 4 out of 6 of the following; • Elevated erythrocyte sedimentation rate (Mustafa, Santesso et al.) and serum C-reactive protein (CRP) concentration; • Elevated synovial leukocyte count; • Elevated synovial neutrophil percentage; • Purulence in affected joint; • Isolation of organism in one culture of peri-prosthetic tissue or fluid • More than 5 neutrophils per 5 high powered fields on analysis of peri-prosthetic tissue at x400 magnification
Functional outcomes including but not limited to	• Harris hip score; (Harris 1969) OR • Oxford hip score; (Dawson, Fitzpatrick et al. 1996) OR • University of California, Los Angeles (UCLA) activity score; (Zahiri, Schmalzried et al. 1998) OR • Parker mobility score. (Parker and Palmer 1993)
Operative risks	• Total operating room time • Skin-to-skin surgical time • Peri-operative blood transfusion requirement
Length of stay in hospital	Self-explanatory
Mortality	Self-explanatory Note: patients excluded from cohorts due to death were included in the analysis for mortality

Types of studies

This review considered both experimental and observational study designs including; randomised controlled trials, non-randomised controlled trials, quasi-experimental, before and after studies, prospective and retrospective cohort studies, case studies, case control studies and analytical cross-sectional studies for inclusion.
Studies with mixed cohorts (B2/3/1, C, Ag or AL) were only included if:
1) There was a proportion of 80% or greater of Vancouver type B2 PFF; or
2) Outcomes were reported specifically for Vancouver type B2 PFF (or authors could provide access to the raw data).
In addition, studies with mixed cohorts including a proportion of 80% or greater B2 population that have mixed intervention methods (ORIF, Revision with or without internal fixation, or Non-op) with pooled data were excluded, unless authors could provide access to the raw data or specific data was available in the publication.
Studies with mixed intervention methods (ORIF, Revision with or without internal fixation, or Non-op) with pooled outcome data were only to be included if all of the cohort is B2 and 80% or greater proportion of Revision or ORIF predominates. This was the case unless authors could provide access to the raw data or specific data in the publication was available.

Search strategy

The search strategy aimed to find both published and unpublished studies. A three-step search strategy was utilised in this review. An initial limited search of PubMed MEDLINE was undertaken using key words such as femoral fracture, peri-prosthetic and arthroplasty followed by analysis of the text words contained in the title and abstract, and of the index terms used to describe the article. A second search using all identified

keywords and index terms was then undertaken across all included databases. Thirdly, the reference list of all identified reports and articles was then searched for additional studies. Studies published in English were considered for inclusion in this review. Articles published prior to 1990 were excluded to ensure management strategies reflect current clinical practice. Additionally, we contacted known experts in the field and prominent authors to enquire about their knowledge of any completed published or unpublished studies relevant to our objective.

The databases we searched include:

PubMed Medline, EMBASE, CINAHL, The Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science.

Additionally, the following grey literature databases were searched; ClinicalTrials.gov and Proquest Theses and Dissertations.

The PubMed Medline search strategy was:

Femoral fractures[mh] OR Femoral fracture*[tw] OR femur fracture*[tw]

AND

Periprosthetic[tw] OR peri-prosthetic[tw] OR peri-prosthetic[tw]

AND

Arthroplasty, replacement, hip[mh] OR hemiarthroplasty[mh] OR hip arthroplasty[tw]

OR

hip replacement[tw] OR hip hemiarthroplasty[tw]

Assessment of methodological quality

The quality assessment of the papers was performed by two independent reviewers (Jamie Ianunzio and Megan Cain), using standardised critical appraisal instruments according to the study design from the Joanna Briggs Institute (Appendix I).

The instruments consist of 9 or 10 ‘yes/no/unclear’ questions, depending on the study design, regarding different aspects of the included papers aiming to assess the quality of the papers. Both the reviewers were properly trained by attending a course to apply the above-mentioned instrument. The critical appraisal was compared and in case of disagreement a third reviewer’s opinion was sought for further discussion. All articles were included in the systematic review regardless of their methodological quality.

Data extraction

Data was extracted from papers included in the review using the standardised data extraction tool from JBI-System for the Unified Management, Assessment and Review of Information (SUMARI) (Appendix II). The data extracted included specific details about the interventions, populations, study methods and outcomes of significance to the review objective and specific objectives. In the event of data of interest being absent in the published article(s), raw data was requested via direct contact with corresponding author(s) and we allowed them 4 weeks to respond. We sought raw data in 37 studies and obtained a response from 10 studies, with only three providing raw data. Table 5 presents the detailed information collected for each study.

Table 5 Description of data extraction.

Study characteristics	**Collected when available**
First author/year of publication	Self-explanatory
Cohort characteristics	Study design, data source
Participants' characteristics	Participants, sampling method, recruitment, index procedure indication, implant details, mechanism of injury, fracture diagnosis method, setting, inclusion criteria, exclusion criteria
Exposure	Intervention category and technique, sex, age, time-frame from index to fracture, exposure allocation, surgeon experiential level, weight bearing status, venous thromboembolism prophylaxis and surgical antibiotic prophylaxis
Outcome	General characteristics, time-frame of assessment
Statistical Analysis	Test used
Results	Proportions/ means with respective Cis for each intervention arm
Limitations and conclusions as reported by authors	Self-explanatory
Limitations and conclusions from reviewer	Self-explanatory

Data synthesis

Data was synthesised in meta-analyses and presented in forest plots where possible. We performed both single group and comparative meta-analyses. Where synthesis in the meta-analysis was not possible, due to significant clinical or methodological heterogeneity, we provided a narrative description of the results including tables and figures to aid in data presentation where appropriate.

Open Meta Analyst was adopted for single group analyses of continuous variables using means, whereas Medcalc was adopted for single group analyses of dichotomous variables using a Freeman-Tukey transformation. For comparative group analyses we used RevMan and adopted Mantel-Haenszel as the statistical method of choice for dichotomous outcomes. The inverse variance was used when the Mantel-Haenzel method was not possible for dichotomous outcomes, and it was also employed for all continuous outcomes.

As we intended to generalise the results beyond the included studies, the random effects model meta-analysis was chosen as the default model as this is a more appropriate approach than the fixed model for this purpose (Tufanaru, Munn et al. 2015). The fixed effect meta-analysis model was used only if it was not appropriate to use the random effects model (for example, if less than five studies were included in the meta-analysis) (Tufanaru, Munn et al. 2015).

We intended on using Odds Ratio, however, for ease of interpretation effect sizes were expressed as risk difference and relative risk (for categorical data) and weighted mean differences (for continuous data) and their respective 95% confidence intervals were calculated for analysis. In the case of zero event rates it was not possible to conduct meta-analysis for Risk Ratios, therefore, we adopted the Peto Odds Ratio (this only applies to 3 comparative meta-analyses). Studies were not included in meta-analyses if

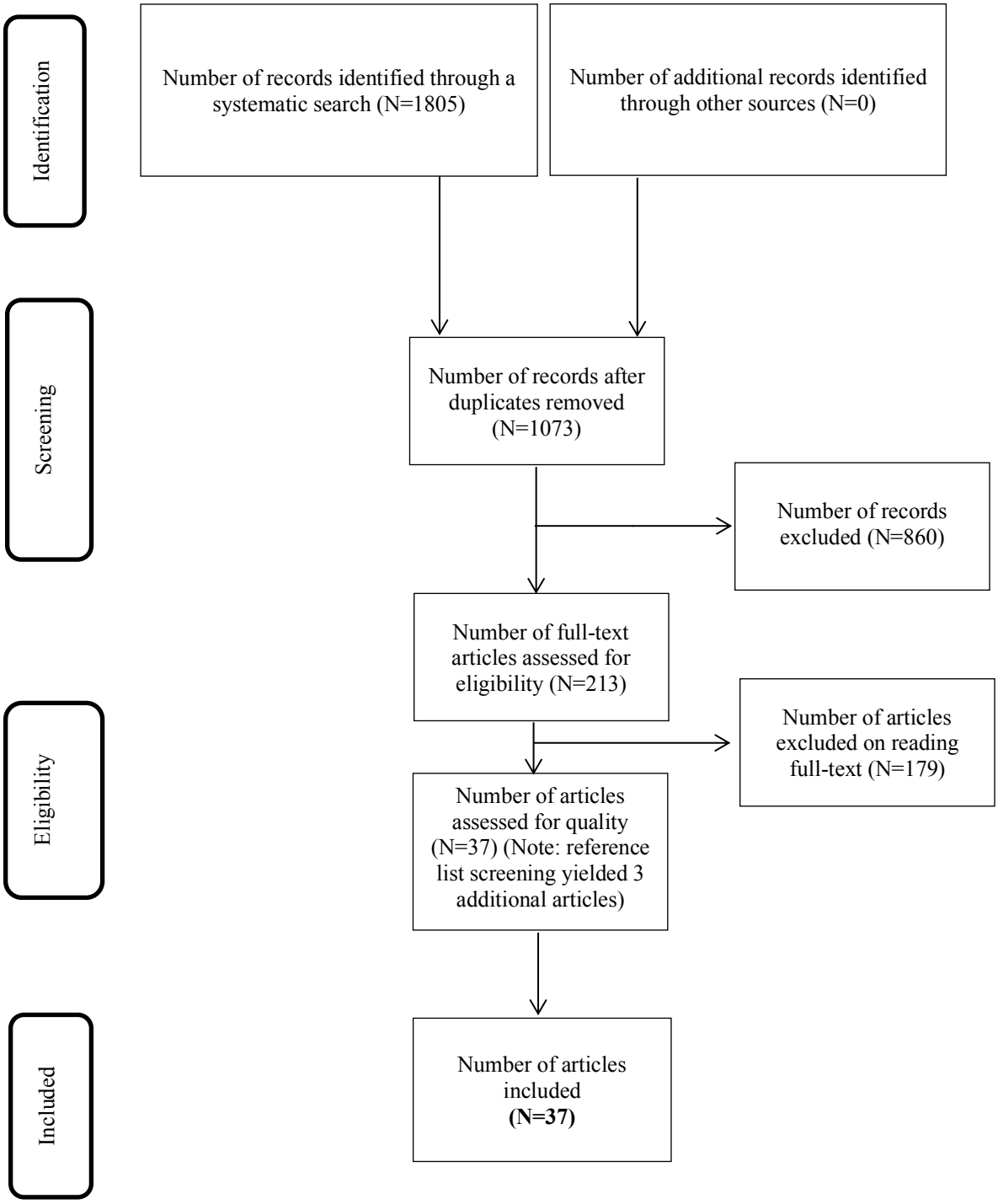
authors did not provide the Standard Deviation (SD) and/or range, or raw data could not facilitate its calculation. We adopted the method of Hozo to calculate the SD from the range where required. Heterogeneity was assessed statistically using the standard Chi-square and I^2 and also explored using sub-group analyses. For I^2 values of up to 25%, 25% to 75%, and more than 75%, heterogeneity was defined as low, moderate and high, respectively (Higgins, Thompson et al. 2003). Although sub-group analyses for age, sex, co-morbidities, smoking status, surgical expertise and intervention technique were planned, only sub-group analysis for intervention technique was possible.

A 'Summary of Findings' Table was created with the GRADEPro GDT software. We adopted the GRADE approach for grading the quality of evidence (Schunemann, Brozek et al.) The 'Summary of Findings' Table presents the following information where appropriate: absolute risks for the treatment and control, estimates of relative risk, and a ranking of the quality of the evidence based on the risk of bias, directness, heterogeneity, precision and risk of publication bias of the review results (Higgins and Green 2013). Outcomes were ranked accordingly in decreasing order of importance as follows: mortality/ attainment of pre-fracture mobility status (Critical score 9), surgical time/ re-operation/ union/ dislocation (Critical score 8), and transfusion (Important score 6).

Chapter 3 - Results

Search results

Figure 1 shows a flowchart of the study selection. From the electronic searches, 1805 potential articles were found, of which 860 duplicates were removed. In the first screening, 213 studies were selected for full text reading. The reference lists of these articles revealed another 45 articles, and a total of 258 studies were selected for full-text reading. After the evaluation, 37 studies were finally included in the systematic review. The main reasons for exclusion were inclusion of mixed exposures and pooled outcomes (n=39), none (n=33) or less than 5 B2 PPF (n=33), and studies not written in English (n=20) (Appendix III).



Adapted from: (Moher, Liberati et al. 2009)

Figure 1 PRISMA flow diagram of search and study selection process.

Description of the included studies

Appendix IV presents the characteristics of the included studies. There were 27 retrospective case series and 10 retrospective cohort studies, which together evaluated outcomes of 926 Vancouver B2 fracture cases. The majority of the studies were conducted in tertiary hospitals in high-income countries, with over 70% located in Europe. Around two thirds of the articles were published in 2010 or later, and 15 studies presented data collected over a period of 10 years or more. Over half of the included studies had a minimum follow-up period of 12 months and included individuals over 70 years old, with females being over-represented in most investigations. With regards to the intervention, 24 studies evaluated revision with or without cables, cerclage or wires, while three studies investigated revision plus ORIF with plate. There were 13 studies that analysed revision without specifying the technique or by adopting multiple methods. Ten articles assessed ORIF with plate, whereas another four studies assessed ORIF without specifying the plating method or utilised an alternative fixation method (e.g. cerclage wires). Finally, one study evaluated a non-operative intervention. Among the 37 included studies, six papers evaluated two interventions of interest, five articles included three interventions, while two studies evaluated four interventions. In order to simplify the understanding of our references we attributed a number for each of the included studies according to their alphabetic order (first author). In addition, when more than one intervention was investigated in the same study, we employed a letter to indicate the different interventions. For example, the study by Bhattacharyya and colleagues (Bhattacharyya, Chang et al. 2007) was the study number 2. As this study evaluated more than one intervention of interest, the referencing system was 2A for Revision +/- wires, cables or cerclages and 2B for ORIF with plate. Details on the referencing system adopted are presented on Table 6. A large variety of outcomes were investigated by the

included studies and the associations between interventions and outcomes were expressed in multiple ways, including means with standard errors or standard deviations, odds ratios, prevalence ratios and β coefficient.

Table 6 Description of studies and referencing system adopted.

Intervention arm	Studies
Revision with or without wires, cables, cerclage	2A (Bhattacharyya, Chang et al. 2007)
	4 (Canbora, Kose et al. 2013)
	6 (Da Assunção, Pollard et al. 2015)
	7 (Eingartner, Volkmann et al. 2006)
	8 (Fink 2014)
	9 (Garcia-Rey, Garcia-Cimbrelo et al. 2013)
	10 (Grammatopoulos, Pandit et al. 2011)
	13A (Holley, Zelken et al. 2007)
	14A (Inngul and Enocson 2015)
	15A(Joestl, Hofbauer et al. 2016)
	15B(Joestl, Hofbauer et al. 2016)
	16 (Ko, Lam et al. 2003)
	17 (Konan, Rayan et al. 2011)
	18A (Korbel, Sponer et al. 2013)
	20A (Lindahl, Garellick et al. 2006)
	22 (Marx, Beier et al. 2012)
	24A (Mukka, Mellner et al. 2016)
	25A (Mukundan, Rayan et al. 2010)
	25C (Mukundan, Rayan et al. 2010)
	26 (Munro, Garbuz et al. 2014)
	27A (Niikura, Lee et al. 2014)
	28A (Pavlou, Panteliadis et al. 2011)
	29 (Pogliacomi, Corsini et al. 2014)
	31 (Sexton, Stossel et al. 2006)
	33B (Solomon, Hussenbocus et al. 2015)
	36 (Young, Pandit et al. 2007)
	37A (Zuurmond, van Wijhe et al. 2010)
	21B (Lunebourg, Mouhsine et al. 2015)
	24B (Mukka, Mellner et al. 2016)
	25B (Mukundan, Rayan et al. 2010)
Revision strut allograft	13C (Holley, Zelken et al. 2007)
	32 (Sledge and Abiri 2002)
	35 (Wu, Yan et al. 2009)
Revision mixed methods/unspecified	1 (Amenabar, Rahman et al. 2015)
	3 (Briant-Evans, Veeramootoo et al. 2009)
	5 (Corten, Macdonald et al. 2012)
	12 (Holder, Papp et al. 2014)
	13B (Holley, Zelken et al. 2007)
	19 (Levine, Della Valle et al. 2008)
	20B (Niikura, Lee et al. 2014)
	23 (Moreta, Aguirre et al. 2015)
	28B (Pavlou, Panteliadis et al. 2011)
	30 (Rayan, Konan et al. 2010)
	37B (Zuurmond, van Wijhe et al. 2010)

Table 6 (cont.) Description of studies and referencing system adopted.

Intervention arm	**Studies**
ORIF with plate	2B (Bhattacharyya, Chang et al. 2007)
	11 (Haidar and Goodwin 2005)
	13D (Holley, Zelken et al. 2007)
	15C (Joestl, Hofbauer et al. 2016)
	18B (Korbel, Sponer et al. 2013)
	21A (Lunebourg, Mouhsine et al. 2015)
	27B (Niikura, Lee et al. 2014)
	28C (Pavlou, Panteliadis et al. 2011)
	28D (Pavlou, Panteliadis et al. 2011)
	33A (Solomon, Hussenbocus et al. 2015)
	34A (Spina, Rocca et al. 2014)
ORIF with wires, cables, cerclage	24C (Mukka, Mellner et al. 2016)
	34B (Spina, Rocca et al. 2014)
ORIF mixed methods or unspecified	14B (Inngul and Enocson 2015)
	20C (Niikura, Lee et al. 2014)
	37C (Zuurmond, van Wijhe et al. 2010)
Non-operative	27C (Niikura, Lee et al. 2014)

Assessment of methodological quality

Most studies obtained a score of over 70% on the methodological quality assessment (Appendix V). Regarding cohort studies (n=10) the most common methodological inadequacies identified were around addressing confounding factors in the analysis, with no studies addressing confounding factors. Additionally, only one out of seven studies were assessed to have measured outcomes in a valid and reliable way. Regarding case series (n=27), the most common methodological flaws were around inadequate identification of the condition and unclear reporting of outcomes and follow-up.

Findings of the review

Findings are presented according to 1) type of study (comparative and single group studies), 2) surgical technique employed (Revision with or without wires/cerclage/cables, ORIF with plate, Revision and ORIF with plate, ORIF with plate, Revision any method, ORIF any method) and 3) outcomes evaluated.

Comparative studies

This section presents results on comparative studies which assessed one or more interventions of interest. The section is structured according to the pair of interventions under study and outcomes.

Revision with or without wires/cerclage/cables vs ORIF with plate

There were six studies (four retrospective cohort studies and two retrospective case series) which investigated various outcomes for the interventions of Revision with or without wires/cerclage/cables and ORIF with plate.

Surgical time

Two meta-analyses were performed as the Revision with or without wires/cerclage/cable exposures 15A and 15B could not be combined without duplicating exposure 15C's data (Joestl, Hofbauer et al. 2016). Both analyses generated a similar result.

Surgical time (analysis 1)

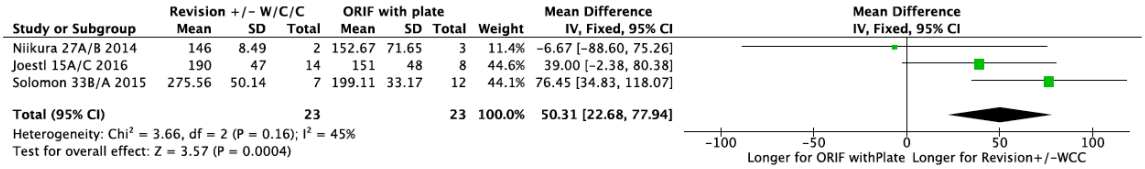


Figure 2 Surgical time (minutes) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 2 shows the surgical time of the exposure in the three studies that reported surgical time for 46 patients. Mean surgical time is in minutes. None of the studies explicitly defined surgical time and refer to the outcome as either 'surgical duration'(Joestl, Hofbauer et al. 2016), 'operation time' (Niikura, Lee et al. 2014) or 'skin-to-skin surgical time' (Solomon, Hussenbocus et al. 2015), all of which were accepted to mean surgical time for the purposes of this meta-analysis.

Overall, there was a statistically significant difference in the surgical time between patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate (p=0.0004). The weighted mean difference in surgical time in the Revision with or without wires/cerclage/cables group was 50.3 minutes (95%CI 22.7 to 77.9) longer than the ORIF with plate group. There was no significant heterogeneity (p=0.16), and I^2 indicates there is a moderate degree of heterogeneity between the studies (45%).

Surgical time (analysis 2)

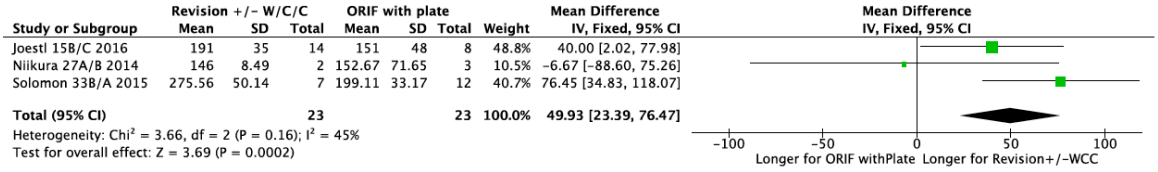


Figure 3 Surgical time (minutes) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 3 shows the surgical time of the three studies that reported surgical time for 46 patients. Mean surgical time is in minutes.

Overall, there was a statistically significant difference in the surgical time between patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate (p=0.0002). The weighted mean difference in surgical time in the Revision with or without wires/cerclage/cables group was 49.9 minutes (95%CI 23.4 to 76.5) longer than the ORIF with plate group. There was no significant heterogeneity (p=0.16), and I^2 indicates there is a moderate degree of heterogeneity between the studies (45%).

Blood loss intra-operatively

One study compared intra-operative blood loss for Revision with or without wires/cerclage/cables, exposure 27A (n=2) and ORIF with plate, exposure 27B (n=3), with a mean intra-operative blood loss of 1502 mL (SD 1368) and 390 mL (SD 233), respectively (Niikura, Lee et al. 2014).

Transfusion packed red blood cell (PRBC) requirement (units)

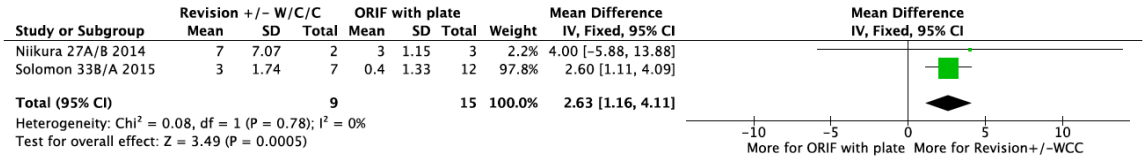
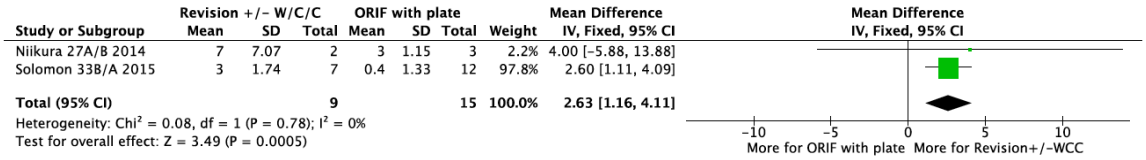


Figure 4 Transfusion PRBC (units) for Revision with or without wires/cerclage/cables vs ORIF with plate.



shows the transfusion PRBC requirement in the two studies that reported transfusion PRBC requirement for 24 patients. Study authors refer to the outcome as either 'intra-operative transfusion' (27A) (Niikura, Lee et al. 2014) or 'peri-operative transfusion' (33B) (Solomon, Hussenbocus et al. 2015), both of which were accepted as transfusion PRBC requirement. Mean transfusion PRBC requirement is in units.

Overall, there was a statistically significant difference in the transfusion PRBC requirement in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate (p=0.0005). The weighted mean difference in transfusion PRBC requirement in the Revision with or without wires/cerclage/cables group was 2.6 units (95%CI 1.2 to 4.1) more than the ORIF with plate group. There was no significant heterogeneity (p=0.78), and I^2 indicates there is no important heterogeneity between the studies (0%).

Subsidence (any)

Two studies compared subsidence for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 15A+B (n=28) with no events observed vs 15C (n=8) (Joestl, Hofbauer et al. 2016) with no events observed and exposure 33B with a prevalence of 14.3% (1/7) vs 33A (n=9) (Solomon, Hussenbocus et al. 2015) with no events observed, respectively. No meta-analysis was possible due to only 33B having an event rate other than zero. Only Solomon and colleagues provided a definition and explicit method for calculating subsidence (Solomon, Hussenbocus et al. 2015).

Union overall (combined analysis 1 and 2)

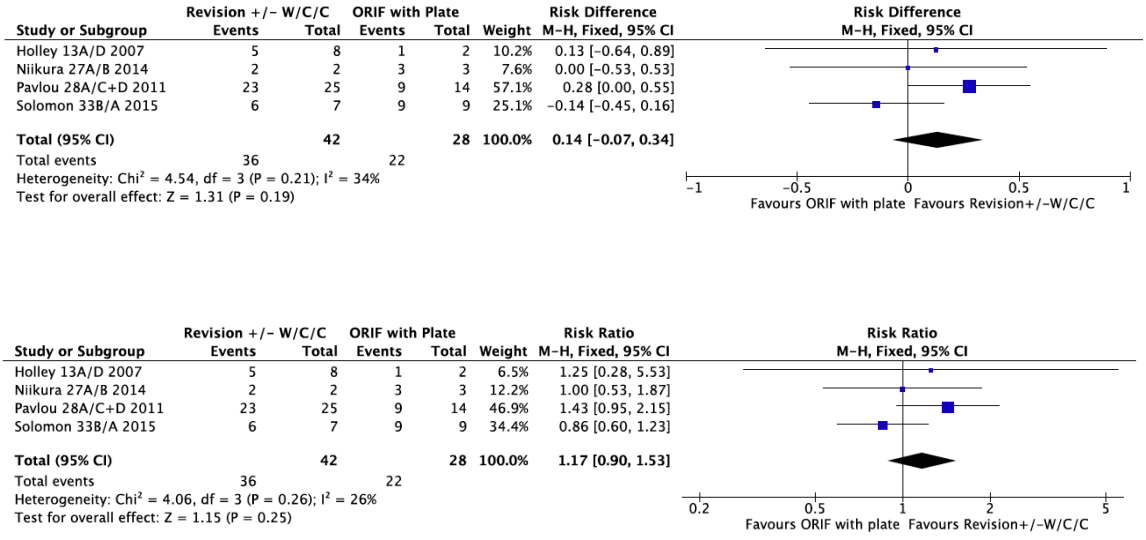


Figure 5 Union (overall) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 5 shows union in the four studies that reported union for 70 patients. Half of the studies (2/4) explicitly defined union and this was generally defined as the presence of a bridging callus across the main fracture site on a minimum two or three sides viewed

in two views on plain film radiographs, however, Pavlou and colleagues additionally considered clinical union (Pavlou, Panteliadis et al. 2011) (Table 7). Only one quarter (1/4) of the studies provided a time to union (Table 7).

The risk difference for union in the Revision with or without wires/cerclage/cables group was 0.14 (95%CI -0.07 to 0.34) more than the ORIF with plate group. There was no significant heterogeneity (p=0.21), and I^2 indicates there is a moderate degree of heterogeneity between the studies (35%).

The risk ratio for union in the Revision with or without wires/cerclage/cables group was 1.17 (95%CI 0.90 to 1.53) more than the ORIF with plate group. There was no significant heterogeneity (p=0.26), and I^2 indicates there is a moderate degree of heterogeneity between the studies (26%).

Overall, there was no statistically significant difference in the prevalence of union in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

Table 7 Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
13A (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment mean 34 months (Range 12-100, No SD reported)
13D (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment Mean 69.5 months (Range 57-82, No SD reported)
27A (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))
27B (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))
28A (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean 5 months (SD 2.2, Range NS)
28C/D (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean C: 8.8 (SD 4.0, Range NS) D: 4.4 (SD 0.51, Range NS)
33B (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 59 months (16-137) – excludes 2 deaths <3 months))
33A (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 67 months (13-82) – excludes 3 deaths <3 months

Sub-group analysis was performed by separating exposure 28C (ORIF with plate without bone graft) and 28D (ORIF with plate with bone graft) to assess for any appreciable change in the meta-analysis result for union (Pavlou, Panteliadis et al. 2011).

Union (analysis 1 – excluding 28D)

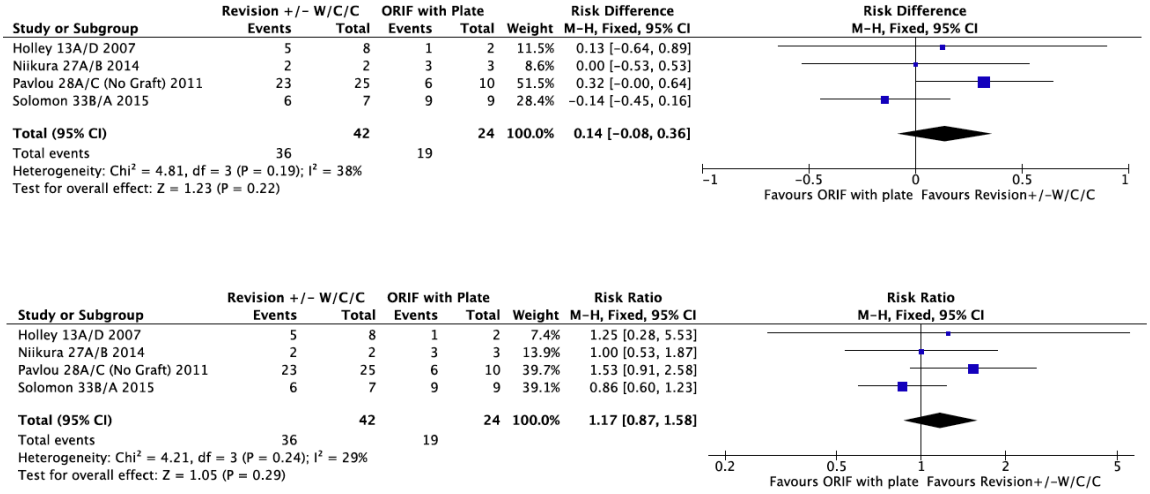


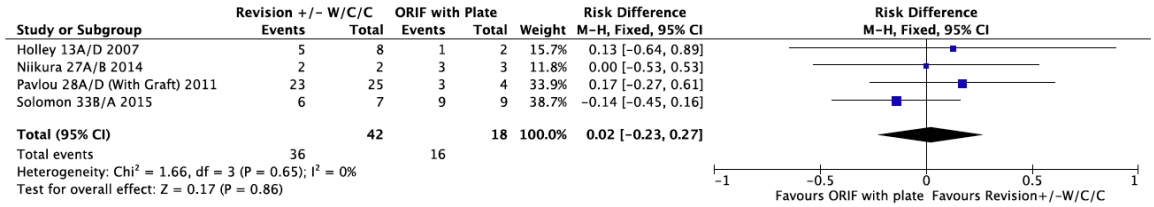
Figure 6 Union (overall) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 6 shows union in the four studies that reported union for 66 patients. Overall, there was no statistically significant difference in the prevalence of union in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

The risk difference for union in the Revision with or without wires/cerclage/cables group was 0.14 (95%CI 0.08 to 0.36) more than the ORIF with plate group. There was no significant heterogeneity (p=0.19), and I^2 indicates there is a moderate degree of heterogeneity between the studies (38%).

The risk ratio for union in the Revision with or without wires/cerclage/cables group was 1.17 (95%CI 0.87 to 1.58) more than the ORIF with plate group. There was no significant heterogeneity (p=0.24), and I^2 indicates there is a moderate degree of heterogeneity between the studies (29%).

Union (analysis 2 – excluding 28C)



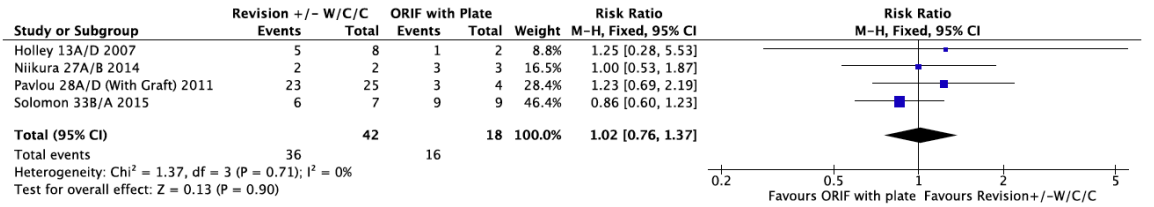


Figure 7 Union (overall) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 7 shows union in the four studies that reported union for 60 patients. Overall, there was no statistically significant difference in the prevalence of union in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

The risk difference for union in the Revision with or without wires/cerclage/cables group was 0.02 (95%CI 0.23 to 0.27) more than the ORIF with plate group. There was no significant heterogeneity (p=0.65), and I^2 indicates there is no important heterogeneity between the studies (0%).

The risk ratio for union in the Revision with or without wires/cerclage/cables group was 1.02 (95%CI 0.76 to 1.37) more than the ORIF with plate group. There was no significant heterogeneity (p=0.71), and I^2 indicates there is no important heterogeneity between the studies (0%).

Time to union

One study compared time to union for Revision with or without wires/cerclage/cables and ORIF with plate. Pavlou and colleagues defined union both radiographically '… cortical continuity on both lateral and AP (antero-posterior) radiographs' and clinically; clinical union '…pain-free weight bearing with or without aid' (Pavlou, Panteliadis et al. 2011). Exposure 28A (n=25) (Pavlou, Panteliadis et al. 2011) with a mean time to union of 4.3 months (SD 1.9) vs 28C (no graft) (n=10) with a mean time to union of 8.8 months (SD 4) (n=10), p-value 0.218 (ANOVA). Exposure 28A (n=25) (Pavlou, Panteliadis et al. 2011) with a mean time to union of 4.3 months (SD 1.9) vs 28D (with graft) (n=4) with a mean time to union of 4.4 months (SD 0.5) (n=4), p-value 0.736 (ANOVA). This comparative analysis would suggest that ORIF with plate and bone graft may neutralise any time advantage revision imparts upon attaining union.

Non-union

One study compared non-union for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 28A (Pavlou, Panteliadis et al. 2011) with a prevalence of 8% (2/25) vs exposure 28C+D with prevalence of 36% (5/14). Pavlou and colleagues defined non-union as 'failure of a fracture to unite 12 months following fixation…'. Furthermore, the study analysed using Odds Ratio (OR); Exposure 28A (n=25) vs 28C (no graft) (n=10) with an OR of 7.7 (95%CI 1.12 to 52.3), p-value 0.038*. Exposure 28A (n=25) vs 28D (with graft) (n=4) with an OR of 3.83 (95%CI 0.26 to 56.2), p-value 0.327

(Pavlou, Panteliadis et al. 2011). This comparative analysis would suggest that ORIF with plate and bone graft may neutralise any advantage Revision imparts upon attaining union.

Femoral osteolysis

One study compared femoral osteolysis for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 33B (n=7) and 33A (n=9), with no events observed in either exposure arm. Femoral osteolysis was defined as a greater than 3mm diameter nonlinear demarcated lesion (recorded for each Gruen zone) (33B), however, no time-frame was stipulated (Solomon, Hussenbocus et al. 2015).

Loss of reduction (fracture)

One study compared loss of reduction (fracture) for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 27A (n=2) and exposure 27B (n=3), with no events observed in either exposure arm (Niikura, Lee et al. 2014). No explicit definition of loss of reduction was reported.

Malunion

One study compared malunion for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 27A (n=2) and 27B (n=3), with no events observed. Malunion was defined by authors as any angular deformity greater than 5° (Niikura, Lee et al. 2014).

Length of stay

One study compared hospital length of stay for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 15A (n=14) with a mean 26 days

(SD 14) and exposure 15B (n=14) with a mean 29 days (SD 16) vs exposure 15C (n=8) with a mean 26 days (SD 13) (Joestl, Hofbauer et al. 2016).

Mortality (overall)

Two studies compared mortality for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 15A+B (n=28) vs 15C (n=8), with no events observed (Joestl, Hofbauer et al. 2016); and exposure 33B vs 33A with a prevalence of 56% (5/9) and 25% (3/12), respectively (Solomon, Hussenbocus et al. 2015). No meta-analysis was possible due to only 33B and 33A having event rates other than zero.

Deep surgical site infection (DSSI)

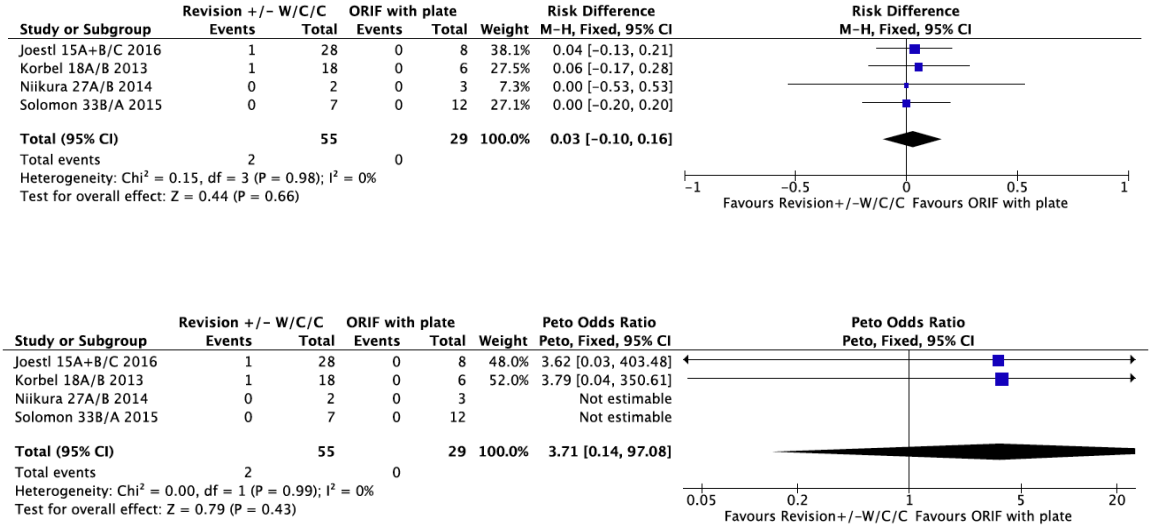


Figure 8 Deep surgical site infection (DSSI) for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 8 shows DSSI in the four studies that reported DSSI for 84 patients. No authors provided a definition for DSSI; only one study (Joestl, Hofbauer et al. 2016) implies aspiration hip joint was performed for diagnosis. The explicit time-frame of

outcome measurement was not reported in any study. Overall, there was no statistically significant difference in the prevalence of DSSI in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference (p=0.66) and OR (p=0.43).

The risk difference for DSSI in the Revision with or without wires/cerclage/cables group was 0.03 (95%CI 0.10 to 0.16) more than the ORIF with plate group. There was no significant heterogeneity (p=0.98), and I^2 indicates there is no important heterogeneity between the studies (0%).

The Peto Odds Ratio for DSSI in the Revision with or without wires/cerclage/cables group was 3.71 (95%CI 0.14 to 97.08) more than the ORIF with plate group. There was no significant heterogeneity (p=0.99), and I^2 indicates there is no important heterogeneity between the studies (0%).

Superficial surgical site infection (SSSI)

Three studies compared SSSI for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 15A+B vs 15A with a prevalence of 3.6% (1/28) and no events observed (0/8) (Joestl, Hofbauer et al. 2016), respectively, exposures 27A (n=2) vs 27B (n=3) (Niikura, Lee et al. 2014), with no events observed and exposures 33B (n=7) vs 33A (n=12) (Solomon, Hussenbocus et al. 2015), with no events observed. No meta-analysis was possible due to only 15A+B having an event rates other than zero (Joestl, Hofbauer et al. 2016).

Dislocation overall (Combined analysis 1 and 2)

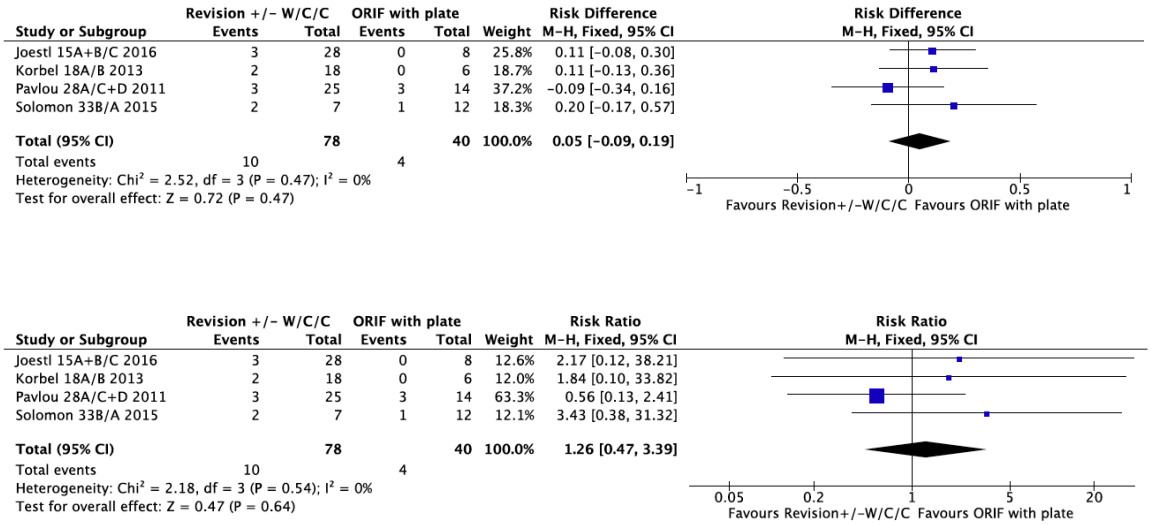


Figure 9 Dislocation for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 9 shows dislocation in the four studies that reported for 118 patients. Only one study (Solomon, Hussenbocus et al. 2015) reported a time period within which dislocation occurred, which was less than 3 months post-operatively. Overall, there was no statistically significant difference in the prevalence of dislocation in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

The risk difference for dislocation in the Revision with or without wires/cerclage/cables group was 0.05 (95%CI 0.09 to 0.19) more than the ORIF with plate group. There was no significant heterogeneity (p=0.47), and I^2 indicates there is no important heterogeneity between the studies (0%).

The risk ratio for dislocation in the Revision with or without wires/cerclage/cables group was 1.26 (95%CI 0.47 to 3.39) more than the ORIF with plate group. There was no

significant heterogeneity (p=0.54), and I^2 indicates there is no important heterogeneity between the studies (0%). Sub-group analysis was performed by separating exposure 28C (ORIF with plate without bone graft) and 28D (ORIF with plate with bone graft) to assess for any appreciable change in the meta-analysis result for dislocation (Pavlou, Panteliadis et al. 2011).

Dislocation Analysis 1 (excluding 28D (with graft))

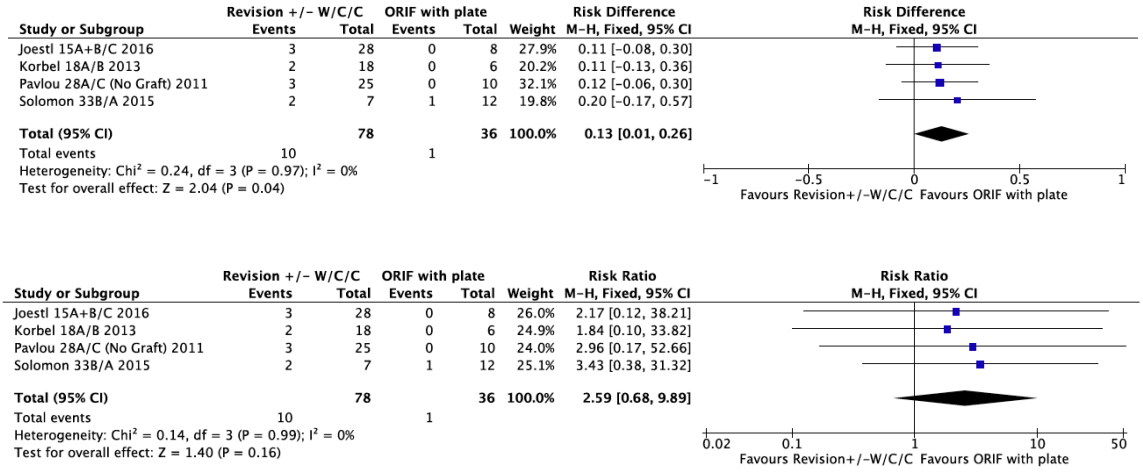


Figure 10 Dislocation for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 10 shows dislocation in the four studies that reported for 114 patients. Overall, there was a statistically significant difference in the prevalence of dislocation in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for risk difference, however, not for risk ratio.

The risk difference for dislocation in the Revision with or without wires/cerclage/cables group was 0.13 (95%CI 0.01 to 0.26) more than the ORIF with

plate group. There was no significant heterogeneity (p=0.97), and I^2 indicates there is no important heterogeneity between the studies (0%).

The risk ratio for dislocation in the Revision with or without wires/cerclage/cables group was 2.59 (95%CI 0.68 to 9.89) more than the ORIF with plate group. There was no significant heterogeneity (p=0.99), and I^2 indicates there is no important heterogeneity between the studies (0%).

Dislocation Analysis 2 (excluding 28C due to no graft (Pavlou, Panteliadis et al. 2011))

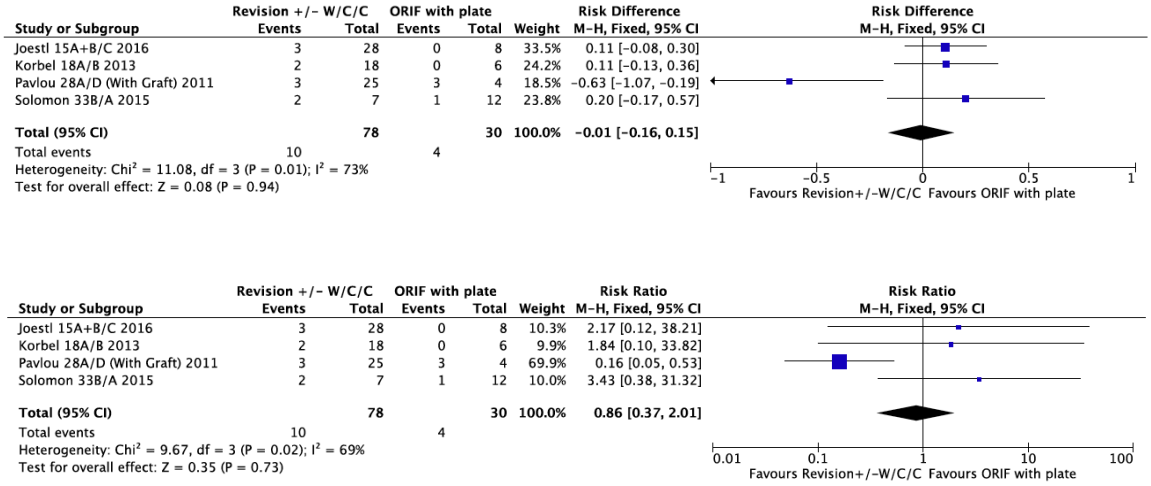


Figure 11 Dislocation for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 11 shows dislocation in the four studies that reported for 108 patients. Overall, there was no statistically significant difference in the prevalence of dislocation in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

The risk difference for dislocation in the Revision with or without wires/cerclage/cables group was -0.01 (95%CI 0.16 to 0.15) less than the ORIF with plate

group. There was significant heterogeneity (p=0.01), and I^2 indicates there is a moderate degree of heterogeneity between the studies (73%).

The risk ratio for dislocation in the Revision with or without wires/cerclage/cables group was 0.86 (95%CI 0.37 to 2.01) less than the ORIF with plate group. There was significant heterogeneity (p=0.02), and I^2 indicates a moderate degree of heterogeneity between the studies (69%).

Re-operation

One study compared re-operation for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 13A vs 13D, with a prevalence of 38% (3/8) and 50% (1/2), respectively (Holley, Zelken et al. 2007). Authors did not provide an explicit definition nor time-frame for re-operation, however, 13A and 13D had a minimum 12 months assessment time-frame (Holley, Zelken et al. 2007).

Parker mobility scores pre and post-operatively

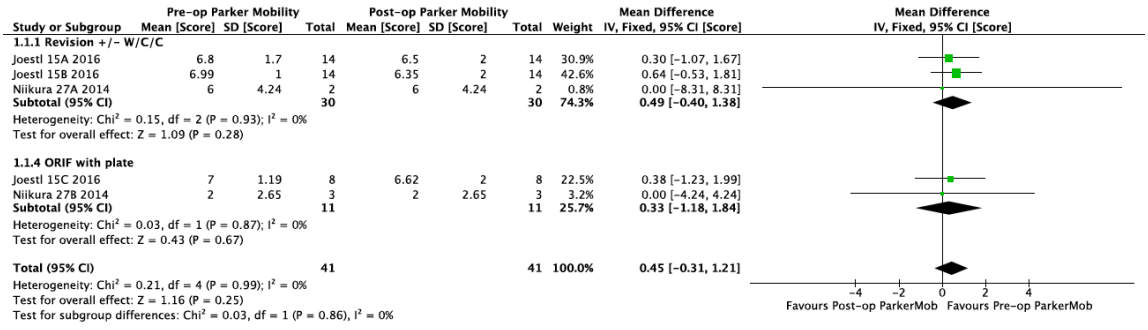


Figure 12 Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 12 shows pre and post-operative Parker mobility scores in the two studies that reported pre and post-operative Parker mobility scores for 41 patients. The time point

pre and post-operatively at which the Parker mobility score was calculated was not explicitly reported in either study.

Overall, there was no statistically significant mean difference in the scores between patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate (p=0.86). The weighted mean difference in the Parker mobility score pre and post-operatively in the Revision with or without wires/cerclage/cables sub-group was 0.49 (95%CI 0.40 to 1.38) points (lower post-operatively) compared with 0.33 (95%CI 1.18 to1.84) points (lower post-operatively) in the ORIF with plate sub-group. There was no significant heterogeneity (p=0.99), and I^2 indicates there is no important heterogeneity between the studies (0%).

Harris hip score (HHS) (post-operative)

One study compared post-operative HHS for Revision with or without wires/cerclage/cables and ORIF with plate, exposure 33B (n=4) vs 33A (n=5), with mean scores of 72 (SD 11.3) and 59 (SD 22.96), respectively. The time point post-operatively at which HHS was calculated was not explicitly reported by study authors (Solomon, Hussenbocus et al. 2015).

Harris hip pain score (post-operative)

One study compared post-operative Harris hip pain score for Revision with or without wires/cerclage/cables vs ORIF with plate, exposure 33B (n=7) vs 33A (n=8), with mean scores of 31.1 (SD 15.18) and 41 (SD 8.4), respectively. The time point post-operatively at which Harris hip pain score was calculated, was not explicitly reported by study authors (Solomon, Hussenbocus et al. 2015).

Attainment of pre-fracture mobility status

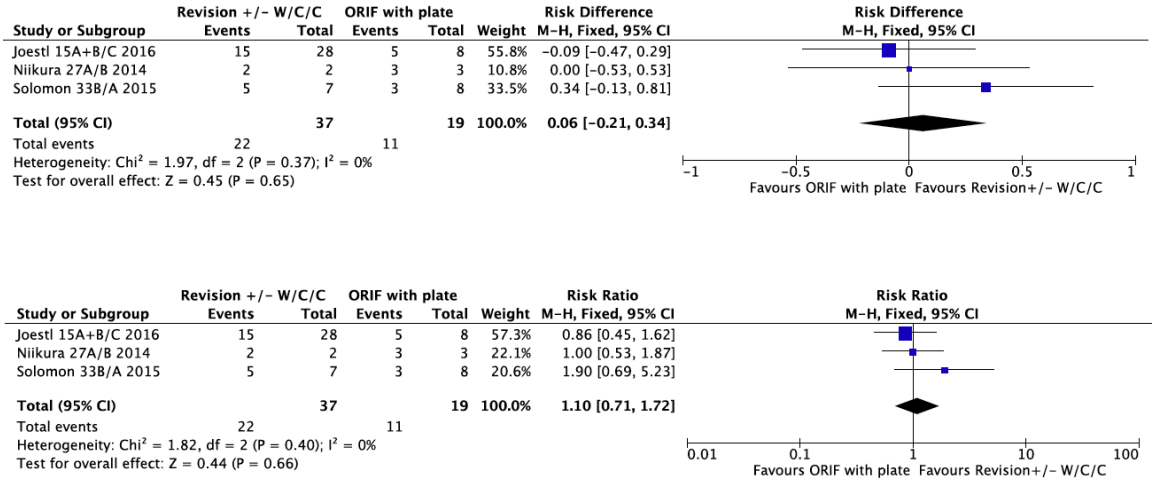


Figure 13 Attainment of pre-fracture mobility status for Revision with or without wires/cerclage/cables vs ORIF with plate.

Figure 13 shows attainment of pre-fracture mobility status in the three studies that reported attainment of pre-fracture mobility status for 56 patients. There was no explicit reporting by authors of how, or at which time point, post-operatively this assessment was made (e.g. clinical or self-reported).

Overall, there was no statistically significant difference in the prevalence of attainment of pre-fracture mobility status in patients treated with Revision with or without wires/cerclage/cables compared with ORIF with plate for both risk difference and risk ratio.

The risk difference for attainment of pre-fracture mobility status in the Revision with or without wires/cerclage/cables group was 0.06 (95%CI 0.21 to 0.34) more than the ORIF with plate group. There was no significant heterogeneity (p=0.37), and I^2 indicates there is no important heterogeneity between the studies (0%).

The risk ratio for attainment of pre-fracture mobility status in the Revision with or without wires/cerclage/cables group was 1.10 (95%CI 0.71 to 1.72) more than the ORIF with plate group. There was no significant heterogeneity (p=0.40), and I^2 indicates there is no important heterogeneity between the studies (0%).

Revision with or without wires/cerclage/cables vs Revision and ORIF with plate

There were two studies (one prospective cohort study and one retrospective cohort study) which investigated outcomes for the interventions of Revision with or without wires/cerclage/cables vs Revision and ORIF with plate (Mukundan, Rayan et al. 2010, Mukka, Mellner et al. 2016).

Union

There were two studies which compared union for Revision with or without wires/cerclage/cables vs Revision and ORIF with plate, exposure 24A with an event rate of 8/8 (100%) vs 24B (Mukka, Mellner et al. 2016) with an event rate of 8/8 (100%) and exposure 25A with an event rate of 19/19 (100%) vs 25B with an event rate of 8/8 (100%) (Mukundan, Rayan et al. 2010).

Revision and ORIF with plate vs ORIF with plate

There was one study (retrospective case series) which investigated outcomes for the interventions of Revision and ORIF with plate vs ORIF with plate (Lunebourg, Mouhsine et al. 2015).

Surgical time

One study compared surgical time for Revision and ORIF with plate and ORIF with plate, exposure 21B (n=7) vs exposure 21A (n=16), with a mean surgical time of 209

minutes (SD 41) and 122 minutes (SD 26), respectively (Lunebourg, Mouhsine et al. 2015). Authors referred to the outcome as operative time (accepted as surgical time) and this was defined as the time from the incision to the dressing of the surgical wound, as documented on the anaesthetic chart.

Malunion

One study compared malunion for Revision and ORIF with plate and ORIF with plate, exposure 21B (n=7) vs ORIF with plate, exposure 21A (n=16), with no events observed in either exposure group (Lunebourg, Mouhsine et al. 2015).

Revision any method vs ORIF any method

There were eleven studies (six retrospective cohort studies, one prospective cohort study and four case series) which investigated various outcomes for the intervention of Revision any method vs ORIF any method.

Surgical Time

Two meta-analyses were performed as the Revision with or without wires/cerclage/cable exposures 15A and 15B could not be combined without duplicating exposure 15C's data (Joestl, Hofbauer et al. 2016) Both analyses generate a similar result (see below).

Surgical time (analysis 1)

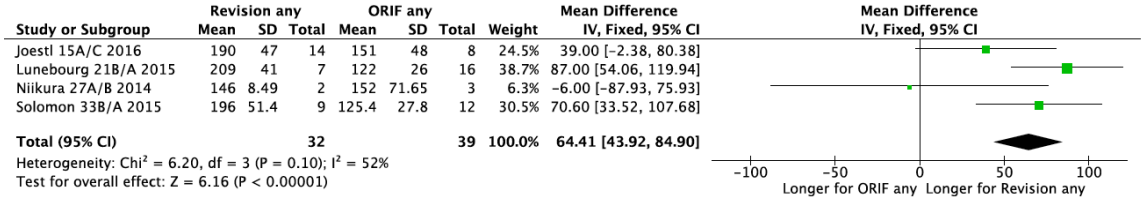


Figure 14 Surgical time (minutes) for Revision any vs ORIF any.

Figure 14 shows the surgical time of the exposure in the four studies that reported surgical time for 71 patients. Mean surgical time is in minutes. None of the studies explicitly defined surgical time and they referred to the outcome as either 'surgical duration', 'operative time', 'operation time' or 'skin-to-skin surgical time', all of which were accepted to mean surgical time for the purposes of this meta-analysis. In this context, the most meaningful reporting for surgical time would be 'skin-to-skin' surgical time as it represents the operative time from incision to the dressing of the surgical wound, which most accurately reflects time spent performing each surgical management strategy.

Overall, there was a statistically significant difference in the surgical time between patients treated with Revision any compared with ORIF any. The weighted mean difference in surgical time in the Revision any group was 64.4 minutes (95%CI 43.9 to 84.9) longer than the ORIF any. There was no significant heterogeneity (p=0.10), and I^2 indicates there is a moderate degree of heterogeneity between the studies (52%).

Surgical time (analysis 2)

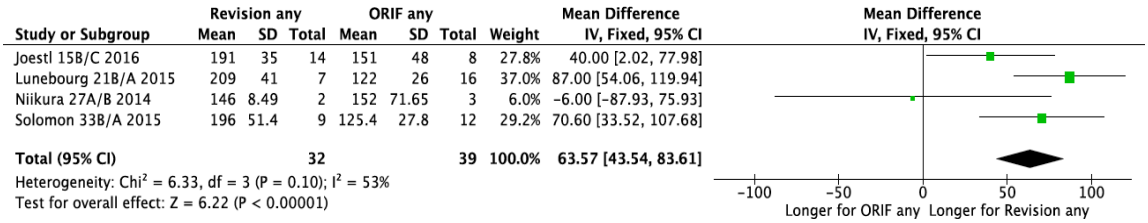


Figure 15 Surgical time (minutes) for Revision any vs ORIF any.

Figure 15 shows the surgical time of the exposure in the four studies that reported surgical time for 71 patients. Mean surgical time is in minutes.

Overall, there was a statistically significant difference in the surgical time between patients treated with Revision any compared with ORIF any. The weighted mean difference in surgical time in the Revision any group was 63.6 minutes (95%CI 43.5 to 83.6) longer than the ORIF any. There was no significant heterogeneity (p=0.10), and I^2 indicates there is a moderate degree of heterogeneity between the studies (53%).

Union (overall)

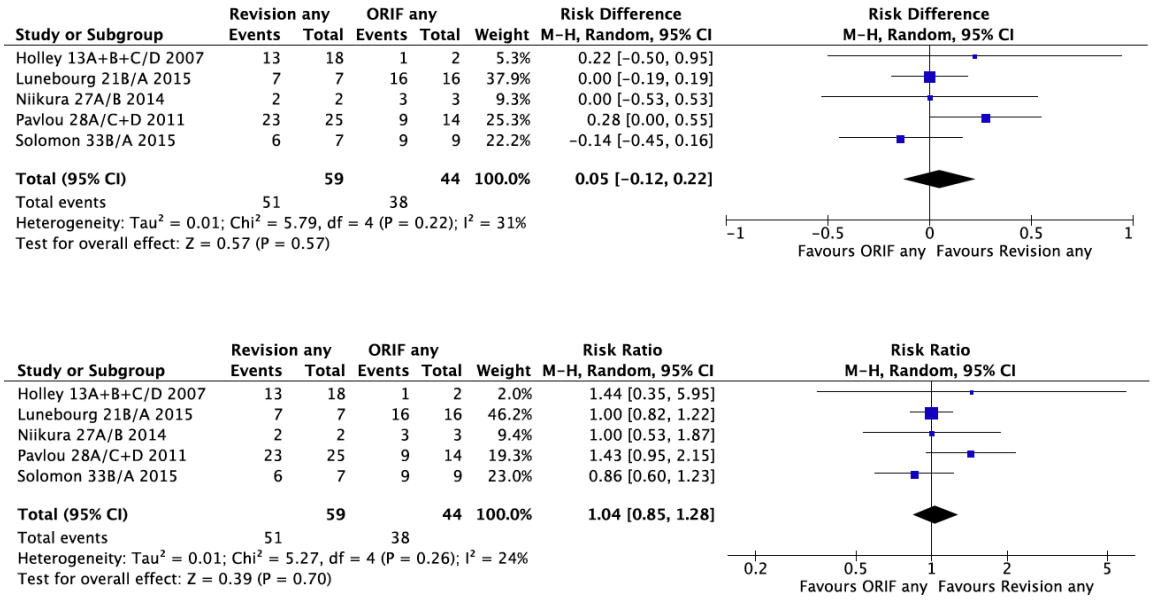


Figure 16 Union (overall) for Revision any vs ORIF any.

Figure 16 shows union in the five studies that reported union for 103 patients. Less than half of the studies (2/5) explicitly defined union and it was assessed radiographically alone in the majority (4/5) of studies. Only 20% (1/5) of the studies provided a time to union (Table 8).

Overall, there was no statistically significant difference in the prevalence of union in patients treated with Revision any with ORIF any, for both risk difference and risk ratio.

The risk difference for union in the Revision any group was 0.05 (95%CI 0.12 to 0.22) more than the ORIF with plate group. There was no significant heterogeneity (p=0.22), and I^2 indicates there is a moderate degree of heterogeneity between the studies (31%).

The risk ratio for union in the Revision any group was 1.04 (95%CI 0.85 to 1.28) more than the ORIF with plate group. There was no significant heterogeneity (p=0.26), and I^2 indicates there is a low degree of heterogeneity between the studies (24%).

Table 8 Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
13A (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment mean 34 months (Range 12-100, No SD reported)
13D (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment Mean 69.5 months (Range 57-82, No SD reported)
21A (Lunebourg, Mouhsine et al. 2015)	Union, N/S	Plain film radiographs	N/S (Note: worst case by 4 months) Pooled mean observation 42 months (SD 20, 16-90)
21B (Lunebourg, Mouhsine et al. 2015)	Union, N/S	Radiographs	N/S (Note: worst case by 4 months) Pooled mean observation 42 months (SD 20, 16-90)
27A (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))
27B (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))
28A (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean 5 months (SD 2.2, Range NS)
28C/D (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean C: 8.8 (SD 4.0, Range NS) D: 4.4 (SD 0.51, Range NS)

Table 8 (cont.) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
33B (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 59 months (16-137) – excludes 2 deaths <3 months))
33A (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 67 months (13-82) – excludes 3 deaths <3 months

Mortality (overall at final follow-up)

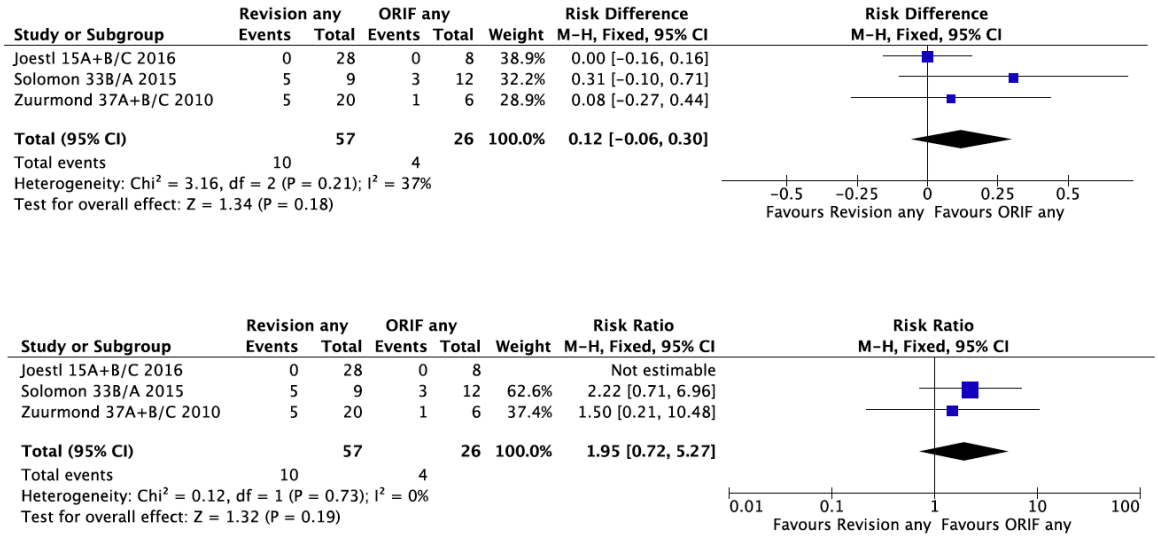


Figure 17 Mortality (overall at final follow-up) for Revision any vs ORIF any.

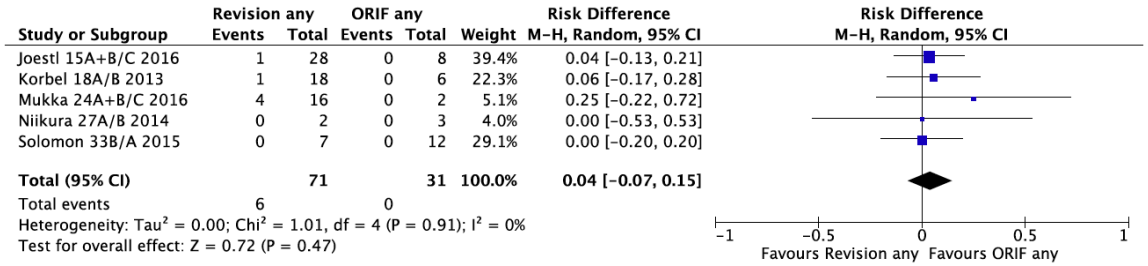
Figure 17 shows mortality in the three studies that reported mortality for 83 patients. Overall, the time-frame for assessment of outcome was similar across all three studies, and up to around ten years.

Overall, there was no statistically significant difference in the prevalence of mortality in patients treated with Revision any compared with ORIF any, for both risk difference and risk ratio.

The risk difference for mortality in the Revision any group was 0.12 (95%CI 0.06 to 0.30) more than the ORIF any, group. There was no significant heterogeneity (p=0.21), and I^2 indicates there was a moderated degree of heterogeneity between the studies (37%).

The risk ratio for mortality in the Revision any group was 1.95 (95%CI 0.72 to 5.27) more than the ORIF any group. There was no significant heterogeneity (p=0.73), and I^2 indicates there is no important heterogeneity between the studies (0%).

Deep surgical site infection



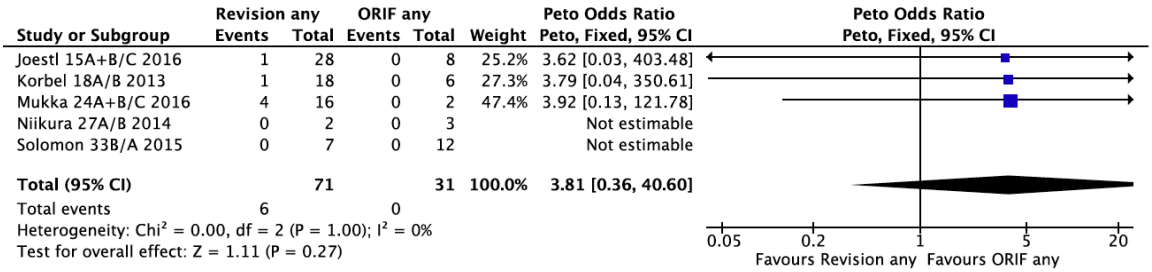


Figure 18 Deep surgical site infection (DSSI) for Revision any vs ORIF any.

Figure 18 shows DSSI in the four studies that reported DSSI for 84 patients. No authors provided a definition for DSSI, however, one study (Joestl, Hofbauer et al. 2016) implies aspiration hip joint was performed for diagnosis. The explicit time-frame of outcome measurement was not reported in any study.

Overall, there was no statistically significant difference in the prevalence of DSSI in patients treated with Revision any compared with ORIF any, for both risk difference and OR.

The risk difference for DSSI in the Revision any group was 0.04 (95%CI 0.07 to 0.15) more than the ORIF any group. There was no significant heterogeneity (p=0.91), and I^2 indicates there is no important heterogeneity between the studies (0%).

The Peto Odds Ratio for DSSI in the Revision any group was 3.81 (95%CI 0.36 to 40.60) more than the ORIF any group. There was no significant heterogeneity (p=1.00), and I^2 indicates there is no important heterogeneity between the studies (0%).

Superficial surgical site infection

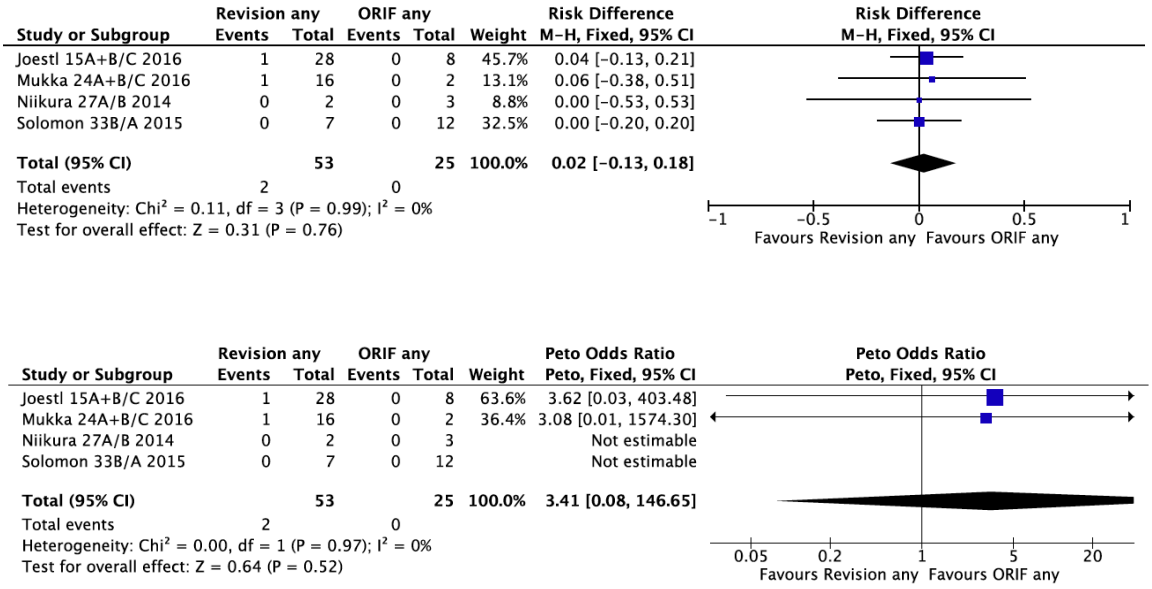


Figure 19 Superficial surgical site infection (SSSI) for Revision any vs ORIF any.

Figure 19 shows SSSI in the four studies that reported SSSI for 78 patients. No authors provided a definition for SSSI. The explicit time-frame of outcome measurement was not reported in any study.

Overall, there was no statistically significant difference in the prevalence of SSSI in patients treated with Revision any compared with ORIF any for both risk difference and OR.

The risk difference for SSSI in the Revision any group was 0.02 (95%CI 0.13 to 0.18) more than the ORIF any group. There was no significant heterogeneity (p=0.99), and I^2 indicates there is no important heterogeneity between the studies (0%).

The Peto Odds Ratio for SSSI in the Revision any group was 3.41 (95%CI 0.08 to 146.7) more than the ORIF any group. There was no significant heterogeneity (p=0.97), and I^2 indicates there is no important heterogeneity between the studies (0%).

Re-operation

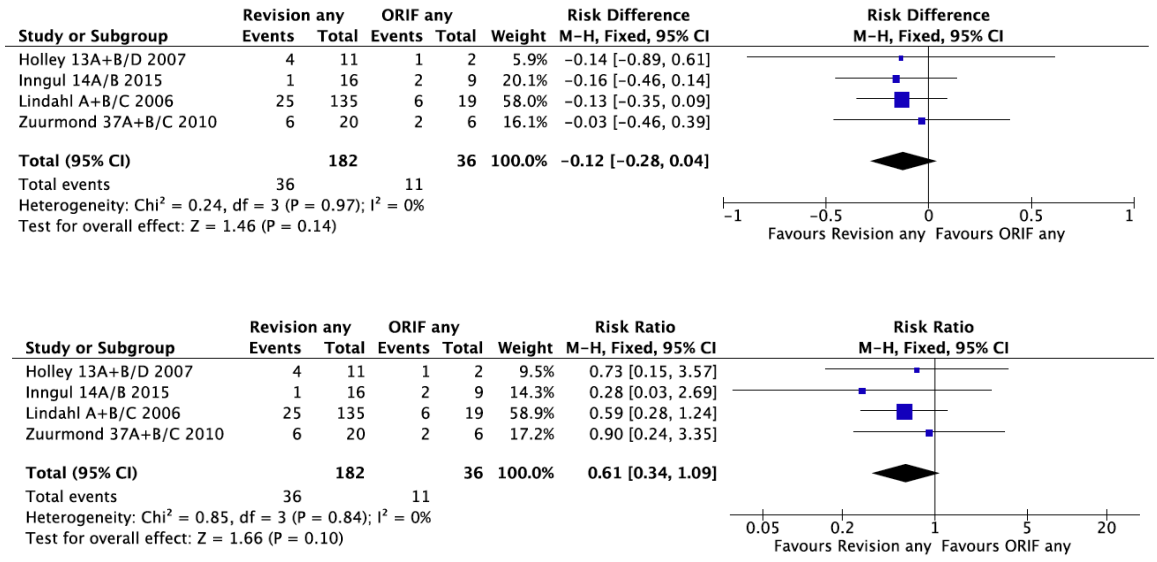


Figure 20 Re-operation for Revision any vs ORIF any.

Figure 20 shows Re-operation in the four studies that reported re-operation for 218 patients. No authors provided an explicit definition nor a time-frame for re-operation. The overall assessment period was similar across studies and up to around 12 years.

Overall, there was no statistically significant difference in the incidence of re-operation in patients treated with Revision any compared with ORIF any for both risk difference and risk ratio.

The risk difference for re-operation in the Revision any group was -0.12 (95%CI 0.28 to 0.04) less than the ORIF any group. There was no significant heterogeneity (p=0.97), and I^2 indicates there is no important heterogeneity between the studies (0%).

The risk ratio for union in the Revision any group was 0.61 (95%CI 0.34 to 1.09) less than the ORIF any group. There was no significant heterogeneity (p=0.84), and I^2 indicates there is no important heterogeneity between the studies (0%).

There was a trend towards Revision being protective against re-operation but this was not statistically significant.

Single study

This section presents results for outcomes for individual interventions under study. It is structured according to the intervention and outcomes.

Revision with or without wires/cerclage/cables

There were 24 studies (15 case series, 8 retrospective cohort studies and one prospective cohort study) which investigated outcomes associated with Revision with or without wires/cerclage/cables.

Surgical time

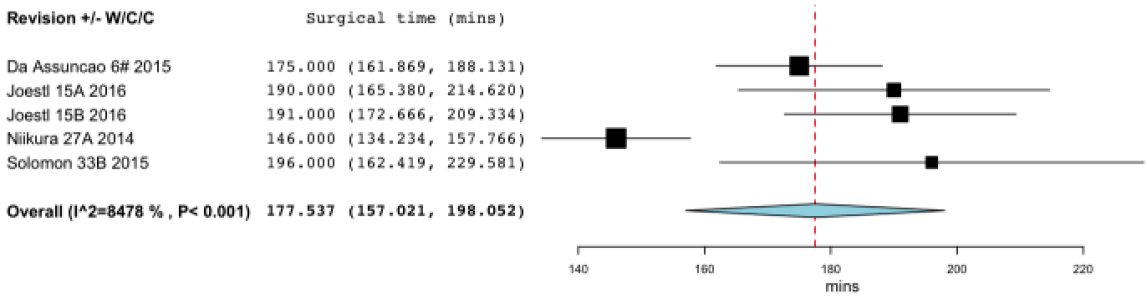


Figure 21 Surgical time (minutes) for Revision with or without wires/cerclage/cables.

Figure 21 shows the meta-analysis for the four studies (n=70) that reported surgical time for the exposure of interest. None of the studies explicitly defined surgical time and refer to the outcome as either ‘surgical time’ (Da Assunção, Pollard et al. 2015), ‘surgical duration’ (Joestl, Hofbauer et al. 2016), ‘operation time’ (Niikura, Sakurai et al. 2014) or ‘skin-to-skin surgical time’ (Solomon, Hussenbocus et al. 2015). In this context, the most meaningful reporting for surgical time would be ‘skin-to-skin’ surgical time as it represents the operative time from incision to the dressing of the surgical wound, which most accurately reflects time spent performing each surgical management strategy (i.e. Revision with or without wires/cerclage/cables).

Overall, the mean surgical time was 177.5 minutes (95%CI 157.0 to 198.0). There was a high degree of heterogeneity between the studies (I^2 = 84.8%).

Blood loss (intra-operative)

One study reported intra-operative blood loss for Revision with or without wires/cerclage/cables, exposure 27A (n=2) (Niikura, Sakurai et al. 2014) with a mean intra-operative blood loss of 1502 mL (535.0 to 2470.0).

Transfusion packed red blood cell (PRBC) requirement (units)

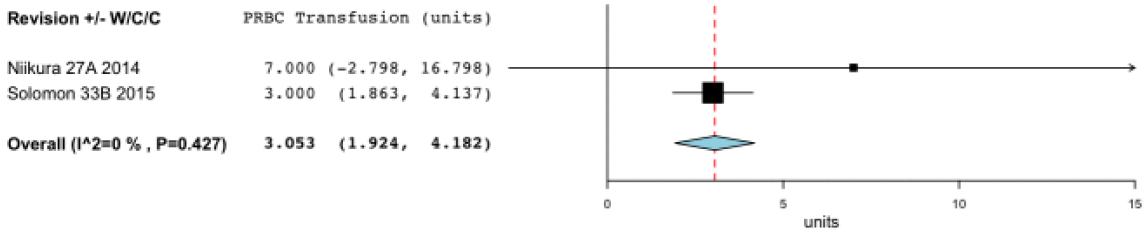


Figure 22 Transfusion packed red blood cell (PRBC) requirement for Revision with or without wires/cerclage/cables.

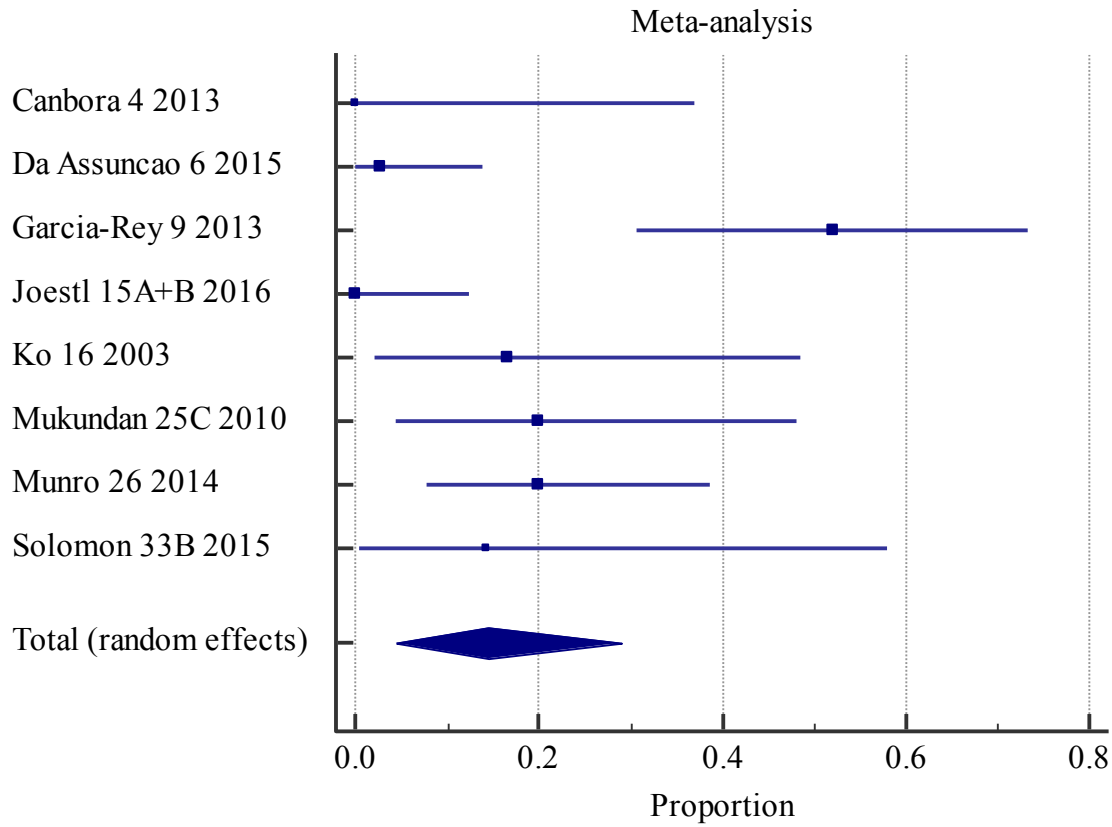
Figure 22 shows the meta-analysis for the outcome transfusion packed red blood cell (TPRBC), which was assessed by 2 studies including a total of 11 patients (Niikura, Sakurai et al. 2014, Solomon, Hussenbocus et al. 2015). The studies refer to the outcome as either ‘intra-operative transfusion’ (Niikura, Sakurai et al. 2014) or ‘peri-operative transfusion’ (Solomon, Hussenbocus et al. 2015), both of which were accepted as peri-operative transfusion PRBC requirement. Overall, the mean transfusion requirement was 3.1 units (95%CI 1.9 to 4.2). There was no important heterogeneity between the studies (I^2 = 0%).

Studies not included in the meta-analysis: Da Assunção and colleagues reported on transfusion packed red blood cell (PRBC) requirement, however, unfortunately did not include the standard deviation or range, and hence was excluded from this meta-analysis (Da Assunção, Pollard et al. 2015).

Transfusion PRBC (1 or more units required within 48 hours of surgery)

One study reported Transfusion PRBC requirement within 48 hours of surgery for Revision with or without wires/cerclage/cables, exposure 15A+B with a prevalence of 64% (18/28) (Joestl, Hofbauer et al. 2016).

Subsidence (any)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	0.000	0.000 to 36.942	5.33	10.45
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	23.08	14.33
Garcia-Rey 9 2013	23	52.174	30.588 to 73.180	14.20	13.40
Joestl 15A+B 2016	28	0.000	0.000 to 12.344	17.16	13.80
Ko 16 2003	12	16.667	2.086 to 48.414	7.69	11.72
Mukundan 25C 2010	15	20.000	4.331 to 48.089	9.47	12.35
Munro 26 2014	30	20.000	7.714 to 38.567	18.34	13.93
Solomon 33B 2015	7	14.286	0.361 to 57.872	4.73	10.01
Total (fixed effects)	161	13.306	8.577 to 19.372	100.00	100.00
Total (random effects)	161	14.460	4.434 to 28.939	100.00	100.00

Test for heterogeneity

Q	36.1292
DF	7
Significance level	P < 0.0001
I^2 (inconsistency)	80.63%
95% CI for I^2	62.62 to 89.96

Figure 23 Subsidence (any) for Revision with or without wires/cerclage/cables.

Figure 23 shows the meta-analysis for the eight studies (n=161) that reported subsidence for the exposure of interest. The terms stem subsidence (7/8 studies) and stem migration (1/8 studies) were accepted as subsidence for the purposes of this meta-analysis. Definition of subsidence was provided in almost all studies (7/8 studies), however, only just over half (5/8 studies) explicitly reported their method for measuring subsidence (Table 9).

Overall, the prevalence of subsidence was 14.5% (95%CI 4.4 to 28.9). There was a high degree of heterogeneity between the studies (I^2 = 80.6%).

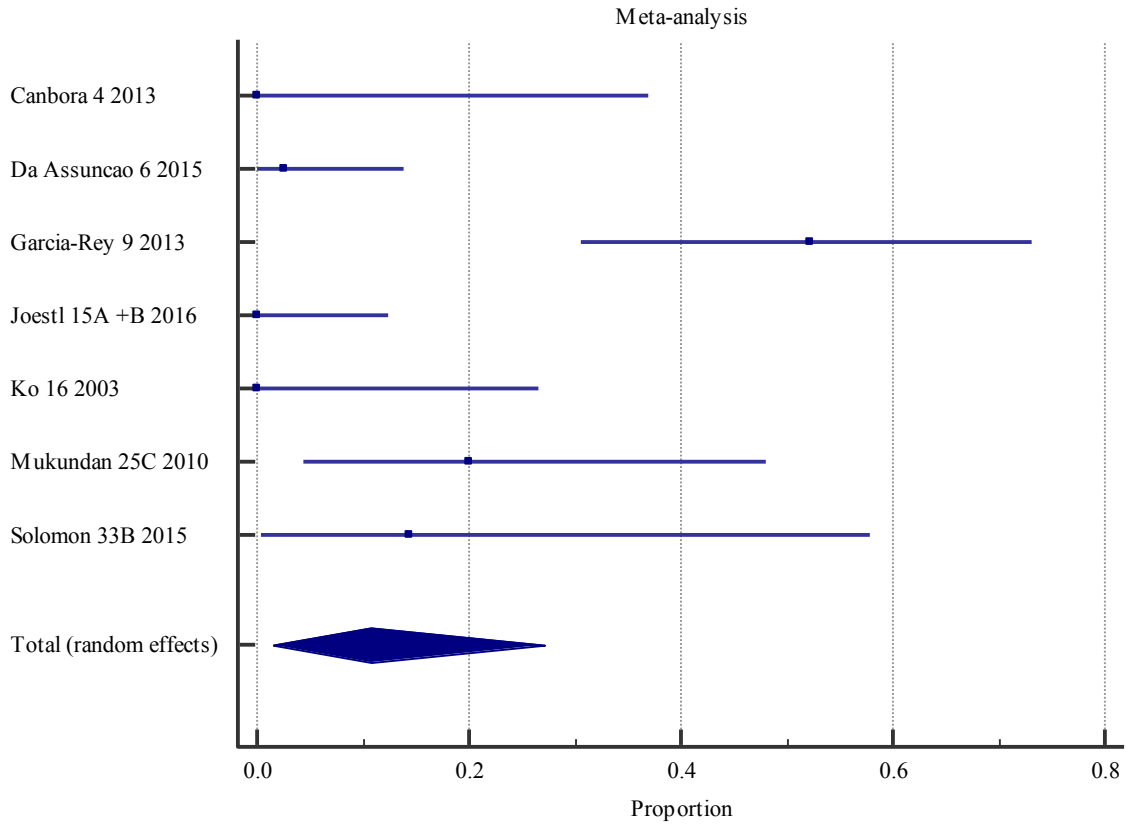
Table 9 Definition of outcomes.

Study	Definition	Method of measurement	TimeframeTime-frame of outcome assessment
4 (Canbora, Kose et al. 2013)	Subsidence, >5mm	"'Stem measured from shoulder prostheses to most medial point of lesser troch, where LT not present or visible used tip of GT or cerclage wire as marker"'	Mean 39 months (Range 15-90, SD not reported)
6 (Da Assunção, Pollard et al. 2015)	Union, 'Radiological subsidence was assessed on a digital Patient Archiving and Communication system, after calibrating the radiographic scale using the known diameter of the prosthetic femoral head.' 'The amount of subsidence was agreed by consensus between two experienced observers (AT and REdA) and was considered significant if > 5 mm.'	Plain film radiographs	At final follow-up (Note: time-frame of outcome assessment between 4 and 66 months)
9 (Garcia-Rey, Garcia-Cimbrelo et al. 2013)	Subsidence, >9mm	'… measuring the vertical subsidence of the femoral stem according to the Callaghan et al. method (1985)'	Pooled mean - 99.6 months (SD 42#, 36-204)
15A/15B (Joestl, Hofbauer et al. 2016)	Stem migration, No distance specified	N/S '…clinical and radiographic assessment'	15A: Range 10-103 months (SD not reported) 15B: Range 9-27 months (SD not reported)
16 (Ko, Lam et al. 2003)	Stem subsidence, >5mm	N/S 'Weekly radiographic assessment'	Minimum 3 years (no maximum reported)

Table 9 (cont.) Definition of outcomes.

Study	Definition	Method of measurement	Time-frame of outcome assessment
25C (Mukundan, Rayan et al. 2010)	Stem subsidence, requiring revision surgery	N/S '…radiographic assessment'	Minimum 2 years (no maximum reported)
26 (Munro, Garbuz et al. 2014)	Subsidence, Distance sub-categorisation not specified for 5/6 B2s) 1/6 >10mm subsidence needing revision	'…measured as movement relative to anatomic landmarks and checked against wires or cables.' (radiographic assessment)	Pooled mean observation 54 months (29.8#, 24-143)
33 (Solomon, Hussenbocus et al. 2015)	Stem subsidence >5mm	Manual measurements: 'Stem subsidence (is) measured using the width of radio-lucent lines present at the stem cement (sc) interface in Gruen zone 1 parallel to the stem long axis on plain film radiographs' and Computer based method of Ein-Bild-Roentegn-Analyse (EBRA)	Overall: median 59 months (16-137) – excludes 2 deaths <3 months

Subsidence (>5mm or requiring revision)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	0.000	0.000 to 36.942	6.52	12.52
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	28.26	16.20
Garcia-Rey 9 2013	23	52.174	30.588 to 73.180	17.39	15.35
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	21.01	15.72
Ko 16 2003	12	0.000	0.000 to 26.465	9.42	13.77
Mukundan 25C 2010	15	20.000	4.331 to 48.089	11.59	14.37
Solomon 33B 2015	7	14.286	0.361 to 57.872	5.80	12.07
Total (fixed effects)	131	9.963	5.520 to 16.219	100.00	100.00
Total (random effects)	131	10.736	1.462 to 27.004	100.00	100.00

Test for heterogeneity

Q	35.8305
DF	6
Significance level	P < 0.0001
I^2 (inconsistency)	83.25%
95% CI for I^2	66.94 to 91.52

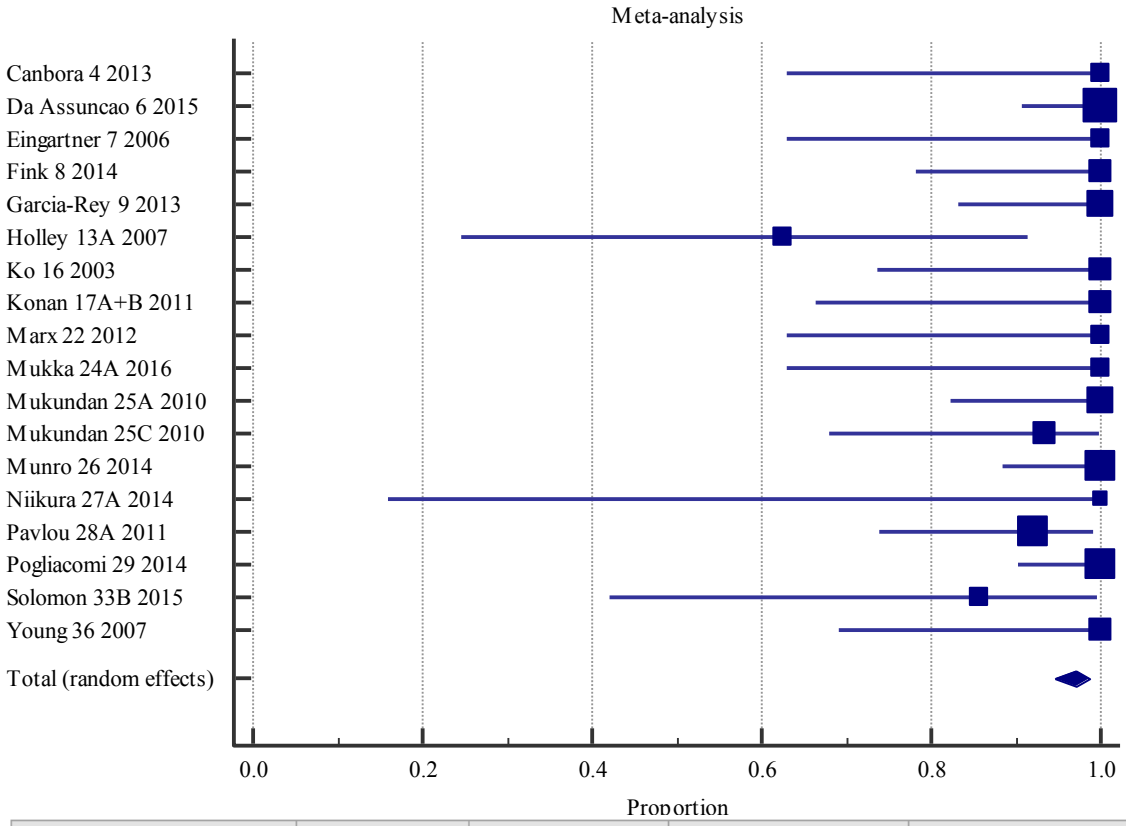
Figure 24 Subsidence (>5mm OR requiring revision) for Revision with or without wires/cerclage/cables.

Figure 24 shows the meta-analysis for the seven studies (n=131) that reported subsidence for the exposure of interest.

Overall, the prevalence of subsidence >5mm or requiring Revision was 10.7% (95%CI 1.4 to 27.0). There was a high degree of heterogeneity between the studies (I^2 = 83.3%).

Studies not included in the meta-analysis: Munro and colleagues reported on subsidence, however, unfortunately did not include the distance of subsidence amongst the B2 PFF patient group, and hence was excluded from this meta-analysis (Munro, Garbuz et al. 2014).

Union (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	100.000	63.058 to 100.000	3.04	3.31
Da Assuncao 6 2015	38	100.000	90.749 to 100.000	13.18	11.92
Eingartner 7 2006	8	100.000	63.058 to 100.000	3.04	3.31
Fink 8 2014	15	100.000	78.198 to 100.000	5.41	5.62
Garcia-Rey 9 2013	20	100.000	83.157 to 100.000	7.09	7.14
Holley 13A 2007	8	62.500	24.486 to 91.477	3.04	3.31
Ko 16 2003	12	100.000	73.535 to 100.000	4.39	4.65
Konan 17A+B 2011	9	100.000	66.373 to 100.000	3.38	3.65
Marx 22 2012	8	100.000	63.058 to 100.000	3.04	3.31
Mukka 24A 2016	8	100.000	63.058 to 100.000	3.04	3.31
Mukundan 25A 2010	19	100.000	82.353 to 100.000	6.76	6.84
Mukundan 25C 2010	15	93.333	68.052 to 99.831	5.41	5.62
Munro 26 2014	30	100.000	88.430 to 100.000	10.47	9.92
Niikura 27A 2014	2	100.000	15.811 to 100.000	1.01	1.15
Pavlou 28A 2011	25	92.000	73.969 to 99.016	8.78	8.57
Pogliacomi 29 2014	36	100.000	90.261 to 100.000	12.50	11.43
Solomon 33B 2015	7	85.714	42.128 to 99.639	2.70	2.96
Young 36 2007	10	100.000	69.150 to 100.000	3.72	3.99
Total (fixed effects)	278	97.129	94.525 to 98.714	100.00	100.00
Total (random effects)	278	96.980	94.533 to 98.720	100.00	100.00

Test for heterogeneity

Q	18.9686
DF	17
Significance level	P = 0.3303
I^2 (inconsistency)	10.38%
95% CI for I^2	0.00 to 46.60

Figure 25 Union (overall) for Revision with or without wires/cerclage/cables.

Figure 25 shows the meta-analysis for the seventeen studies (n=278) that reported union (overall) for revision with or without wires/cerclage/cables. Just over half of the studies (10/18) explicitly defined union and it was generally defined as the presence of a bridging callus across the main fracture site on a minimum of two or three sides viewed in two views on plain film radiographs. Some studies (3/18) additionally considered clinical union, for example, the patient being able to fully weight bear without pain, and lacked pain on clinical stressing of fracture site (Garcia-Rey, Garcia-Cimbrelo et al. 2013). The time to union was reported in half of the studies (9/18) (Table 9). Overall, the prevalence of union was 97.0% (95%CI 94.5 to 98.7). There was a low degree of heterogeneity between the studies (I^2 = 10.4%).

Table 9 Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
4 (Canbora, Kose et al. 2013)	Union, 'union defined as bony bridging across osteotomy site or no migration of fracture fragment.'	Plain film radiographs	N/S (Note: time-frame of outcome assessment mean 39 months (Range 15-90, SD not reported))
6 (Da Assunção, Pollard et al. 2015)	Union, 'Radiological union … presence of bridging callus across main fracture site in two orthogonal planes as judged by two experienced consultants'	Plain film radiographs	N/S (Note: time-frame of outcome assessment between 4 and 66 months)
7 (Eingartner, Volkmann et al. 2006)	Union, '…complete osseous consolidation of fracture'	Plain film radiographs	Mean 5.6 months (SD 2#, 3-11)
8 (Fink, Urbansky et al. 2014)	Union, N/S	Plain film radiographs	Mean 3.6 months (SD 1.3, No range given)
9 (Garcia-Rey, Garcia-Cimbrelo et al. 2013)	Union, 'patient was bearing full weight without pain, lacked pain on clinical stressing of fracture site and radiographic evidence of callus bridging the fracture' (on two views in this paper)	Clinical and plain film radiographs	Mean 5 months (Range 3-8, No SD reported)
13A (Holley, Zelken et al. 2007)Holley	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment mean 34 months (Range 12-100, No SD reported)
16 (Ko, Lam et al. 2003)	Union, 'Fracture healing was judged by full pain-free weight-bearing ability, lack of pain on clinical stressing at the fracture site, and radiographic evidence of callus bridging the fractures'	Plain film radiographs	Mean 14.5 weeks (Range 12-16, No SD reported)

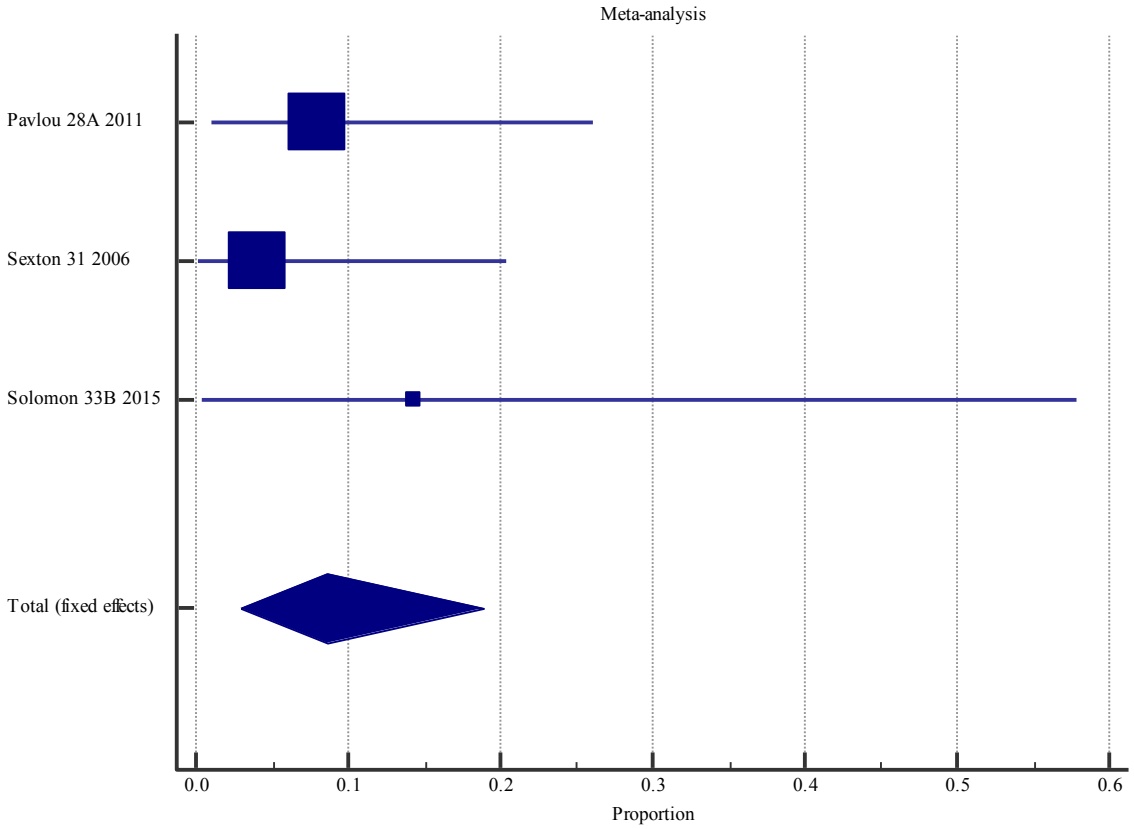
Table 9 (cont,) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
17A (Konan, Rayan et al. 2011)	Union, N/S	N/S '… patients were followed up clinically and radiologically.'	Mean 5.2 months (Range 3-6, No SD reported)
22 (Marx, Beier et al. 2012)	Union, N/S	Post-operative radiographs	N/S (Note: Time-frame of outcomes assessment: Mean 74 months (No SD or range reported))
24 (Mukka, Mellner et al. 2016)	Union, N/S	Plain film radiographs	N/S Follow up mean in months: 24 (Range 20-1823 days, No SD stated)
25A/25C (Mukundan, Rayan et al. 2010)	Union, 'Fractures were considered to be united clinically when the patient could fully weight bear with no pain' and absence of non-union on plain film radiographs	Clinical and plain film radiographs	N/S (Note: time-frame of outcomes assessment: Minimum 2 years (no maximum reported))
26 (Munro, Garbuz et al. 2014)	Union, 'Femoral union was defined as bone bridging across the fracture site on three of four cortices.'	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled mean observation 54 months (29.8#, 24-143))
27A (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))

Table 9 (cont,) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
28A (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean 5 months (SD 2.2, Range NS)
29 (Pogliacomi, Corsini et al. 2014)	Union, N/S	Plain film radiographs	N/S specific to B2s Note: Pooled mean 4.5 months (Range 3-8 months (SD N/S)
33B (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 59 months (16-137) – excludes 2 deaths <3 months))
36 Young (Young, Pandit et al. 2007)	Union, N/S	Plain film radiographs	Mean 4.5 months (No SD or Range reported)

Non-union



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Pavlou 28A 2011	25	8.000	0.984 to 26.031	43.33	43.33
Sexton 31 2006	25	4.000	0.101 to 20.352	43.33	43.33
Solomon 33B 2015	7	14.286	0.361 to 57.872	13.33	13.33
Total (fixed effects)	57	8.657	2.949 to 18.802	100.00	100.00
Total (random effects)	57	8.657	2.934 to 17.013	100.00	100.00

Test for heterogeneity

Q	1.0533
DF	2
Significance level	P = 0.5906
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 93.63

Figure 26 Non-union (overall) for Revision with or without wires/cerclage/cables.

Figure 26 shows the meta-analysis for the three studies (n=57) that reported non-union for Revision with or without wires/cerclage/cables. Non-union was defined by two

studies (Sexton, Stossel et al. 2006, Pavlou, Panteliadis et al. 2011) as failure to unite by 12 months post-operatively, it was not explicitly defined in the third study, however, it was interpreted as failure to unite (Pavlou, Panteliadis et al. 2011). Overall, the prevalence of non-union was 8.7% (95%CI 2.9 to 17.0). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Osseointegration (ingrowth fixation stem)

Three studies reported osseointegration for Revision with or without wires/cerclage/cables, exposure 9, 16 and 29, with a prevalence of 100% (20/20), 100% (12/12) and 100% (36/36), respectively. Importantly, only one study (Garcia-Rey, Garcia-Cimbrelo et al. 2013) provided an explicit definition; '…Femoral component fixation radiographic ingrowth, fibrous stable, or unstable according to criteria for porous prosthesis as described by (Engh, Glassman et al. 1990).

Femoral osteolysis

One study reported femoral osteolysis for Revision with or without wires/cerclage/cables, exposure 33B, with a prevalence of 0% (0/7). Femoral osteolysis was defined as a greater than 3mm diameter nonlinear demarcated lesion (recorded for each Gruen zone), however, no time-frame was stipulated (Solomon, Hussenbocus et al. 2015).

Malrotation

One study reported malrotation for Revision with or without wires/cerclage/cables, exposure 16 (Ko, Lam et al. 2003), with a prevalence of 0% (0/12). No explicit definition of malrotation was reported.

Loss of reduction (fracture)

One study reported loss of reduction (fracture) for Revision with or without wires/cerclage/cables, exposure 27A (Niikura, Sakurai et al. 2014), with a prevalence of 0% (0/2). No explicit definition of loss of reduction was reported.

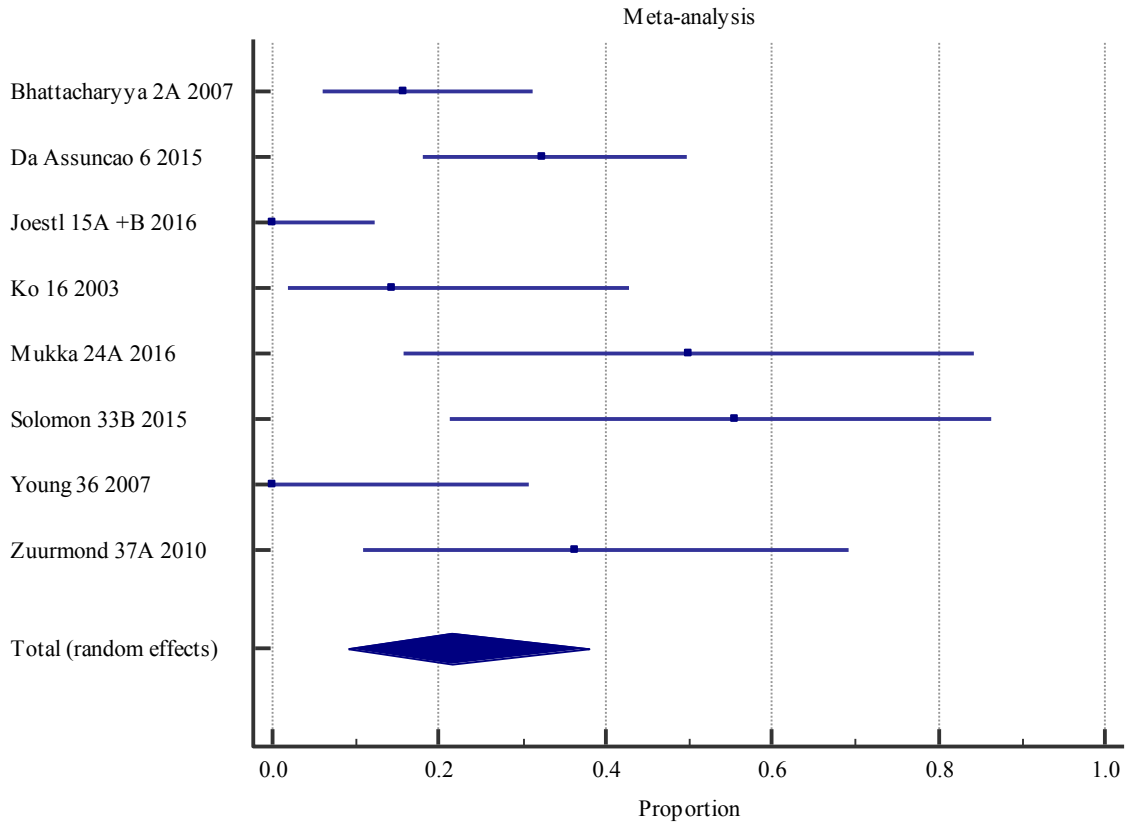
Heterotopic ossification

Two studies reported heterotopic ossification for Revision with or without wires/cerclage/cables, exposure 16 (Ko, Lam et al. 2003) and 36 (Spina, Rocca et al. 2014), with a prevalence of 0% (0/12) and 10% (1/10), respectively. No explicit definition or time-frame for heterotopic ossification was reported.

Malunion

Two studies reported malunion for Revision with or without wires/cerclage/cables, exposure 27A (Niikura, Sakurai et al. 2014) and 31 (Sexton, Stossel et al. 2006), with event rates of 0/2 (0%) and 0/25 (0%), respectively. Malunion was defined radiologically by Niikura and colleagues '…as angular deformity greater than 5°.' (Niikura, Sakurai et al. 2014).

Mortality (overall at final follow-up)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Bhattacharyya 2A 2007	38	15.789	6.023 to 31.253	23.93	14.54
Da Assuncao 6 2015	37	32.432	18.014 to 49.785	23.31	14.50
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	17.79	14.01
Ko 16 2003	14	14.286	1.779 to 42.813	9.20	12.35
Mukka 24A 2016	8	50.000	15.701 to 84.299	5.52	10.62
Solomon 33B 2015	9	55.556	21.201 to 86.300	6.13	11.00
Young 36 2007	10	0.000	0.000 to 30.850	6.75	11.34
Zuurmond 37A 2010	11	36.364	10.926 to 69.210	7.36	11.64
Total (fixed effects)	155	19.040	13.322 to 25.920	100.00	100.00
Total (random effects)	155	21.639	8.971 to 37.929	100.00	100.00

Test for heterogeneity

Q	34.8418
DF	7
Significance level	P < 0.0001
I^2 (inconsistency)	79.91%
95% CI for I^2	61.00 to 89.65

Figure 27 Mortality (overall at final follow-up) for Revision with or without wires/cerclage/cables.

Figure 27 shows the meta-analysis for the eight studies (n=155) that reported mortality (overall) for the exposure of interest. Around 90% (7/8) of the studies provided a time period for mortality, which was similar across studies, and up to around 5 years. Overall, the prevalence of mortality was 21.6% (95%CI 9.0 to 38.0) and results from the meta-analysis indicated a high degree of heterogeneity between the studies (I^2 = 79.9%). In studies where patients were excluded based on mortality, either directly, e.g. mortality within three months post-operatively OR in-directly, e.g. where minimum follow-up periods were applied to exclusion criteria, and the reason for not reaching this time period was mortality, the patients were included in the meta-analysis. Note: raw data was requested and used for Ko and colleagues, Mukka and colleagues and Solomon and colleagues for this outcome (Ko, Lam et al. 2003, Solomon, Hussenbocus et al. 2015, Mukka, Mellner et al. 2016).

Intra-operative mortality

One study reported intra-operative mortality for Revision with or without wires/cerclage/cables, exposure 27A (n=2) (Niikura, Sakurai et al. 2014) with no events observed.

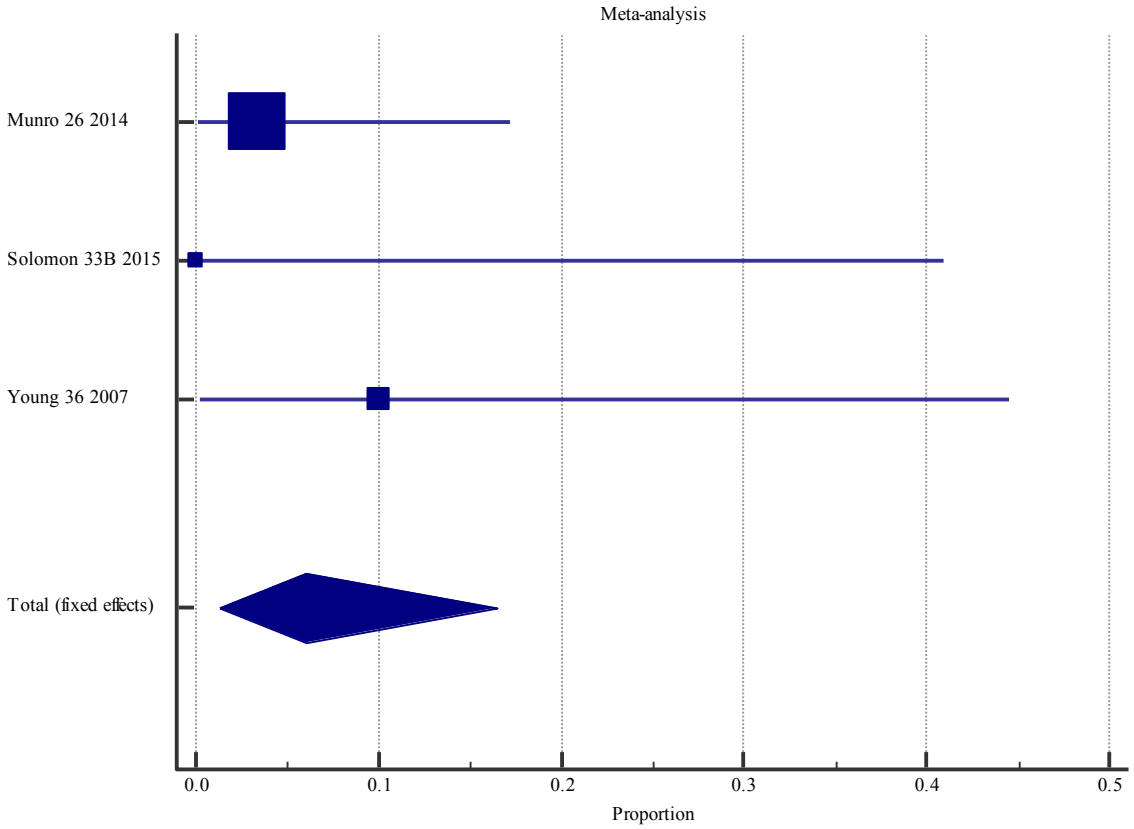
Multi-organ failure

One study reported multi-organ failure for Revision with or without wires/cerclage/cables, exposure 6 (Da Assunção, Pollard et al. 2015), with a prevalence of 2.7% (1/37). No explicit definition of multi-organ failure was reported.

Pressure ulcer (heel)

One study reported pressure ulcer for Revision with or without wires/cerclage/cables, exposure 6 (Da Assunção, Pollard et al. 2015), with a prevalence of 2.7% (1/37). No explicit definition of the pressure ulcer, aside from location was reported.

Aseptic loosening femur



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Munro 26 2014	30	3.333	0.0844 to 17.217	62.00	62.00
Solomon 33B 2015	7	0.000	0.000 to 40.962	16.00	16.00
Young 36 2007	10	10.000	0.253 to 44.502	22.00	22.00
Total (fixed effects)	47	5.961	1.238 to 16.495	100.00	100.00
Total (random effects)	47	5.961	1.163 to 14.121	100.00	100.00

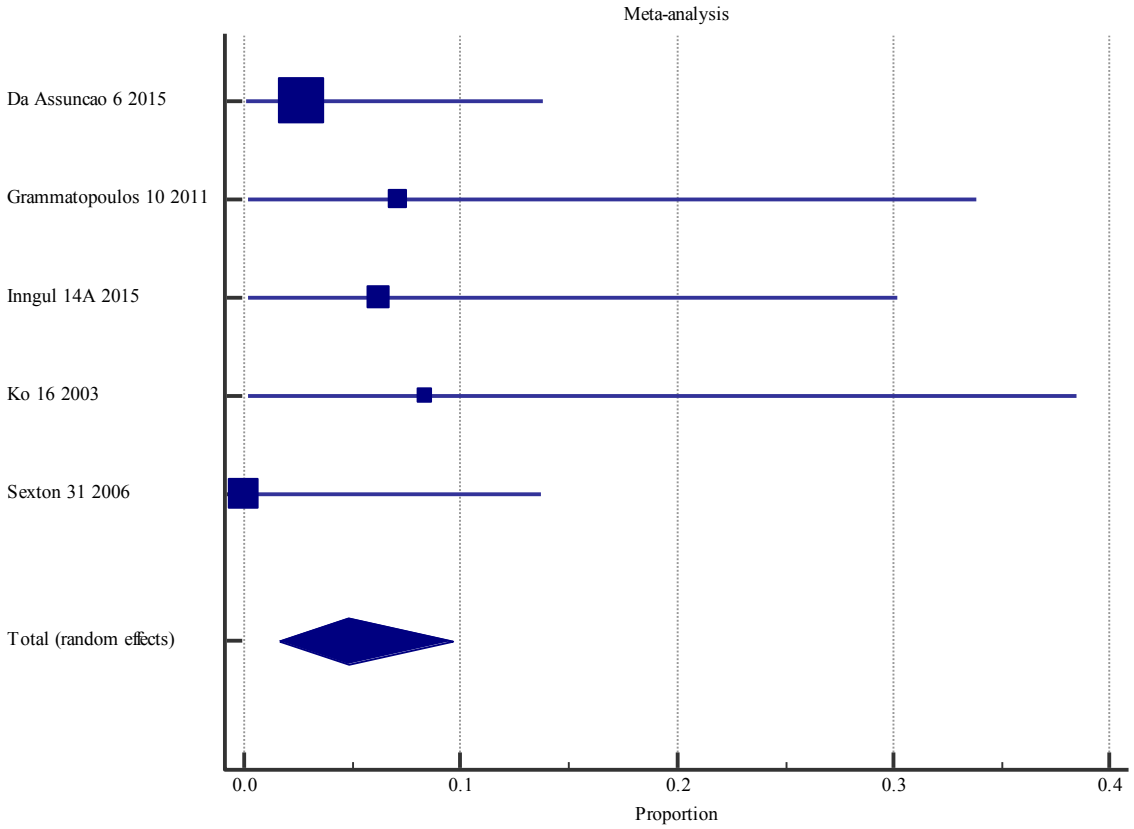
Test for heterogeneity

Q	0.9429
DF	2
Significance level	P = 0.6241
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 92.88

Figure 28 Aseptic loosening for Revision with or without wires/cerclage/cables.

Figure 28 shows the meta-analysis for the three studies (n=47) that reported aseptic loosening femur for the exposure of interest. Solomon and colleagues (Solomon, Hussenbocus et al. 2015) defined loosening using Harris' criteria (Harris, McCarthy et al. 1982), the remaining two studies did not provide any definition (Young, Pandit et al. 2007, Munro, Garbuz et al. 2014). Munro and colleagues, Solomon and colleagues and Young and colleagues observed patients for a minimum 24 months (no maximum reported specifically for B2 cohort), 3 months (maximum 12 years), 12 months (maximum 72 months) (Young, Pandit et al. 2007, Munro, Garbuz et al. 2014, Solomon, Hussenbocus et al. 2015). Overall, the prevalence of aseptic femoral loosening was 6.0% (95%CI 1.2 to 16.5). There was no important heterogeneity between the studies ($I^2 = 0\%$). Note, raw data from Solomon et al. (2015) was utilised for this outcome.

Peri-prosthetic femoral fracture post-operatively



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	35.45	35.45
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	13.64	13.64
Inngul 14A 2015	16	6.250	0.158 to 30.232	15.45	15.45
Ko 16 2003	12	8.333	0.211 to 38.480	11.82	11.82
Sexton 31 2006	25	0.000	0.000 to 13.719	23.64	23.64
Total (fixed effects)	105	4.849	1.667 to 10.696	100.00	100.00
Total (random effects)	105	4.849	1.645 to 9.626	100.00	100.00

Test for heterogeneity

Q	3.3824
DF	4
Significance level	P = 0.4960
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 76.85

Figure 29 Peri-prosthetic femoral fracture (post-operatively) for Revision with or without wires/cerclage/cables.

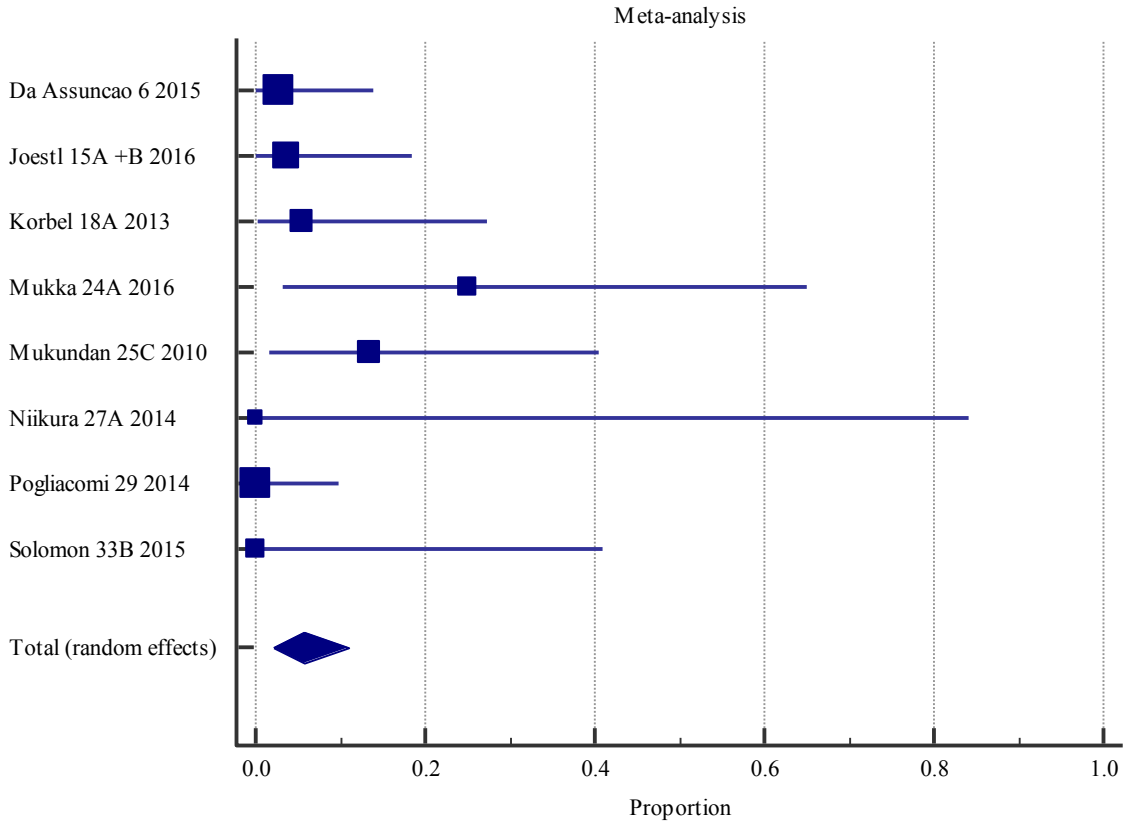
Figure 29 shows the meta-analysis for the 5 studies (n=105) that reported post-operative PFF for the exposure of interest. Studies used plain film radiographs to assess for any new post-operative fracture. The time-frame of outcome measurement was reported in 80% (4/5) of the studies and was similar across studies (up to around 6 years).

Overall, the prevalence of post-operative PFF was 4.8% (95%CI 1.6 to 9.6). There was no important heterogeneity between the studies (I^2 = 0%).

Peri-prosthetic femoral fracture intra-operatively

One study reported intra-operative PFF for Revision with or without wires/cerclage/cables, exposure 8 (n=15), with no events observed (Fink, Urbansky et al. 2014).

Deep surgical site infection (DSSI)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	24.37	21.06
Joestl 15A +B 2016	28	3.571	0.0904 to 18.348	18.12	17.56
Korbel 18A 2013	18	5.556	0.141 to 27.294	11.88	13.09
Mukka 24A 2016	8	25.000	3.185 to 65.086	5.62	7.20
Mukundan 25C 2010	15	13.333	1.658 to 40.460	10.00	11.50
Niikura 27A 2014	2	0.000	0.000 to 84.189	1.87	2.65
Pogliacomi 29 2014	36	0.000	0.000 to 9.739	23.12	20.43
Solomon 33B 2015	7	0.000	0.000 to 40.962	5.00	6.50
Total (fixed effects)	152	5.078	2.235 to 9.714	100.00	100.00
Total (random effects)	152	5.680	2.114 to 10.832	100.00	100.00

Test for heterogeneity

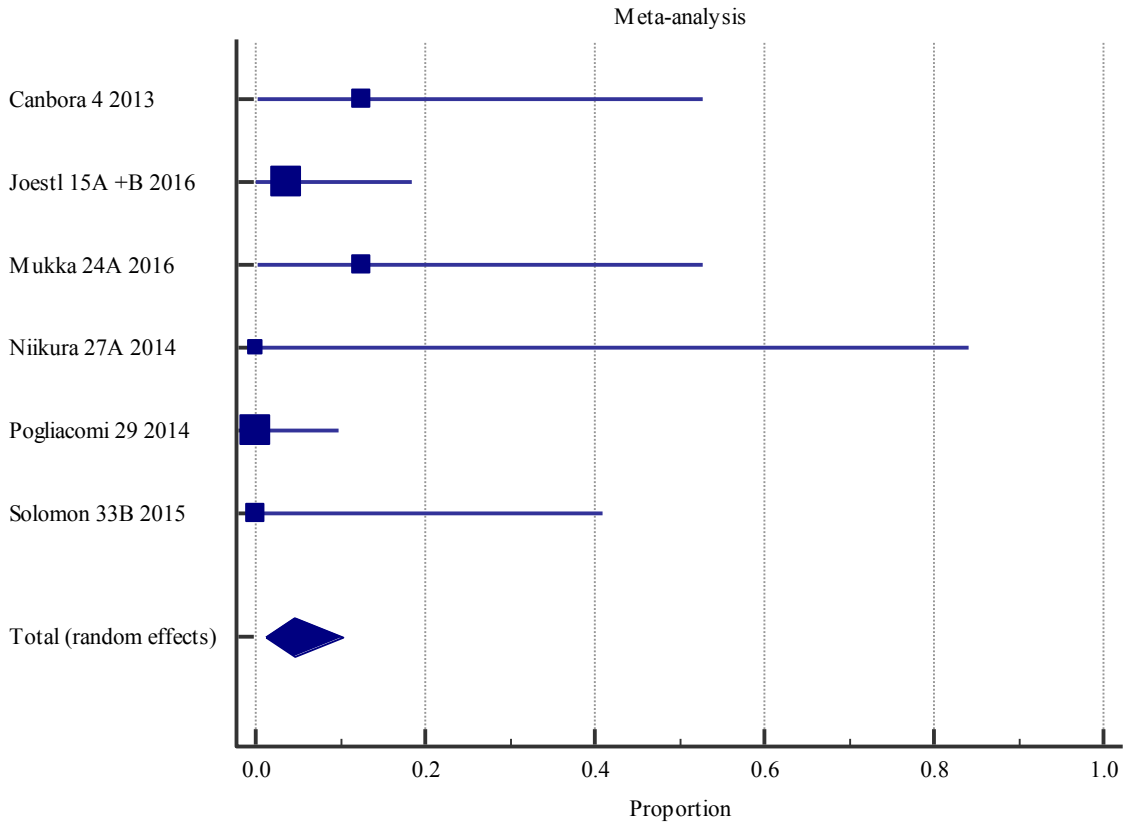
Q	9.4675
DF	7
Significance level	P = 0.2208
I^2 (inconsistency)	26.06%
95% CI for I^2	0.00 to 66.56

Figure 30 Deep surgical site infection (DSSI) for Revision with or without wires/cerclage/cables.

Figure 30 shows the meta-analysis for the eight studies (n=152) that reported DSSI for the exposure of interest. No authors provided a definition for DSSI, only one study (Joestl, Hofbauer et al. 2016) implies aspiration hip joint was performed for diagnosis. The explicit time-frame of outcome measurement was not reported in any study, however, the overall assessment period across studies was similar, and up to around 10 years.

Overall, the prevalence of DSSI was 5.7% (95%CI 2.1 to 10.8). There was a moderate degree of heterogeneity between the studies (I^2 = 26.1%). Note raw data from Mukka and colleagues was used for this outcome (Mukka, Mellner et al. 2016).

Superficial surgical site infection (SSSI)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	12.500	0.316 to 52.651	9.47	10.67
Joestl 15A +B 2016	28	3.571	0.0904 to 18.348	30.53	29.60
Mukka 24A 2016	8	12.500	0.316 to 52.651	9.47	10.67
Niikura 27A 2014	2	0.000	0.000 to 84.189	3.16	3.74
Pogliacomi 29 2014	36	0.000	0.000 to 9.739	38.95	35.77
Solomon 33B 2015	7	0.000	0.000 to 40.962	8.42	9.56
Total (fixed effects)	89	4.138	1.122 to 10.331	100.00	100.00
Total (random effects)	89	4.505	1.059 to 10.176	100.00	100.00

Test for heterogeneity

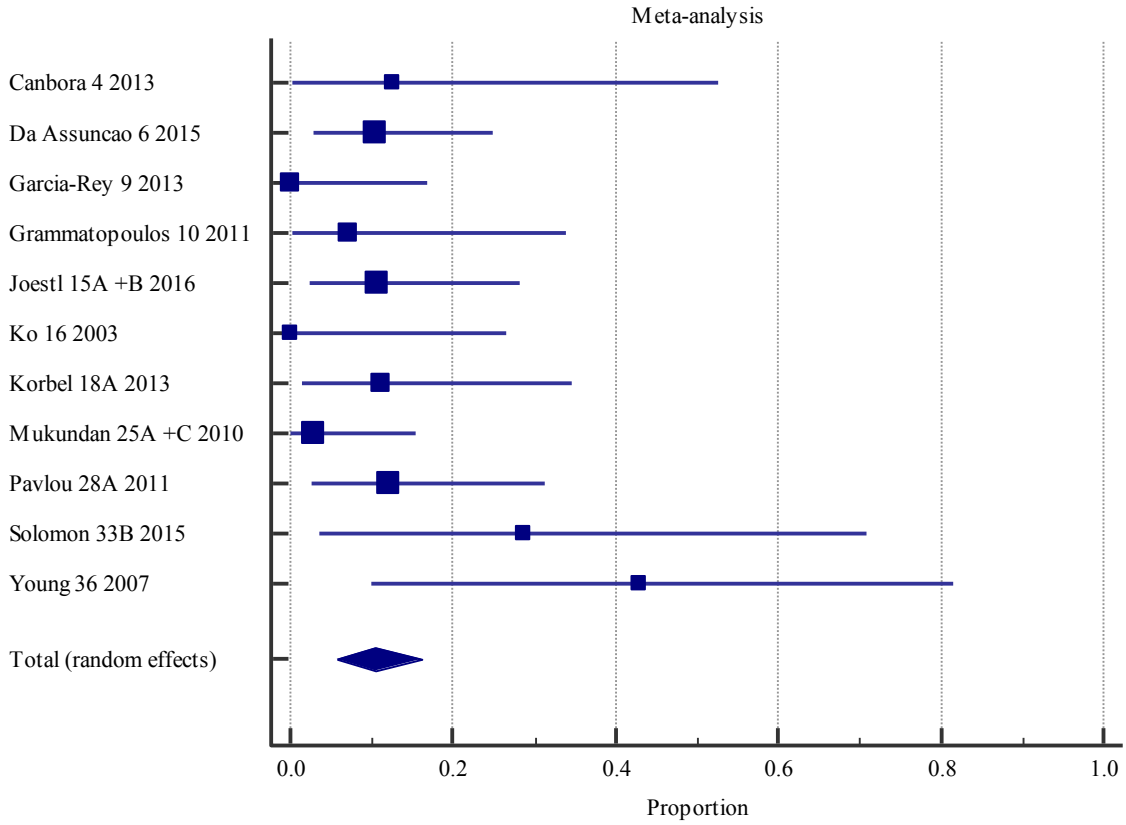
Q	5.6023
DF	5
Significance level	P = 0.3469
I^2 (inconsistency)	10.75%
95% CI for I^2	0.00 to 78.00

Figure 31 Superficial surgical site infection (SSSI) for Revision with or without wires/cerclage/cables.

Figure 31 shows the meta-analysis for the six studies (n=89) that reported SSSI for the exposure of interest. No authors provided a definition for SSSI, however, one (Canbora, Kose et al. 2013) implies wound swab was performed for diagnosis. The explicit time-frame of the outcome measurement was not reported in any study, however, the overall assessment period across studies was similar, and up to around 10 years.

Overall, the prevalence of SSSI was 4.5% (95%CI 1.1 to 10.2). There was no important heterogeneity between the studies (I^2 = 10.8%). Note: raw data from Mukka and colleagues was used for this outcome (Mukka, Mellner et al. 2016).

Dislocation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	12.500	0.316 to 52.651	4.05	5.44
Da Assuncao 6 2015	38	10.526	2.943 to 24.805	17.57	13.87
Garcia-Rey 9 2013	20	0.000	0.000 to 16.843	9.46	9.92
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	6.76	7.96
Joestl 15A +B 2016	28	10.714	2.267 to 28.226	13.06	11.96
Ko 16 2003	12	0.000	0.000 to 26.465	5.86	7.19
Korbel 18A 2013	18	11.111	1.375 to 34.712	8.56	9.32
Mukundan 25A +C 2010	34	2.941	0.0744 to 15.327	15.77	13.17
Pavlou 28A 2011	25	12.000	2.547 to 31.219	11.71	11.26
Solomon 33B 2015	7	28.571	3.669 to 70.958	3.60	4.96
Young 36 2007	7	42.857	9.899 to 81.595	3.60	4.96
Total (fixed effects)	211	9.850	6.267 to 14.549	100.00	100.00
Total (random effects)	211	10.379	5.755 to 16.167	100.00	100.00

Test for heterogeneity

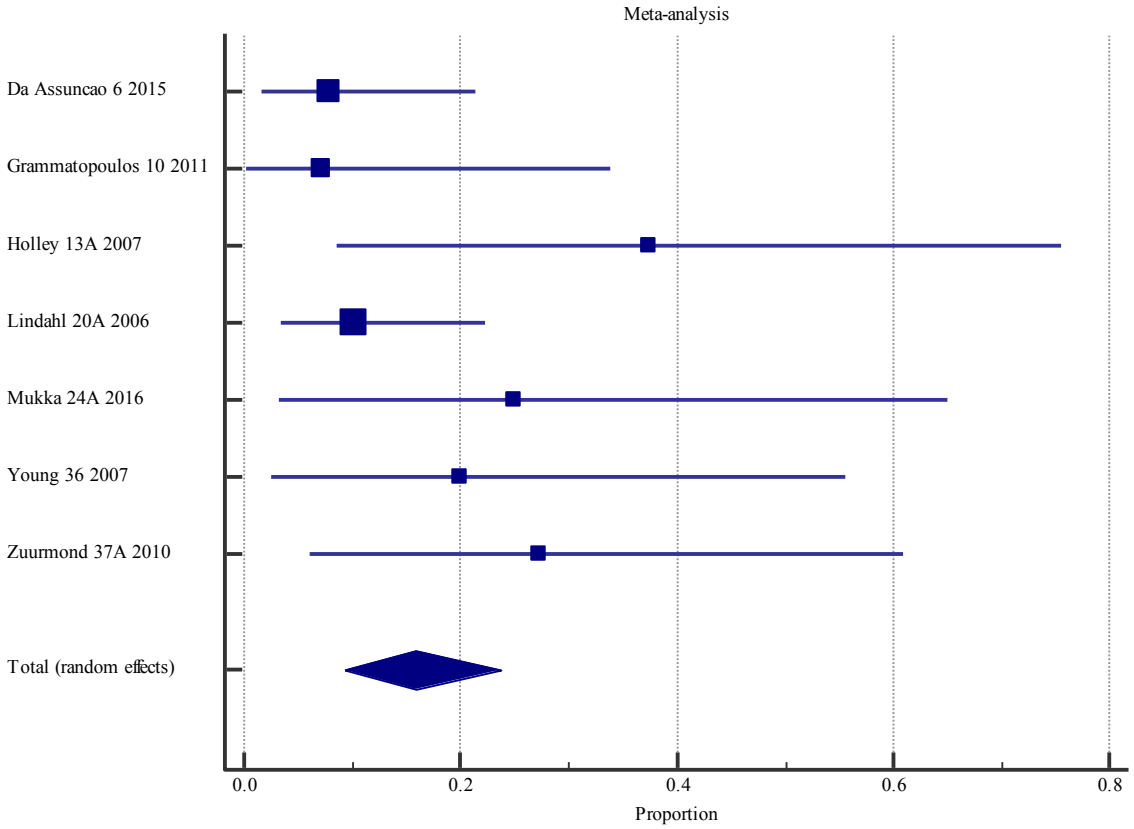
Q	15.8109
DF	10
Significance level	P = 0.1052
I^2 (inconsistency)	36.75%
95% CI for I^2	0.00 to 68.91

Figure 32 Dislocation (any) for Revision with or without wires/cerclage/cables.

Figure 32 shows the meta-analysis for the eleven studies (n=211) that reported dislocation for the exposure of interest. No authors provided a definition for dislocation. Only one study (Solomon, Hussenbocus et al. 2015) reported a time period within which dislocation occurred, which was less than 3 months post-operatively. The overall assessment period was similar across studies, and up to around ten years. Out of studies where events occurred, only 11% (1/9) reported a direction of dislocation.

Overall, the prevalence of dislocation was 10.4% (95%CI 5.8 to16.2). There was a moderate degree of heterogeneity between the studies (I^2 = 36.8%).

Re-operation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	38	7.895	1.659 to 21.377	26.90	24.14
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	10.34	12.27
Holley 13A 2007	8	37.500	8.523 to 75.514	6.21	8.01
Lindahl 20A 2006	49	10.204	3.397 to 22.228	34.48	27.84
Mukka 24A 2016	8	25.000	3.185 to 65.086	6.21	8.01
Young 36 2007	10	20.000	2.521 to 55.610	7.59	9.51
Zuurmond 37A 2010	11	27.273	6.022 to 60.974	8.28	10.23
Total (fixed effects)	138	14.575	9.269 to 21.387	100.00	100.00
Total (random effects)	138	15.868	9.338 to 23.737	100.00	100.00

Test for heterogeneity

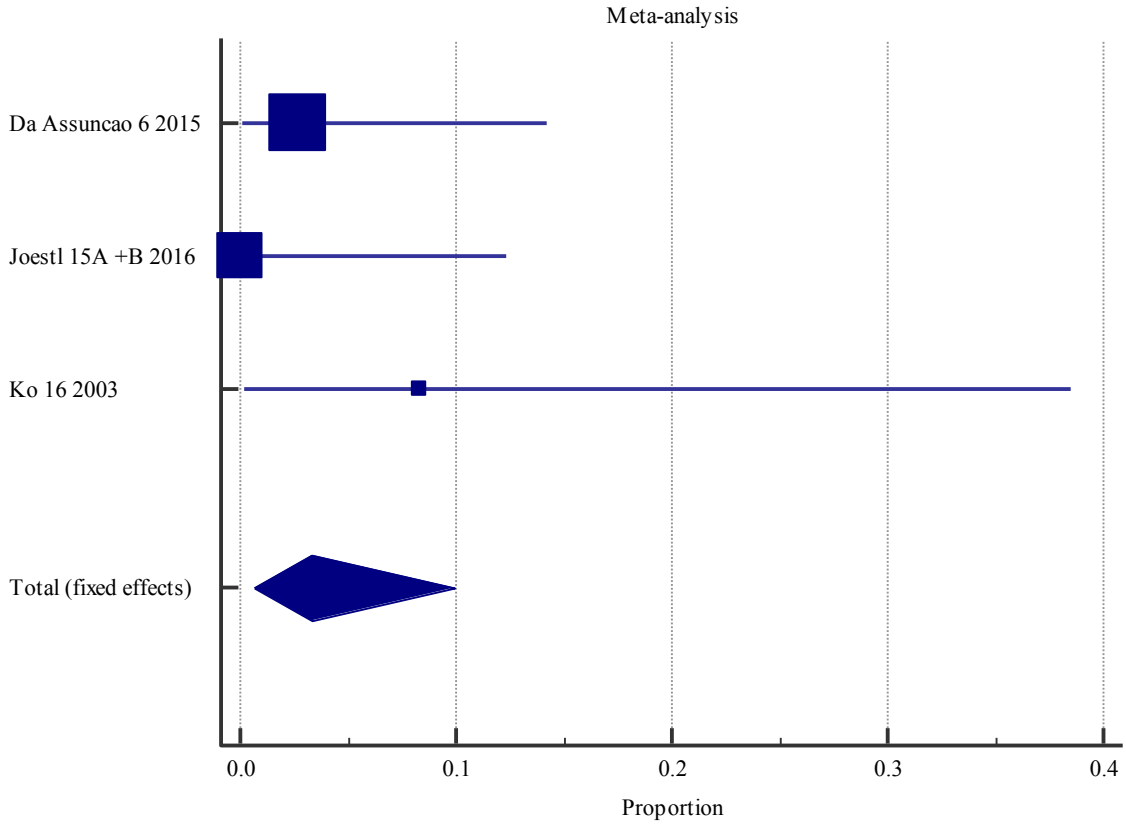
Q	7.8927
DF	6
Significance level	P = 0.2461
I^2 (inconsistency)	23.98%
95% CI for I^2	0.00 to 66.47

Figure 33 Re-operation for Revision with or without wires/cerclage/cables.

Figure 33 shows the meta-analysis for the seven studies (n=138) that reported re-operation for the exposure of interest. No authors provided an explicit definition or a time-frame for re-operation. The overall assessment period was similar across studies, and up to around twelve years.

Overall, the prevalence of re-operation was 15.9% (95%CI 9.3 to 23.7). There was a low degree of heterogeneity between the studies (I^2 = 24.0%).

Deep vein thrombosis (DVT)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	37	2.703	0.0684 to 14.160	47.50	45.80
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	36.25	36.48
Ko 16 2003	12	8.333	0.211 to 38.480	16.25	17.72
Total (fixed effects)	77	3.316	0.598 to 9.947	100.00	100.00
Total (random effects)	77	3.384	0.441 to 8.934	100.00	100.00

Test for heterogeneity

Q	2.2775
DF	2
Significance level	P = 0.3202
I^2 (inconsistency)	12.19%
95% CI for I^2	0.00 to 97.05

Figure 34 Deep vein thrombosis for Revision with or without wires/cerclage/cables.

Figure 34 shows the meta-analysis for the three studies (n=77) that reported DVT for the exposure of interest. No authors provided an explicit definition for DVT. Ko and colleagues reported Doppler ultrasound was used for diagnosis of DVT. The time-frame

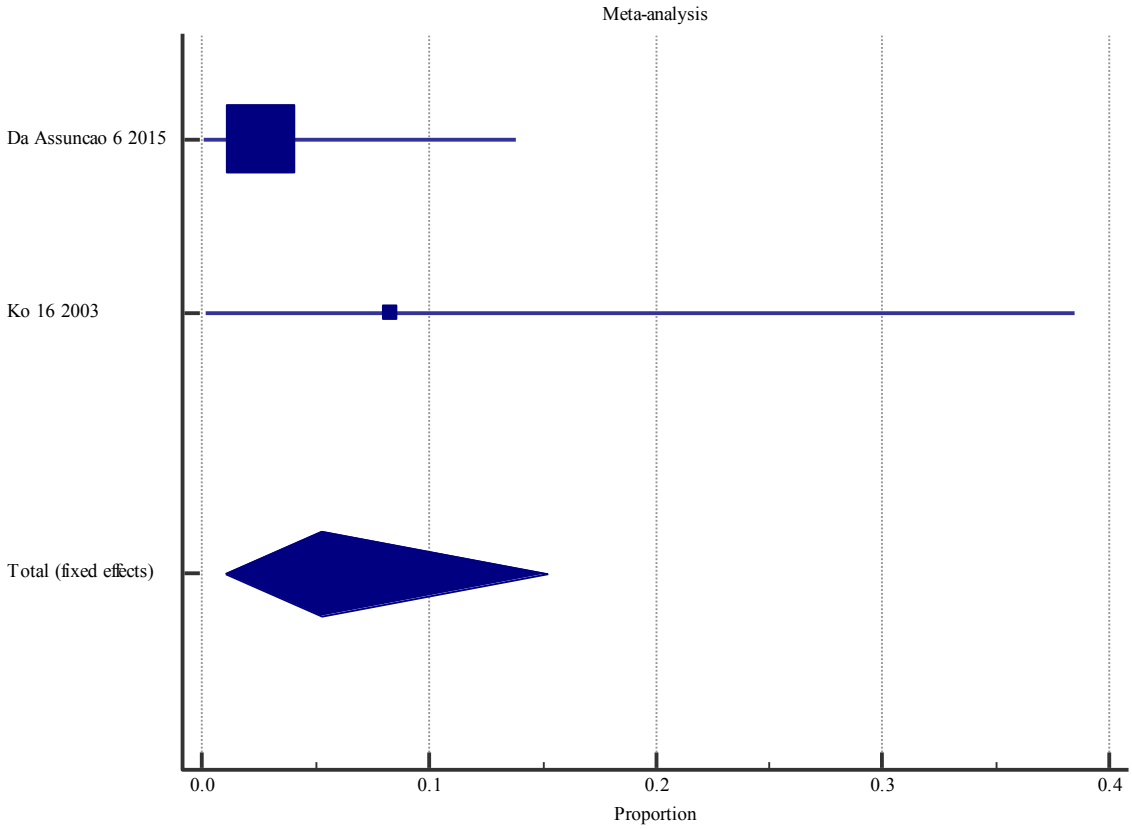
of detection was reported by Ko and colleagues only, 3 weeks post-operatively (Ko, Lam et al. 2003). The overall assessment period was similar across studies, and up to around nine years.

Overall, the prevalence of DVT was 3.3% (95%CI 0.6 to 10.0). There was a low degree of heterogeneity between the studies (I^2 = 12.2%).

Pulmonary embolism (PE)

One study reported PE for Revision with or without wires/cerclage/cables, exposure 15A+B (n=28), with no events observed. No explicit definition of PE was reported (Joestl, Hofbauer et al. 2016).

Leg length discrepancy (LLD) (any)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	75.00	75.00
Ko 16 2003	12	8.333	0.211 to 38.480	25.00	25.00
Total (fixed effects)	50	5.263	0.990 to 15.244	100.00	100.00
Total (random effects)	50	5.263	0.911 to 12.901	100.00	100.00

Test for heterogeneity

Q	0.8475
DF	1
Significance level	P = 0.3572
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 0.00

Figure 35 Leg length discrepancy for Revision with or without wires/cerclage/cables.

Figure 35 shows the meta-analysis for the two studies (n=50) that reported LLD for the exposure of interest. No authors provided an explicit definition, diagnostic method or a time-frame for identifying LLD, however, Ko and colleagues reported LLD was

significant if there was a 2cm or greater discrepancy (Ko, Lam et al. 2003). The overall assessment period was similar across studies, and up to around five years.

Overall, the prevalence of LLD was 5.3% (95%CI 1.0 to 15.2). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Thigh pain

Two studies reported thigh pain for Revision with or without wires/cerclage/cables, exposure 6 (Da Assunção, Pollard et al. 2015) and 16 (Ko, Lam et al. 2003) with event rates of 1/38 (2.6%) and 0/12 (0%), respectively. Authors did not provide a clear definition for this outcome.

Neurovascular injury

Two studies reported neurovascular injury for Revision with or without wires/cerclage/cables, exposure 15A+B (Joestl, Hofbauer et al. 2016) and 18A (Korbel, Sponer et al. 2013), with event rates of 0/28 (0%) and 2/18 (11%) (both of which were femoral nerve palsies which resolved by 3 months post-operatively), respectively.

Revision femoral component

Two studies reported a Revision femoral component for Revision with or without wires/cerclage/cables, exposure 16 (n=12) (Ko, Lam et al. 2003) and 36 (Young, Pandit et al. 2007) (n=10), with no events observed in either study.

Femoral stem breakage

One study reported femoral stem breakage for Revision with or without wires/cerclage/cables, exposure 18A (Korbel, Sponer et al. 2013), with an event rate of 1/18 (0%).

SF-12 mental score post-operatively

One study reported post-operative SF-12 mental score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014) with a mean score of 53 (SD NS, range NS). No explicit time-frame was specified for this outcome, however, the overall assessment period was 24 to 143 months.

SF-12 physical score post-operatively

One study reported post-operative SF-12 physical score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014) with a mean score of 41 (SD NS, range NS). No explicit time-frame was specified for this outcome, however, the overall assessment period was 24 to 143 months.

Harris hip score (post-operative)

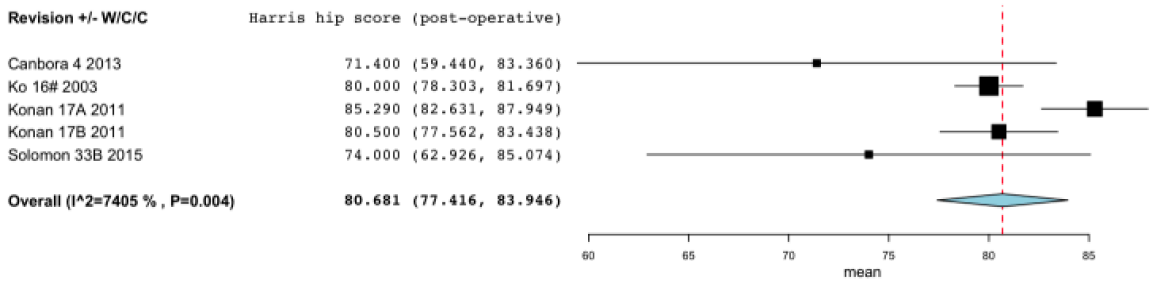


Figure 36 Harris hip score (HHS) (post-operative) for Revision with or without wires/cerclage/cables.

Figure 36 shows the meta-analysis for the five studies (n=41) that reported post-operative HHS for the exposure of interest. The time point post-operatively at which HHS was calculated was not explicitly reported in any study, however, Canbora and colleagues state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) (Canbora, Kose et al. 2013). The overall assessment period across studies ranged from 15 to 137 months.

Overall, the mean HHS was 80.7 (95%CI 77.4 to 83.9). There was a moderate degree of heterogeneity between the studies (I^2 = 74.1%).

Studies not included in the meta-analysis: Young and colleagues reported HHS post-operatively and found a mean of 69.1, however, unfortunately, did not include the standard deviation or range, hence the study was excluded from this meta-analysis (Young, Pandit et al. 2007).

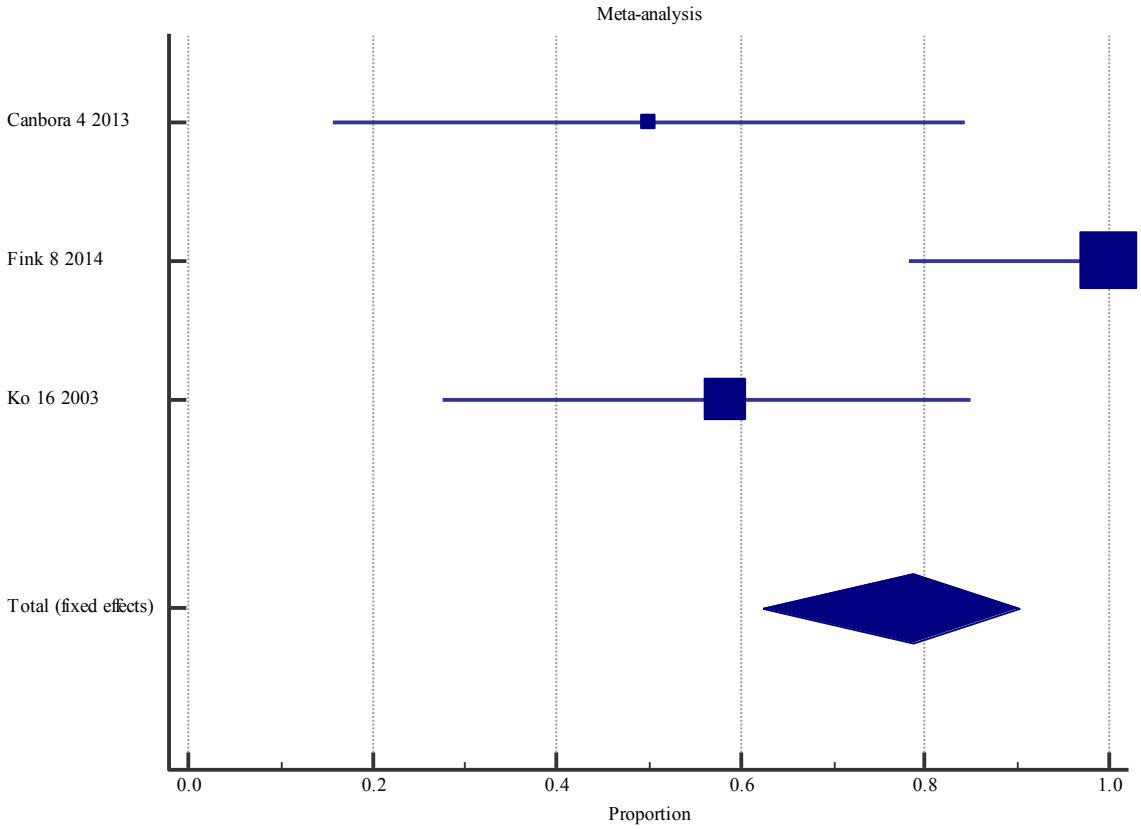
Harris hip pain score (post-operative)

One study reported post-operative Harris hip pain score for Revision with or without wires/cerclage/cables, exposure 33B* (n=7), with a mean score of 31.1 (SD 15.18) (Solomon, Hussenbocus et al. 2015).

Barthel ADLs index (post-operative)

One study reported post-operative Barthel ADLs index for Revision with or without wires/cerclage/cables, exposure 4 (n=8) (Canbora, Kose et al. 2013), with a mean score of 73.75 (SD 25.31) at mean follow-up of 39 months (Range 15-19, No SD reported).

Beals and Towers' criteria: Scoring an excellent outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	50.000	15.701 to 84.299	23.68	31.76
Fink 8 2014	15	100.000	78.198 to 100.000	42.11	34.56
Ko 16 2003	12	58.333	27.667 to 84.835	34.21	33.68
Total (fixed effects)	35	78.561	62.248 to 90.173	100.00	100.00
Total (random effects)	35	74.310	32.961 to 98.927	100.00	100.00

Test for heterogeneity

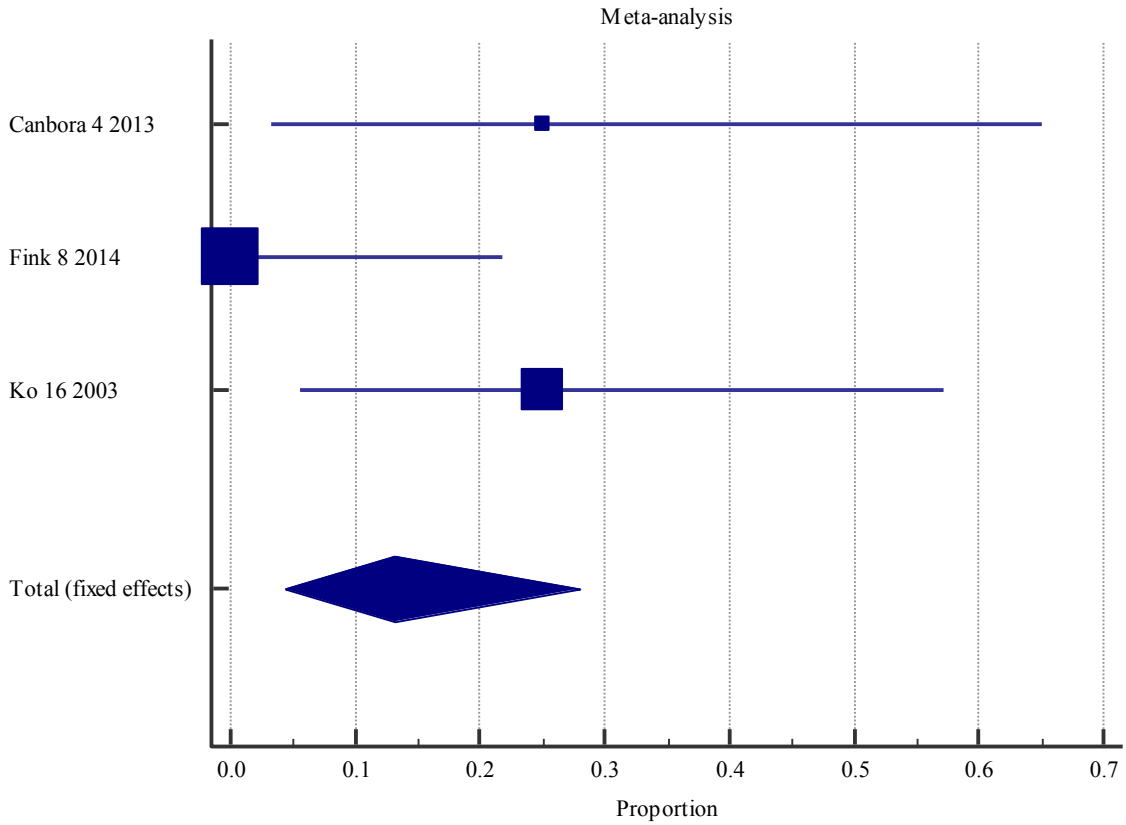
Q	14.0637
DF	2
Significance level	P = 0.0009
I^2 (inconsistency)	85.78%
95% CI for I^2	58.52 to 95.12

Figure 37 Beals and Towers' criteria excellent outcome for Revision with or without wires/cerclage/cables.

Figure 37 shows the meta-analysis for the three studies (n=35) that reported an excellent score on the Beals and Towers' criteria for Revision with or without wires/cerclage/cables. The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) (Canbora, Kose et al. 2013). The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria excellent outcome was 78.6% (95%CI 62.2 to 90.2). There was a high degree of heterogeneity between the studies (I^2 =85.8%).

Beals and Towers' criteria good outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	25.000	3.185 to 65.086	23.68	30.07
Fink 8 2014	15	0.000	0.000 to 21.802	42.11	35.95
Ko 16 2003	12	25.000	5.486 to 57.186	34.21	33.98
Total (fixed effects)	35	13.111	4.386 to 28.029	100.00	100.00
Total (random effects)	35	14.935	1.075 to 40.491	100.00	100.00

Test for heterogeneity

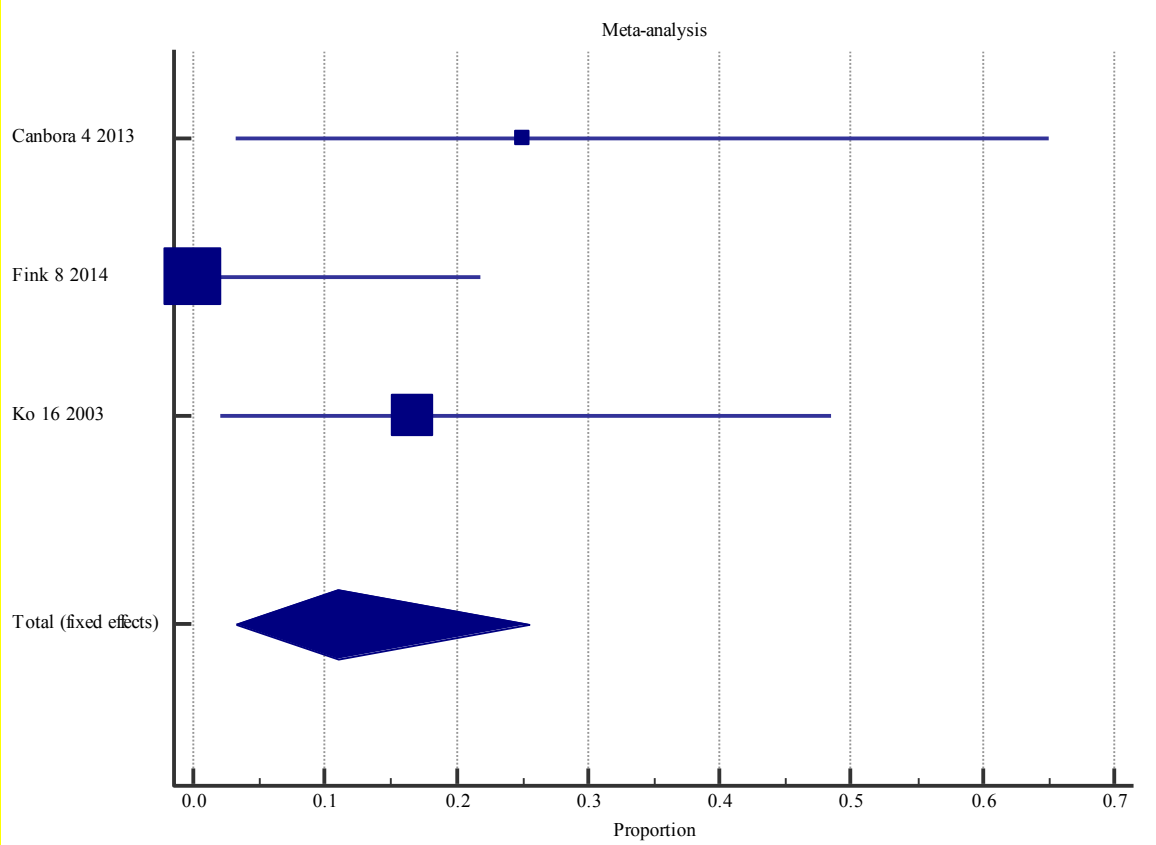
Q	6.5919
DF	2
Significance level	P = 0.0370
I^2 (inconsistency)	69.66%
95% CI for I^2	0.00 to 91.14

Figure 38 Beals and Towers' criteria good outcome for Revision with or without wires/cerclage/cables.

Figure 38 shows the meta-analysis for the three studies (n=35) that reported Beals and Towers' criteria for the exposure of interest. The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) (Canbora, Kose et al. 2013). The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria good outcome was 13.1% (95%CI 4.4 to 28.0). There was a moderate degree of heterogeneity between the studies (I^2 = 69.7%).

Beals and Towers' criteria poor outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	25.000	3.185 to 65.086	23.68	29.26
Fink 8 2014	15	0.000	0.000 to 21.802	42.11	36.65
Ko 16 2003	12	16.667	2.086 to 48.414	34.21	34.09
Total (fixed effects)	35	11.050	3.223 to 25.469	100.00	100.00
Total (random effects)	35	12.561	1.036 to 34.009	100.00	100.00

Test for heterogeneity

Q	5.2107
DF	2
Significance level	P = 0.0739
I^2 (inconsistency)	61.62%
95% CI for I^2	0.00 to 89.05

Figure 39 Beals and Towers' criteria poor outcome for Revision with or without wires/cerclage/cables.

Figure 39 shows the meta-analysis for the three studies (n=35) that reported Beals and Towers' criteria for the exposure of interest. The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) (Canbora, Kose et al. 2013). The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria poor outcome was 11.1% (95%CI 3.2 to 25.5). There was a moderate degree of heterogeneity between the studies (I^2 = 62.0%).

Parker mobility score (post-operative)

Three studies reported post-operative Parker mobility score for Revision with or without wires/cerclage/cables, exposure 15A (n=14), 15B (n=14) (Joestl, Hofbauer et al. 2016) and 27A (n=2) (Niikura, Lee et al. 2014) with mean scores of 6.5 (SD 2, Range NS), 6.4 (SD 2, Range NS) and 6 (SD 4.2, Range NS), respectively. Note, for reference, mean pre-operative Parker mobility score for exposure 15A (n=14), 15B (n=14) (Joestl, Hofbauer et al. 2016) and 27A (n=2) were 6.8 (SD 1.7, Range NS), 6.99 (SD 1, Range NS) and 6 (SD 4.2, Range NS), respectively.

Modified Charnley-D'Aubigne score excellent, good and poor outcome

One study reported post-operative Modified Charnley-D'Aubigne score excellent outcome for Revision with or without wires/cerclage/cables, exposure 25A+C, with a prevalence of 59% (20/34) (Mukundan, Rayan et al. 2010). The time point post-operatively at which the Modified Charnley-D'Aubigne score was assessed was not

explicitly reported. One study reported post-operative Modified Charnley-D'Aubigne score good outcome for Revision with or without wires/cerclage/cables, exposure 25A+C, with a prevalence of 24% (8/34) (Mukka, Mellner et al. 2016). The time point post-operatively at which the Modified Charnley-D'Aubigne score was assessed was not explicitly reported. One study reported post-operative Modified Charnley-D'Aubigne score poor outcome for Revision with or without wires/cerclage/cables, exposure 25A+C, with prevalence of 18% (6/34) (Mukundan, Rayan et al. 2010). The time point post-operatively at which the Modified Charnley-D'Aubigne score was assessed was not explicitly reported (Mukundan, Rayan et al. 2010).

Oxford hip score (post-operative)

Four studies reported on Oxford hip score assessed post-operatively (Young, Pandit et al. 2007, Zuurmond, van Wijhe et al. 2010, Munro, Garbuz et al. 2014, Da Assunção, Pollard et al. 2015). However, the scores were inversely proportional and measured in different scales, hence meta-analysis was not possible. Da Assunção and colleagues found a mean Oxford hip score of 35.0 (95%CI 31.4; 38.4), where the assessment scale was from 0 to 48, with higher scores indicating better function (Da Assunção, Pollard et al. 2015). On the other hand, Zuurmond et al., found a mean of 28.0 (95%CI 23.0; 33.0), with higher scores indicating impaired function (Zuurmond, van Wijhe et al. 2010). The scale range was not reported.

Munro and colleagues (Munro, Garbuz et al. 2014) and Young and colleagues (Young, Pandit et al. 2007) both reported OHS post-operatively (with mean scores of 74 (n=16) and 32 (n=7), respectively), however, unfortunately did not include the standard deviation or range, hence meta-analysis was not possible.

WOMAC global score (post-operative)

One study reported post-operative WOMAC global score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 76 (SD NS, range NS). The time point post-operatively at which the WOMAC global score was assessed was not reported by study authors.

WOMAC pain score (post-operative)

One study reported post-operative WOMAC pain score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 80 (SD NS, range NS). The time point post-operatively at which the WOMAC pain score was assessed was not reported by study authors.

WOMAC function score (post-operative)

One study reported post-operative WOMAC function score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 75 (SD NS, range NS). The time point post-operatively at which the WOMAC function score was assessed was not reported by study authors.

WOMAC stiffness score (post-operative)

One study reported post-operative WOMAC stiffness score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 70 (SD NS, range NS). The time point post-operatively at which the WOMAC stiffness score was assessed was not reported by study authors.

UCLA activity score (post-operative)

One study reported post-operative UCLA activity score for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 4 (SD NS, range NS). The time point post-operatively at which the UCLA activity score was assessed was not reported by study authors.

Satisfaction score overall (self-reported, scale 0 (completely unsatisfied) –100 (completely satisfied).

One study reported post-operative Satisfaction score overall for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 96 (SD NS, range NS). The time point post-operatively at which the Satisfaction score (overall) was assessed was not reported by study authors.

Satisfaction score pain (self-reported, scale 0-100)

One study reported post-operative Satisfaction score pain for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 98 (SD NS, range NS). The time point post-operatively at which the Satisfaction score for pain (self-reported) was assessed was not reported by study authors.

Satisfaction score function (self-reported, scale 0-100)

One study reported post-operative Satisfaction score function for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 90 (SD NS, range NS). The time point post-operatively at which the Satisfaction score for function (self-reported) was assessed was not reported by study authors.

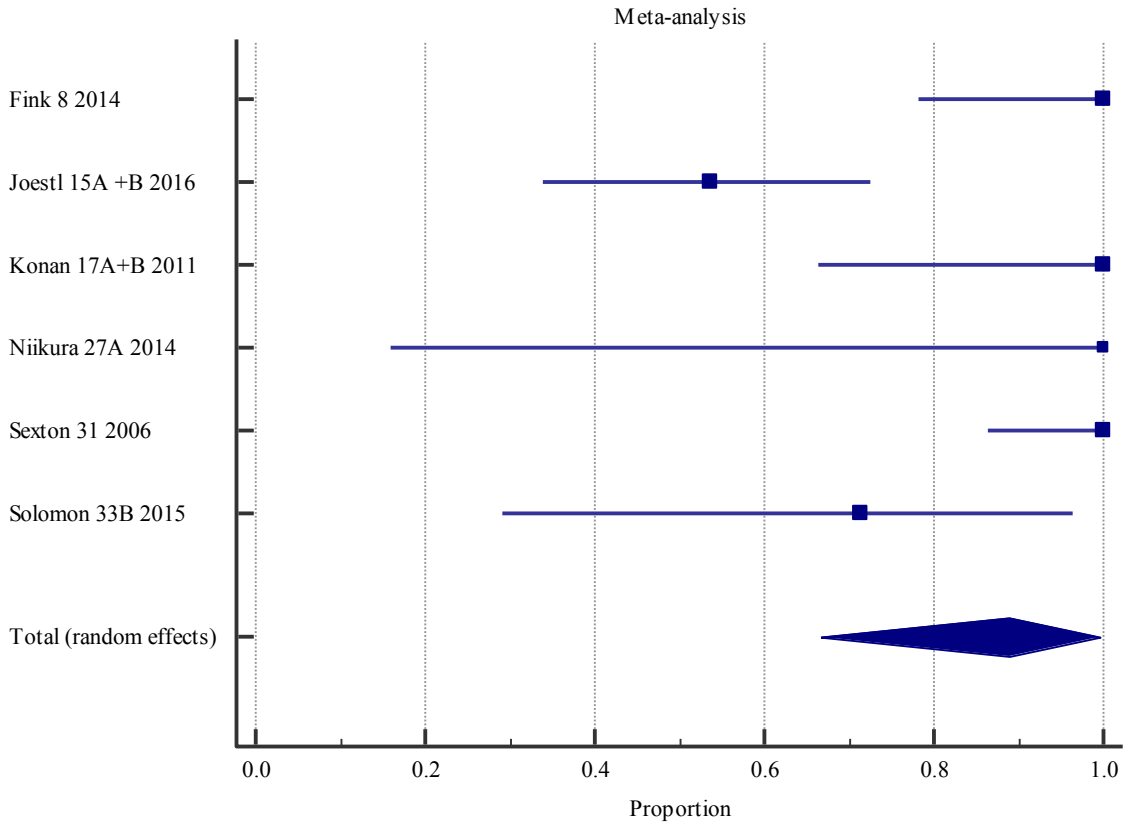
Satisfaction score recreation (self-reported, scale 0-100)

One study reported post-operative Satisfaction score recreation for Revision with or without wires/cerclage/cables, exposure 26 (n=16) (Munro, Garbuz et al. 2014), with a mean score of 86 (SD NS, range NS). The time point post-operatively at which the Satisfaction score for recreation (self-reported) was assessed was not reported by study authors.

Ambulatory status (post-operatively)

One study reported post-operative ambulatory status for Revision with or without wires/cerclage/cables, exposure 27A (Niikura, Lee et al. 2014), with 1/2 (50%) mobilising with walker and 1/2 (50%) mobilising without aids. This assessment was made at final follow-up which occurred at mean 18.4 months (SD14.2).

Attainment of pre-fracture mobility status



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Fink 8 2014	15	100.000	78.198 to 100.000	17.39	18.05
Joestl 15A +B 2016	28	53.571	33.870 to 72.489	31.52	19.28
Konan 17A+B 2011	9	100.000	66.373 to 100.000	10.87	16.63
Niikura 27A 2014	2	100.000	15.811 to 100.000	3.26	11.16
Sexton 31 2006	25	100.000	86.281 to 100.000	28.26	19.09
Solomon 33B 2015	7	71.429	29.042 to 96.331	8.70	15.80
Total (fixed effects)	86	87.226	78.642 to 93.275	100.00	100.00
Total (random effects)	86	88.822	66.563 to 99.575	100.00	100.00

Test for heterogeneity

Q	31.6375
DF	5
Significance level	P < 0.0001
I^2 (inconsistency)	84.20%
95% CI for I^2	67.21 to 92.38

Figure 40 Attainment of pre-fracture mobility status for Revision with or without wires/cerclage/cables.

Figure 40 shows the meta-analysis for the six studies (n=86) that reported attainment of pre-fracture mobility status for the exposure of interest. The time point post-operatively at which mobility status was assessed was only reported by Sexton and colleagues, which was 18 months post-operatively (Sexton, Stossel et al. 2006). There was no explicit reporting of how this assessment was made by authors (e.g. clinical or self-reported). The overall assessment period across studies was similar, and up to around nine years.

Overall, the prevalence of attainment pre-fracture mobility status was 88.8% (95%CI 66.6 to 99.6). There was a high degree of heterogeneity between the studies (I^2 = 84.2%).

Attainment of pre-fracture social status

One study reported attainment of pre-fracture social status for Revision with or without wires/cerclage/cables, exposure 27A (Niikura, Lee et al. 2014), with an event rate of 2/2 (100%) both patients living independently at home. The time point post-operatively at which the social status assessment was made was not reported by study authors.

Revision and ORIF with plate

There were five studies (two retrospective cohort studies, two case series and one prospective cohort study) which investigated outcomes associated with the intervention of Revision and ORIF with plate.

Surgical time

One study reported surgical time for Revision and ORIF with plate, exposure 21B (n=7) with a mean surgical time of 209 minutes (SD 41) (Lunebourg, Mouhsine et al. 2015). The operative time was defined as the time from the incision to the dressing of the surgical wound, as documented on the anaesthetic chart.

Union (overall)

Three studies reported union for Revision and ORIF with plate, exposure 21B (Lunebourg, Mouhsine et al. 2015), 24B (Mukka, Mellner et al. 2016) and 25B (Mukundan, Rayan et al. 2010), with prevalence rates of 100% (7/7), 100% (8/8) and 100% (8/8), respectively. Only Mukundan and colleagues explicitly defined union, and no studies reported a time-frame required to achieve union (Mukundan, Rayan et al. 2010). The overall assessment period across studies ranged from 2 months to 6 years.

Malunion

One study reported malunion for Revision and ORIF with plate, exposure 21B (Mukundan, Rayan et al. 2010), with no events observed. Authors defined malunion was '…as fracture union with > 5 degree angle in any plane.' No explicit time-frame was reported for this outcome. The overall assessment period of the study ranged from 16 to 90 months.

Length of stay

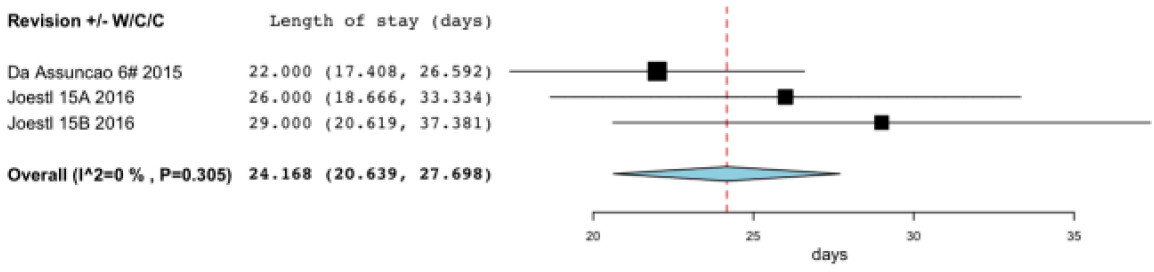


Figure 41 Length of stay for Revision and ORIF with plate.

Figure 41 shows the meta-analysis for the three studies (n=59) that reported length of stay for the exposure of interest. Joestl and colleagues specified 'hospital' length of stay, however, Da Assunção and colleagues did not provide an explicit definition of length of stay (e.g. primary hospital where surgery was performed, or combined with step-down or transitional care facility) (Da Assunção, Pollard et al. 2015, Joestl, Hofbauer et al. 2016).

Overall, the mean length of stay was 24 days (95%CI 21 to 28). There was no important heterogeneity between the studies (I^2 = 0%).

Mortality (at one year)

One study reported mortality for Revision and ORIF with plate, exposure 24B (Mukka, Mellner et al. 2016), with prevalence at one year of 25% (2/8).

Aseptic loosening femur

One study reported aseptic loosening femur for Revision and ORIF with plate, exposure 21B (n=7) (Lunebourg, Mouhsine et al. 2015), with no events observed. Although no explicit definition was provided by the authors, they do state radiographs

were performed at 6 weeks, 3 months, 1 year then as clinically indicated to assess for aseptic loosening.

Deep surgical site infection (DSSI)

One study reported DSSI for Revision and ORIF with plate, exposure 24B (Mukka, Mellner et al. 2016), with a prevalence of 25% (2/8). Authors did not provide a definition for DSSI.

Superficial surgical site infection (SSSI)

One study reported SSSI for Revision and ORIF with plate, exposure 24B (n=8) (Mukka, Mellner et al. 2016), with no events observed. Authors did not provide a definition for SSSI.

Re-operation

One study reported Re-operation for Revision and ORIF with plate, exposure 24B (Mukka, Mellner et al. 2016), with a prevalence of 25% (2/8). Authors did not provide an explicit definition nor a time-frame for re-operation.

Studies not included in the meta-analysis: (Lunebourg, Mouhsine et al. 2015). Reported on re-operation (by way of Revision) for Vancouver B2 PFF in their cohorts, however, unfortunately, only explicitly specified the exposure (either 21A ORIF with plate or 21B Revision + ORIF with plate) in one out of two revision cases and hence could not be included in our meta-analysis without introducing some uncertainty.

Modified Charnley-D'Aubigne score excellent outcome

One study reported post-operative Modified Charnley-D'Aubigne score excellent outcome for Revision and ORIF with plate, exposure 25B (Mukundan, Rayan et al. 2010), with a prevalence of 63% (5/8). The time point post-operatively at which the Modified Charnley-D'Aubigne score was assessed was not explicitly reported.

Modified Charnley-D'Aubigne score good outcome

One study reported post-operative Modified Charnley-D'Aubigne score good outcome for Revision and ORIF with plate, exposure 25B (Mukundan, Rayan et al. 2010), with a prevalence of 38 (3/8). The time point post-operatively at which the Modified Charnley-D'Aubigne score was assessed was not explicitly reported.

Revision and cortical strut allograft(s)

There were three studies (all case series) which reported on outcomes for the intervention of Revision and cortical strut allograft(s).

Surgical time

One study reported surgical time (referred to as 'procedure time' by authors) for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with a mean surgical time of 215 minutes (SD and Range NS). No definition of outcome was provided by the authors.

Transfusion packed red blood cell (PRBC) requirement (units)

One study reported transfusion PRBC for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with a mean transfusion PRBC of 2 units (no SD reported).

Subsidence (any)

One study reported subsidence (any) for Revision and cortical strut allograft, exposure 32 (Sledge and Abiri 2002), with a prevalence of 64% (2/7) (2mm and 5mm subsidence). Authors did not provide a definition, method of measuring, nor a time-frame of assessment for subsidence.

Subsidence (>5mm or requiring revision)

One study reported subsidence (>5mm or requiring revision) for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with no events

observed. Authors did not provide a definition, method of measuring nor a time-frame of assessment for subsidence.

Union (fracture)

Two studies reported union for Revision and cortical strut allograft(s), exposure 13C (Holley, Zelken et al. 2007) and 35 (Wu, Yan et al. 2009), with a prevalence of 86% (6/7) and 100% (5/5), respectively. Wu and colleagues reported a mean time to union of 5.6 months (Range 3-9, SD NS), however, Holley and colleagues did not specify a time-frame (Holley, Zelken et al. 2007, Wu, Yan et al. 2009).

Length of stay (LOS)

One study reported hospital LOS for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with a mean LOS time of 6 days (SD and Range NS).

Cortical strut ingrowth

Two studies reported cortical strut ingrowth for Revision and cortical strut allograft(s), exposure 32 (Sledge and Abiri 2002) and 35 (Wu, Yan et al. 2009), with a prevalence of 100% (7/7) and 100% (5/5), respectively. Sledge and colleagues refers to this as spot welding at strut host junction on plain film radiograph and Wu and colleagues as ‘trabecular bridging between any part of the graft and host bone’ (on radiograph). Wu and colleagues report a mean time to achieve cortical strut ingrowth of 11.5 months (SD: 2.4, range: 7;18) (Wu, Yan et al. 2009).

Aseptic loosening femur

One study reported aseptic loosening femur for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with no events observed. No explicit definition or a time-frame of assessment of aseptic loosening femur was reported by authors.

Peri-prosthetic fracture (post-operatively)

One study reported PFF post-operatively for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002), with no events observed. Authors imply the use of plain film radiographs to identify PFF post-operatively, however, the timing of this assessment is not clear.

Pulmonary embolism (PE)

One study reported PE for Revision and cortical strut allograft, exposure 13C (Holley, Zelken et al. 2007), with an event prevalence of 14% (1/7). Authors refer to the PE as 'non-fatal', however, do not provide the method of diagnosis nor a time-frame of assessment. The overall assessment period for the study was a mean 65.9 months (Range 24-111, No SD reported).

Harris hip score (post-operative)

Two studies reported post-operative Harris hip score for Revision and cortical strut allograft, exposure 32 (n=7) (Sledge and Abiri 2002) and 35 (n=5) (Wu, Yan et al. 2009), with mean scores of 83 (SD NS, range NS) and 70 (SD 9.3), respectively. The time point post-operatively at which HHS was calculated was reportedly at final follow-

up in Wu and colleagues, however, not specified by Sledge and colleagues. The overall assessment period across studies was similar and up to around seven years.

Satisfaction score (post-operative) (self-reported visual analogue scale 0 (no pain) – 100 (intolerable pain)

One study reported post-operative satisfaction score for Revision and cortical strut allograft, exposure 35 (n=5) (Wu, Yan et al. 2009), with a mean score of 18.4 (Range 11-25, SD NS). Authors do not specify a time-frame of assessment.

Attainment of pre-fracture mobility status

One study reported attainment pre-fracture mobility status for Revision and cortical strut allograft, exposure 32 (Sledge and Abiri 2002), with an event rate of 86% (6/7). Authors do not specify how this is concluded, nor a time-frame of assessment.

Revision mixed methods/unspecified

There were eleven studies (eight retrospective case series and three retrospective cohort studies) which investigated various outcomes for the intervention of Revision mixed methods/unspecified.

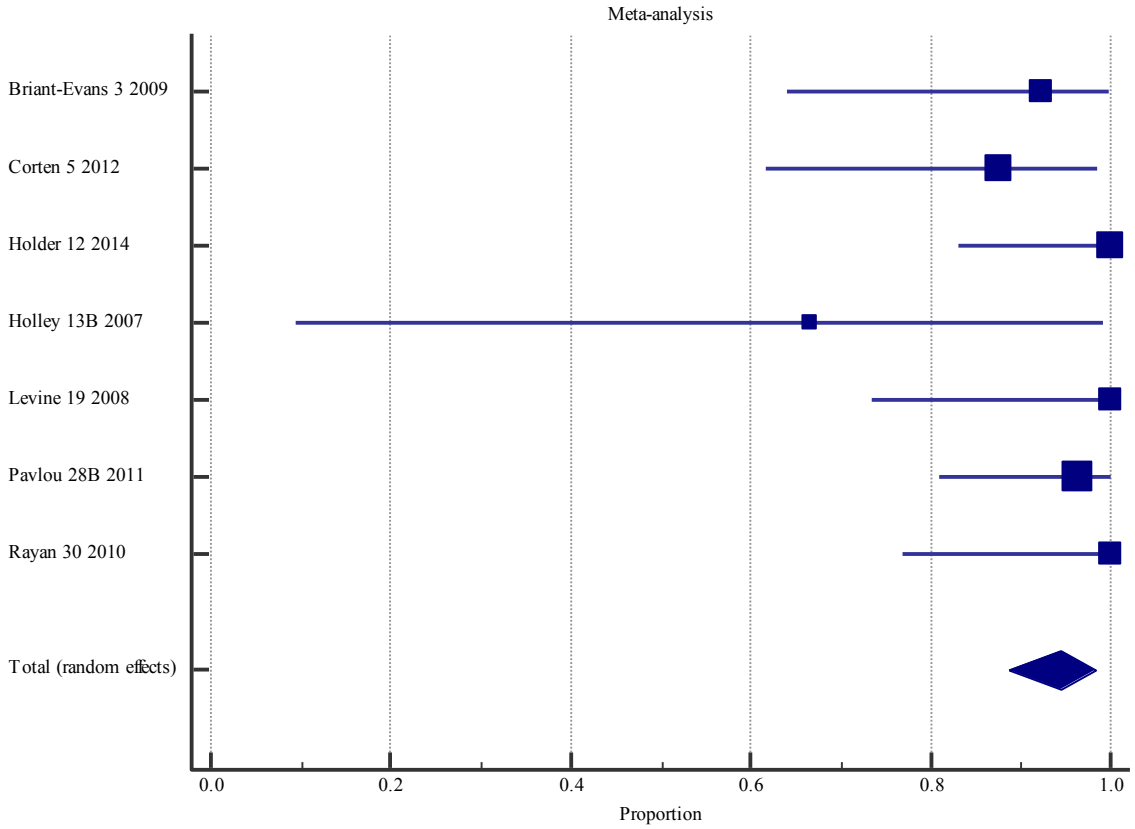
Subsidence (any)

Two studies reported subsidence for Revision mixed methods/unspecified, exposure 5 (Corten, Macdonald et al. 2012) and exposure 30 (Rayan, Konan et al. 2010), with a prevalence of 3.2% (1/31 – 5mm, stable at up to 4 years observation) and 0% (0/14), respectively. Neither studies explicitly defined subsidence.

Subsidence (>5mm or requiring revision)

Two studies reported subsidence (>5mm or requiring revision) for Revision mixed methods/unspecified, exposure 5 (n=31) (Corten, Macdonald et al. 2012) and exposure 30 (n=14) (Rayan, Konan et al. 2010), with no events observed in both studies. Neither studies explicitly defined subsidence.

Union (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Briant-Evans 3 2009	13	92.308	63.970 to 99.805	12.50	13.20
Corten 5 2012	16	87.500	61.652 to 98.449	15.18	15.45
Holder 12 2014	20	100.000	83.157 to 100.000	18.75	18.20
Holley 13B 2007	3	66.667	9.430 to 99.160	3.57	4.31
Levine 19 2008	12	100.000	73.535 to 100.000	11.61	12.41
Pavlou 28B 2011	27	96.296	81.029 to 99.906	25.00	22.46
Rayan 30 2010	14	100.000	76.836 to 100.000	13.39	13.97
Total (fixed effects)	105	94.534	88.561 to 97.942	100.00	100.00
Total (random effects)	105	94.367	88.599 to 98.194	100.00	100.00

Test for heterogeneity

Q	7.4166
DF	6
Significance level	P = 0.2840
I^2 (inconsistency)	19.10%
95% CI for I^2	0.00 to 62.80

Figure 42 Union (overall) for Revision mixed methods/unspecified.

Figure 42 shows the meta-analysis for the seven studies (n=105) that reported union for exposure of interest. Just over half of the studies (4/7) explicitly defined union and the same proportion considered clinical as well as radiographic union. The time to union was only explicitly reported in around a quarter of studies (Table 10). Overall, the prevalence of union was 94.4% (95%CI 88.6 to 98.2). There was a low degree of heterogeneity between the studies (I^2 = 19.1%).

Table 10 Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
3 (Briant-Evans, Veeramootoo et al. 2009)	Union, '…callus bridging (at) fracture in two radiographic views.'	Plain film radiographs	Range 2-11 months
5 (Corten, Macdonald et al. 2012)	Union, '… clinical union in the presence of radiographic evidence of bone bridging in both AP and lateral XR'	Clinical and plain film radiographs	Unclear. Range between 1 and 11 years.
12 (Holder, Papp et al. 2014)	Union, N/S	Plain film radiographs	Unclear. Pooled range of observation for union outcome 2-64 months
13 (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment mean 68 months (Range 26-139, No SD reported))
19 (Levine, Della Valle et al. 2008)	Union, Defined clinically as no pain on weight bearing, palpation and stressing fracture site and; Radiographically by bridging callus	Clinically and plain film radiographs	Unclear. Maximum time to union 24 weeks.
28B (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean 4.26 months (SD 1.9, Range NS)
30 (Rayan, Konan et al. 2010)	Union, N/S	Clinical and plain film radiographs	Minimum 2 years radiographic follow-up (Note: Pooled range 3-6 months to union)

Malunion

One study reported malunion for Revision mixed methods/unspecified, exposure 30 (n=14) (Rayan, Konan et al. 2010), with no events observed. No definition of malunion was provided by the authors.

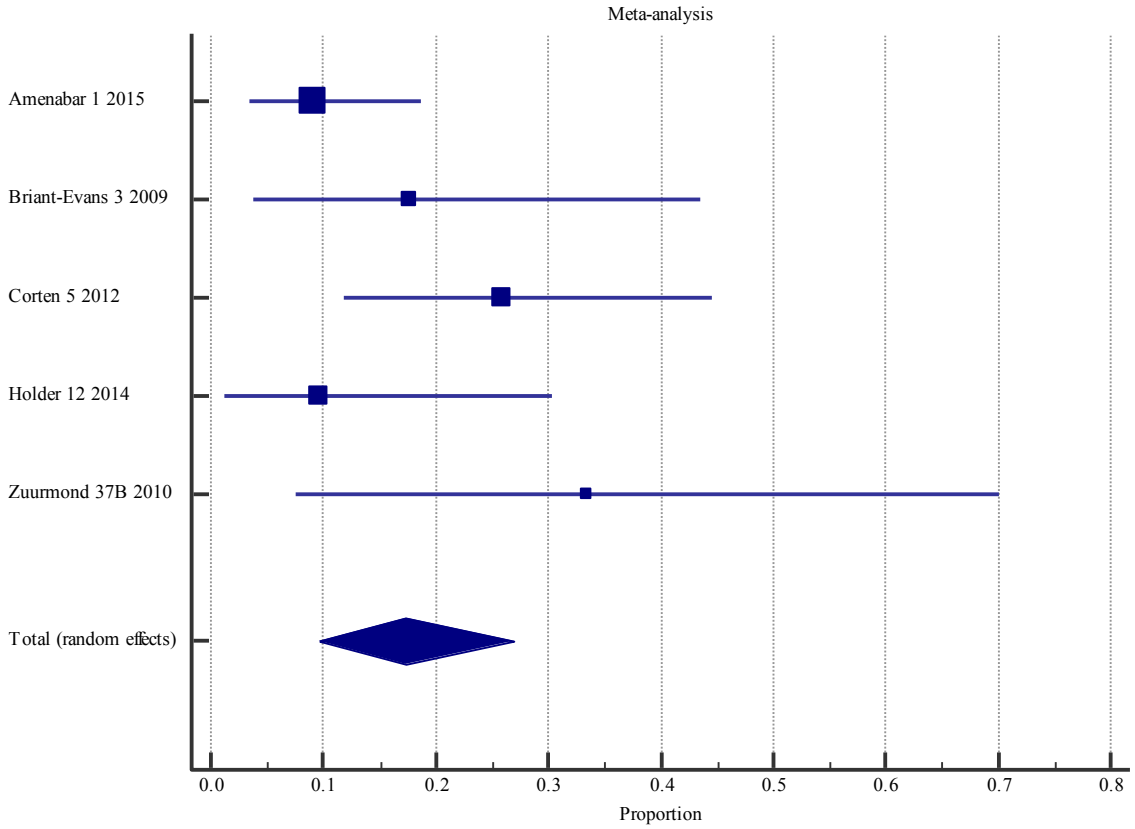
Cortical strut ingrowth

One study reported cortical strut ingrowth for Revision mixed methods/unspecified, exposure 5 (Corten, Macdonald et al. 2012), with a prevalence of 100% (14/14). Method of assessment by authors; 'Ingrowth of the cortical onlay struts was evaluated according to the criteria for incorporation described by Emerson et al. (1992)'.

Union Extended trochanteric osteotomy (ETO)

One study reported union ETO for Revision mixed methods/unspecified, exposure 19 (Levine, Della Valle et al. 2008), with a prevalence of 100% (12/12) at mean 13.1 weeks (no SD or range reported). No definition of union ETO was provided by the authors.

Mortality (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	66	9.091	3.410 to 18.744	44.97	31.46
Briant-Evans 3 2009	17	17.647	3.799 to 43.432	12.08	16.34
Corten 5 2012	31	25.806	11.856 to 44.613	21.48	22.93
Holder 12 2014	21	9.524	1.175 to 30.377	14.77	18.56
Zuurmond 37B 2010	9	33.333	7.485 to 70.070	6.71	10.71
Total (fixed effects)	144	15.641	10.213 to 22.487	100.00	100.00
Total (random effects)	144	17.332	9.552 to 26.839	100.00	100.00

Test for heterogeneity

Q	7.0701
DF	4
Significance level	P = 0.1322
I^2 (inconsistency)	43.42%
95% CI for I^2	0.00 to 79.22

Figure 43 Mortality (overall) for Revision mixed methods/unspecified.

Figure 43 shows the meta-analysis for the five studies (n=144) that reported mortality (overall) for the exposure of interest. 80% (4/5) of the studies provided a time period for mortality, including mortality within 3 months (Holder, Papp et al. 2014), 6 months (Corten, Macdonald et al. 2012), 2 years (Amenabar, Rahman et al. 2015) and 'at end of study' (Briant-Evans, Veeramootoo et al. 2009), which could be between 3 months up to 9 years.

Overall, the prevalence of mortality was 17.3% (95%CI 9.6 to 26.8). There was a moderate degree of heterogeneity between the studies (I^2 = 43.4%). In studies where patients were excluded based on mortality, either directly, e.g. mortality within three months post-operatively OR in-directly, e.g. where minimum follow-up periods were applied to exclusion criteria and reason for not reaching this time period was mortality, the patients were included in the meta-analysis.

Failure (any complication requiring Revision surgery)

One study reported failure for Revision mixed methods/unspecified, exposure 1, (Amenabar, Rahman et al. 2015) with a prevalence of 9.2% (7/76). Authors defined failure '…as those stems that required Revision surgery and replacement for any reason (including infection).' They did not provide an explicit time-frame for these 'failures' between 1.5 and 29.8 months post-operatively.

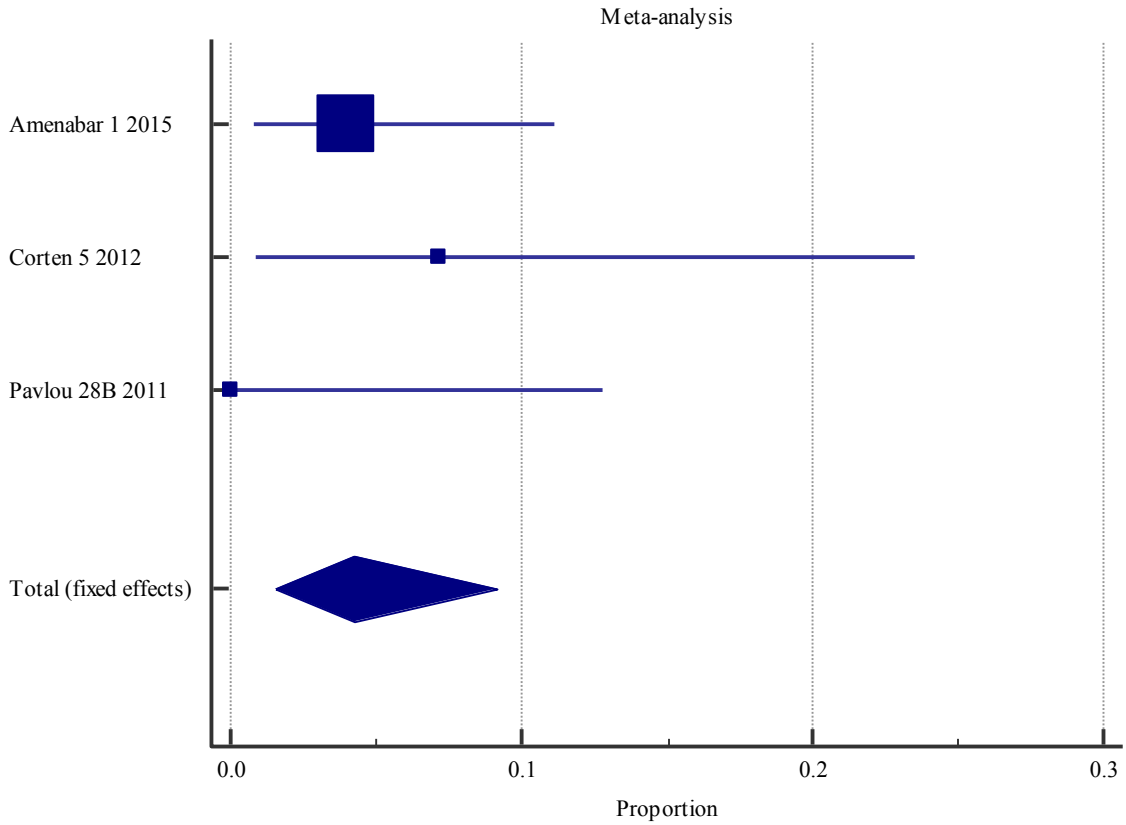
Aseptic loosening femur

One study reported aseptic loosening femur for Revision mixed methods/unspecified, exposure 1 (Amenabar, Rahman et al. 2015), with a prevalence of 6.6% (5/76). No definition of aseptic loosening femur was described by the authors. The time-frame for identification was reported between 1.5 and 29.8 months post-operatively.

Peri-prosthetic fracture (post-operatively)

Two studies reported PFF post-operatively for Revision mixed methods/unspecified, exposure 1 (Amenabar, Rahman et al. 2015) and 5, with prevalence rates of 2.6% (2/76) and 3.2% (1/31), respectively. Authors imply the use of plain film radiographs to identify PFF post-operatively, however, the timing of this assessment is not clear.

Deep surgical site infection



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	76	3.947	0.822 to 11.105	57.46	53.08
Corten 5 2012	28	7.143	0.877 to 23.503	21.64	23.83
Pavlou 28B 2011	27	0.000	0.000 to 12.770	20.90	23.10
Total (fixed effects)	131	4.232	1.513 to 9.166	100.00	100.00
Total (random effects)	131	4.199	1.247 to 8.781	100.00	100.00

Test for heterogeneity

Q	2.3509
DF	2
Significance level	P = 0.3087
I^2 (inconsistency)	14.93%
95% CI for I^2	0.00 to 97.15

Figure 44 Deep surgical site infection (DSSI) for Revision mixed methods/unspecified.

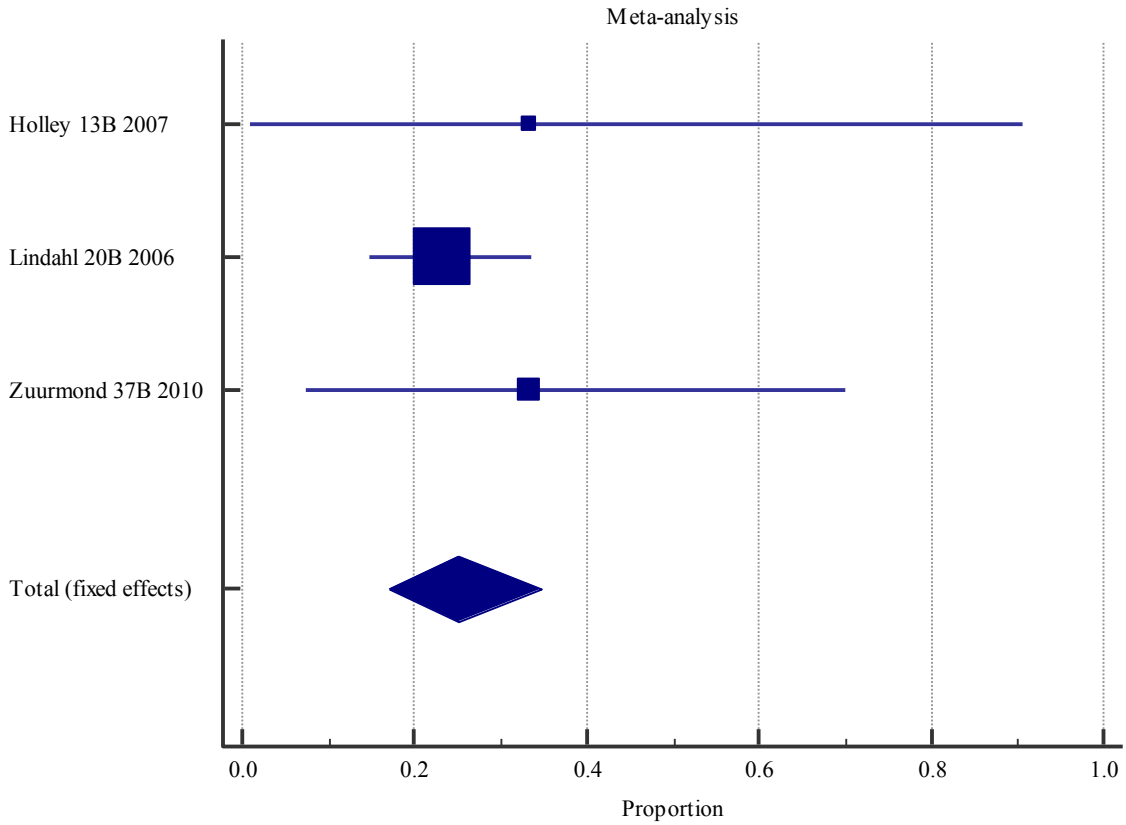
Figure 44 shows the meta-analysis for the three studies (n=131) that reported DSSI for the exposure of interest. No authors provided a definition for DSSI. The explicit time-frame of outcome measurement was not reported in any study.

Overall, the prevalence of DSSI was 4.2% (95%CI 1.5 to 9.2). There was a mild degree of heterogeneity between the studies (I^2 = 14.9%).

Superficial surgical site infection

One study reported SSSI for Revision mixed methods/unspecified, exposure 28B (n=27) (Pavlou, Panteliadis et al. 2011), with no events observed. Authors did not provide a definition, nor a time-frame of assessment for SSSI, however, patients were assessed until union or 12 months, whichever occurred first.

Re-operation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Holley 13B 2007	3	33.333	0.840 to 90.570	3.96	3.96
Lindahl 20B 2006	86	23.256	14.821 to 33.606	86.14	86.14
Zuurmond 37B 2010	9	33.333	7.485 to 70.070	9.90	9.90
Total (fixed effects)	98	25.128	17.026 to 34.740	100.00	100.00
Total (random effects)	98	25.128	17.194 to 34.005	100.00	100.00

Test for heterogeneity

Q	0.8429
DF	2
Significance level	P = 0.6561
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 92.04

Figure 45 Re-operation for Revision mixed methods/unspecified.

Figure 45 shows the meta-analysis for the three studies (n=98) that reported re-operation for the exposure of interest. No authors provided an explicit definition nor time-

frame for re-operation. The overall assessment period across studies was similar, and up to around twelve years.

Overall, the prevalence of re-operation was 25.1% (95%CI 17.0 to 34.7). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Neurovascular injury

One study reported neurovascular injury for Revision mixed methods/unspecified, exposure 30 (Rayan, Konan et al. 2010), with a prevalence of 0.7% (1/14), a sciatic nerve palsy which completely recovered over an unspecified time period.

SF-12 mental score post-operatively (at time of last follow-up)

One study reported post-operative SF-12 mental score for Revision mixed methods/unspecified, exposure 1 (n=76) (Amenabar, Rahman et al. 2015) with a mean score of 55.1 (SD 8.1). Aside from stating score was assessed at final follow-up, explicit time-frame was specified for this outcome. The overall assessment period across studies was similar, and up to around 14 years.

SF-12 physical score post-operatively

One study reported post-operative SF-12 physical score for Revision mixed methods/unspecified, exposure 1 (n=76) (Amenabar, Rahman et al. 2015) with a mean score of 37.4 (SD 9.4). Aside from stating that the score was assessed at final follow-up, an explicit time-frame was specified for this outcome. The overall assessment period across studies was similar, and up to around 14 years.

Harris hip score (post-operative)

Two studies reported post-operative Harris hip score for Revision mixed methods/unspecified, exposure 5 (n=31) (Corten, Macdonald et al. 2012) and 23 (n=6), with mean scores of 77.5 (SD NS, range NS) and 73 (SD 3.2), respectively. The time point post-operatively at which HHS was calculated was not explicitly reported in any study, however, the earliest assessment was performed 10 months and 1 year post-operatively for Corten et al. (Corten, Macdonald et al. 2012) and Moreta et al. (Moreta, Aguirre et al. 2015), respectively.

WOMAC pain score (post-operative)

One study reported post-operative WOMAC pain score for Revision mixed methods/unspecified, exposure 5 (n is unclear) (Corten, Macdonald et al. 2012), with a mean score of 3 (SD NS, range NS). The time point post-operatively for the WOMAC pain score was at a minimum one year.

WOMAC function score (post-operative)

One study reported post-operative WOMAC function score for Revision mixed methods/unspecified, exposure 5 (n is unclear) (Corten, Macdonald et al. 2012), with a mean score of 13 (SD NS, range NS). The time point post-operatively for the WOMAC function score was at a minimum one year.

WOMAC stiffness score (post-operative)

One study reported post-operative WOMAC stiffness score for Revision mixed methods/unspecified, exposure 5 (n is unclear) (Corten, Macdonald et al. 2012), with a

mean score of 2 (SD NS, range NS). The time point post-operatively for the WOMAC function score was at a minimum one year.

Attainment of pre-fracture mobility status

Two studies reported attainment of pre-fracture mobility status for Revision mixed methods/unspecified, exposure 5 and 23, with a prevalence of 50% (8/16) and 42% (6/14), respectively. Corten and colleagues (Corten, Macdonald et al. 2012) did not explicitly report how this was measured or concluded; however, they imply functional assessments were made at the earliest 1 year post-operatively. Moreta and colleagues (Moreta, Aguirre et al. 2015), assessed this based on follow-up clinical review or phone interview using categories of mobility. It is unclear whether or not this pre and post-operative assessment is self-reported, clinician assessed or a combination.

Revision any

There were thirty-five studies (twenty-five retrospective case series and ten cohort studies) which investigated various outcomes for the interventions of Revision any.

Surgical time

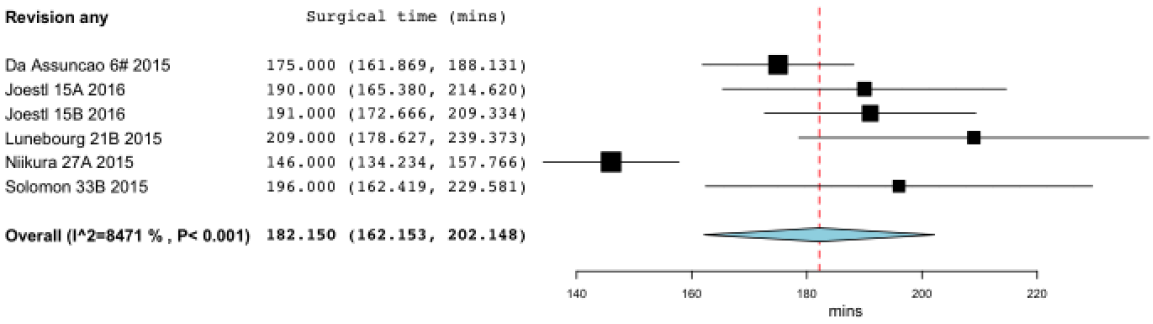


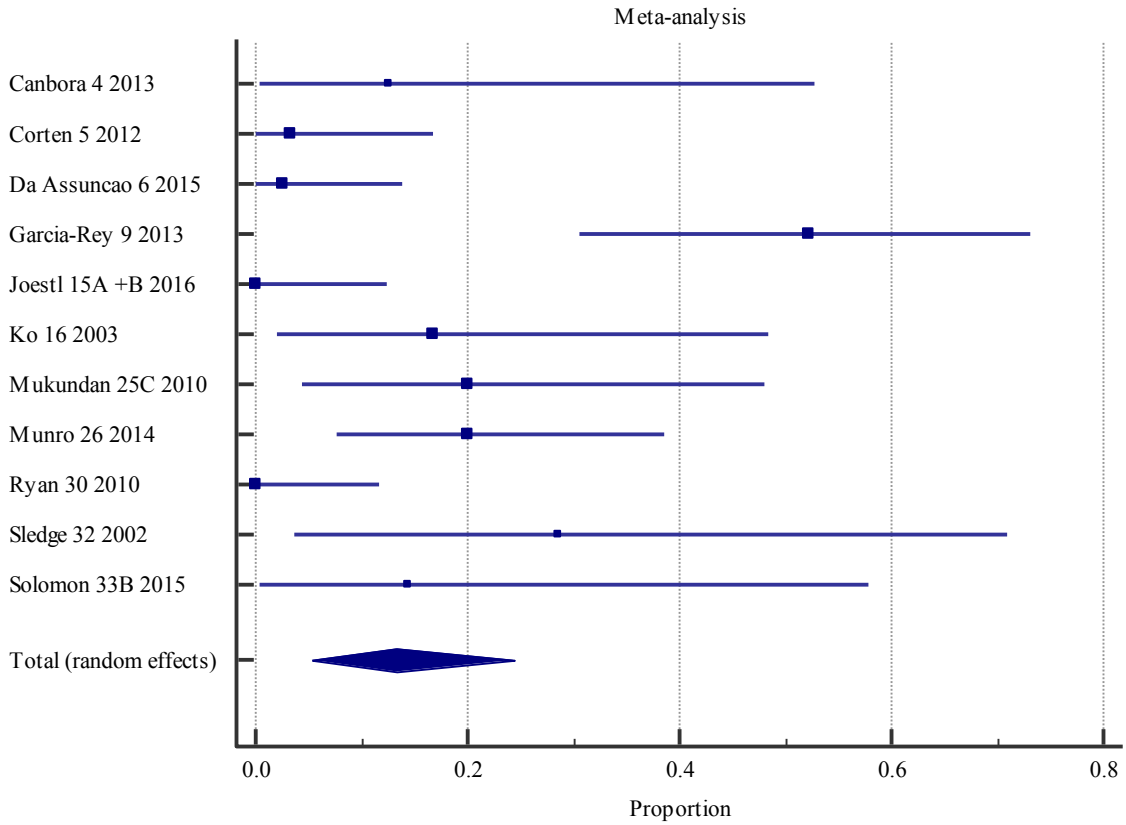
Figure 46 Surgical time (minutes) for Revision any.

Figure 46 shows the meta-analysis for the six studies (n=77) that reported surgical time for the exposure of interest. Only Lunebourg et al. explicitly defined operative time; '… as the time from the incision to the dressing of the surgical wound (as documented on the anaesthetic chart).' (Lunebourg, Mouhsine et al. 2015). Studies refer to the outcome as either 'surgical time' (Da Assunção, Pollard et al. 2015), 'surgical duration' (Joestl, Hofbauer et al. 2016), 'operative time' (Lunebourg, Mouhsine et al. 2015) 'operation time' (Niikura, Lee et al. 2014) or 'skin-to-skin surgical time' (Solomon, Hussenbocus et al. 2015). In this context, the most meaningful reporting for surgical time would be 'skin-to-skin' surgical time as it represents the operative time from incision to the dressing of the surgical wound, which most accurately reflects time spent performing each surgical management strategy (i.e. Revision any).

Overall, the mean surgical time was 182.2 minutes (95%CI 162.2 to 202.1). There was a high degree of heterogeneity between the studies (I^2 = 84.7%).

Studies not included in the meta-analysis: Sledge 32 and colleagues reported on surgical time (mean surgical time 215 minutes), however, unfortunately did not include the standard deviation or range, hence this was excluded from the meta-analysis (Sledge and Abiri 2002).

Subsidence (any)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	12.500	0.316 to 52.651	3.75	7.42
Corten 5 2012	31	3.226	0.0816 to 16.702	13.33	10.26
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	16.25	10.54
Garcia-Rey 9 2013	23	52.174	30.588 to 73.180	10.00	9.77
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	12.08	10.10
Ko 16 2003	12	16.667	2.086 to 48.414	5.42	8.42
Mukundan 25C 2010	15	20.000	4.331 to 48.089	6.67	8.92
Munro 26 2014	30	20.000	7.714 to 38.567	12.92	10.21
Ryan 30 2010	30	0.000	0.000 to 11.570	12.92	10.21
Sledge 32 2002	7	28.571	3.669 to 70.958	3.33	7.08
Solomon 33B 2015	7	14.286	0.361 to 57.872	3.33	7.08
Total (fixed effects)	229	10.636	7.036 to 15.243	100.00	100.00
Total (random effects)	229	13.341	5.222 to 24.451	100.00	100.00

Test for heterogeneity

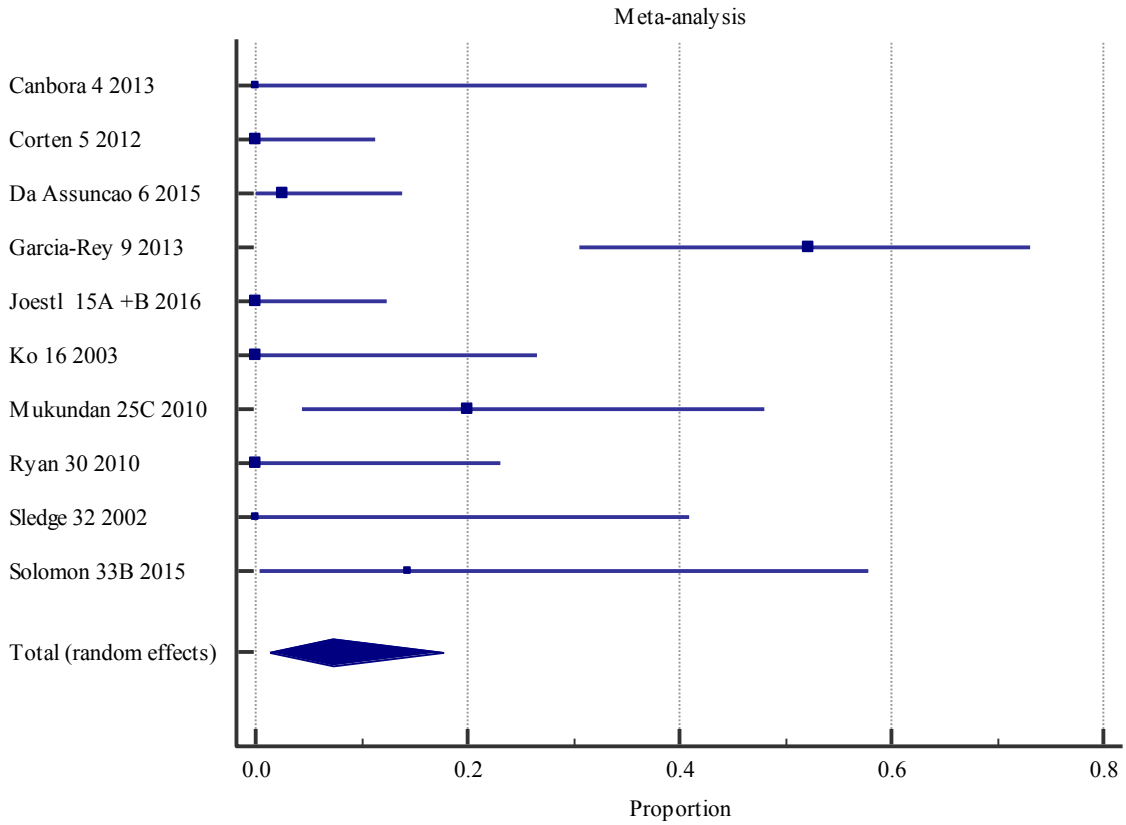
Q	47.7343
DF	10
Significance level	P < 0.0001
I^2 (inconsistency)	79.05%
95% CI for I^2	63.10 to 88.11

Figure 47 Subsidence (any) for Revision any.

Figure 47 shows the meta-analysis for the eleven studies (n=229) that reported subsidence for the exposure of interest. The terms stem subsidence (10/11 studies) and stem migration (1/11 studies) were accepted as subsidence for the purposes of this meta-analysis. Definition of subsidence was provided in the majority of studies (7/11 studies), however, only just under half (5/11 studies) explicitly reported their method for measuring subsidence.

Overall, the prevalence of subsidence was 13.3% (95%CI 5.2 to 24.5). There was a high degree of heterogeneity between the studies (I^2 = 79.1%).

Subsidence (>5mm or requiring revision)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	0.000	0.000 to 36.942	4.66	8.53
Corten 5 2012	31	0.000	0.000 to 11.219	16.58	11.46
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	20.21	11.75
Garcia-Rey 9 2013	23	52.174	30.588 to 73.180	12.44	10.97
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	15.03	11.31
Ko 16 2003	12	0.000	0.000 to 26.465	6.74	9.58
Mukundan 25C 2010	15	20.000	4.331 to 48.089	8.29	10.11
Ryan 30 2010	14	0.000	0.000 to 23.164	7.77	9.95
Sledge 32 2002	7	0.000	0.000 to 40.962	4.15	8.17
Solomon 33B 2015	7	14.286	0.361 to 57.872	4.15	8.17
Total (fixed effects)	183	6.708	3.615 to 11.209	100.00	100.00
Total (random effects)	183	7.271	1.271 to 17.612	100.00	100.00

Test for heterogeneity

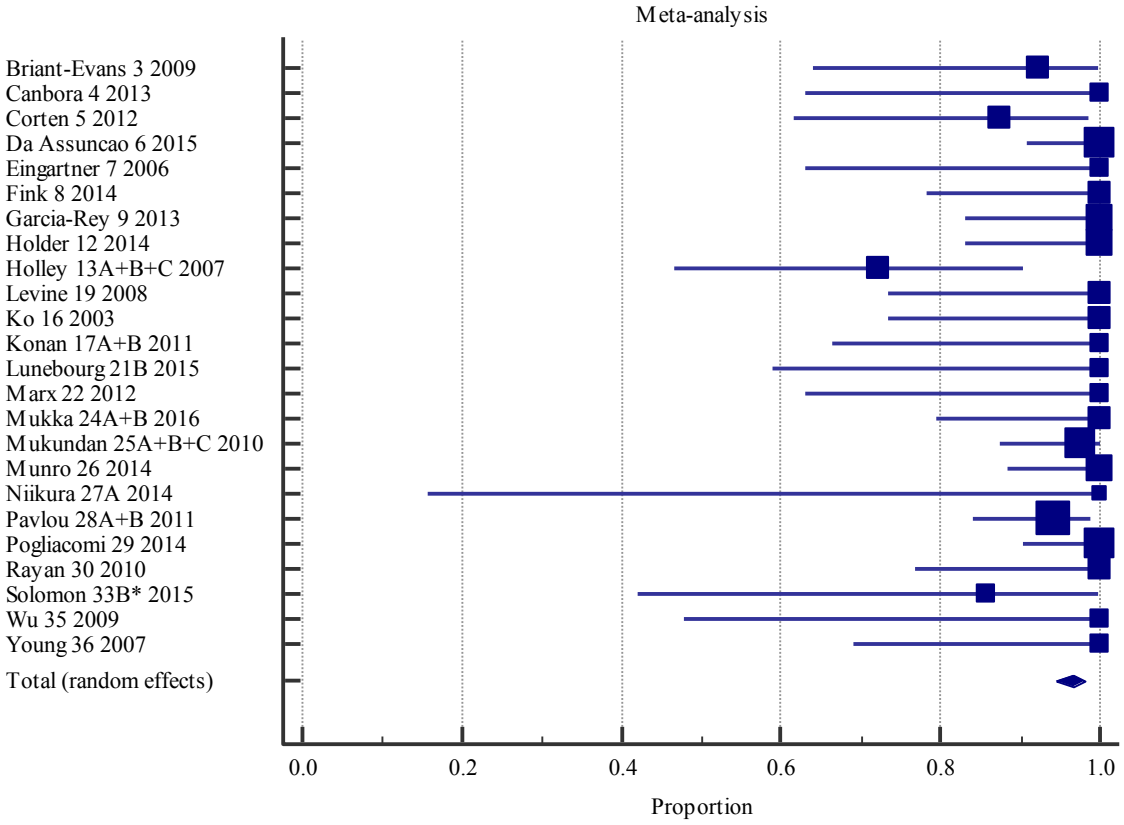
Q	42.8458
DF	9
Significance level	P < 0.0001
I^2 (inconsistency)	78.99%
95% CI for I^2	61.89 to 88.42

Figure 48 Subsidence (>5mm OR requiring revision) for Revision with or without wires/cerclage/cables.

Figure 48 shows the meta-analysis for the ten studies (n=183) that reported subsidence (>5mm or revision) for the exposure of interest. Overall, the prevalence of subsidence >5mm or requiring Revision was 7.3% (95%CI 1.3 to 17.6). There was a high degree of heterogeneity between the studies (I^2 = 79.0%).

Studies not included in the meta-analysis: Munro and colleagues reported on subsidence, however, unfortunately did not include the distance of subsidence amongst the B2 PFF patient group, hence this was excluded from the meta-analysis (Munro, Garbuz et al. 2014).

Union (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Briant-Evans 3 2009	13	92.308	63.970 to 99.805	3.17	3.34
Canbora 4 2013	8	100.000	63.058 to 100.000	2.04	2.20
Corten 5 2012	16	87.500	61.652 to 98.449	3.85	4.00
Da Assuncao 6 2015	38	100.000	90.749 to 100.000	8.82	8.37
Eingartner 7 2006	8	100.000	63.058 to 100.000	2.04	2.20
Fink 8 2014	15	100.000	78.198 to 100.000	3.62	3.78
Garcia-Rey 9 2013	20	100.000	83.157 to 100.000	4.75	4.86
Holder 12 2014	20	100.000	83.157 to 100.000	4.75	4.86
Holley 13A+B+C 2007	18	72.222	46.520 to 90.305	4.30	4.43
Levine 19 2008	12	100.000	73.535 to 100.000	2.94	3.11
Ko 16 2003	12	100.000	73.535 to 100.000	2.94	3.11
Konan 17A+B 2011	9	100.000	66.373 to 100.000	2.26	2.43
Lunebourg 21B 2015	7	100.000	59.038 to 100.000	1.81	1.96
Marx 22 2012	8	100.000	63.058 to 100.000	2.04	2.20
Mukka 24A+B 2016	16	100.000	79.409 to 100.000	3.85	4.00
Mukundan 25A+B+C 2010	42	97.619	87.434 to 99.940	9.73	9.08
Munro 26 2014	30	100.000	88.430 to 100.000	7.01	6.87
Niikura 27A 2014	2	100.000	15.811 to 100.000	0.68	0.75
Pavlou 28A+B 2011	52	94.231	84.053 to 98.794	11.99	10.77
Pogliacomi 29 2014	36	100.000	90.261 to 100.000	8.37	8.01
Rayan 30 2010	14	100.000	76.836 to 100.000	3.39	3.56
Solomon 33B* 2015	7	85.714	42.128 to 99.639	1.81	1.96
Wu 35 2009	5	100.000	47.818 to 100.000	1.36	1.48
Young 36 2007	10	100.000	69.150 to 100.000	2.49	2.66
Total (fixed effects)	418	96.586	94.440 to 98.073	100.00	100.00
Total (random effects)	418	96.554	94.526 to 98.127	100.00	100.00

Test for heterogeneity

Q	24.9667
DF	23
Significance level	P = 0.3520
I^2 (inconsistency)	7.88%
95% CI for I^2	0.00 to 41.20

Figure 49 Union (overall) for Revision any.

Figure 49 shows the meta-analysis for the twenty-four studies (n=418) that reported union (overall) for the exposure of interest. Half of the studies (12/24) explicitly defined union and these were generally defined as the presence of a bridging callus across the main fracture site on a minimum of two or three sides viewed in two views on plain film radiographs. Some studies (6/24) additionally considered clinical union, for example, i.e. the patient being able to fully weight bear without pain and lacked pain on clinical stressing of fracture site (Garcia-Rey, Garcia-Cimbrelo et al. 2013). Only one-third of studies reported a time to union. The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of union was 96.6% (95%CI 94.4 to 98.1). There was a mild degree of heterogeneity between the studies (I^2 = 7.9%).

Table 10 Definition of union, method of measurement, and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
3 (Briant-Evans, Veeramootoo et al. 2009)	Union, '…callus bridging (at) fracture in two radiographic views.'	Plain film radiographs	Range 2-11 months
4 (Canbora, Kose et al. 2013)	Union, 'union defined as bony bridging across osteotomy site or no migration of fracture fragment.'	Plain film radiographs	N/S (Note: time-frame of outcome assessment mean 39 months (Range 15-90, SD not reported))
5 (Corten, Macdonald et al. 2012)	Union, '… clinical union in the presence of radiographic evidence of bone bridging in both AP and lateral XR'	Clinical and plain film radiographs	Unclear. Range between 1 and 11 years.
6 (Da Assunção, Pollard et al. 2015)	Union, 'Radiological union … presence of bridging callus across main fracture site in two orthogonal planes as judged by two experienced consultants'	Plain film radiographs	N/S (Note: time-frame of outcome assessment between 4 and 66 months)
7 (Eingartner, Volkmann et al. 2006)	Union, '… complete osseous consolidation of fracture'	Plain film radiographs	Mean 5.6 months (SD 2#, 3-11)
8 (Fink, Urbansky et al. 2014)	Union, N/S	Plain film radiographs	Mean 3.6 months (SD 1.3, No range given)
9 (Garcia-Rey, Garcia-Cimbrelo et al. 2013)	Union, 'patient was bearing full weight without pain, lacked pain on clinical stressing of fracture site and radiographic evidence of callus bridging the fracture' (on two views in this paper)	Clinical and plain film radiographs	Mean 5 months (Range 3-8, No SD reported)

Table 10 (cont.) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
12 (Holder, Papp et al. 2014)	Union, N/S	Plain film radiographs	Unclear. Pooled range of observation for union outcome 2-64 months
13A (Holley, Zelken et al. 2007) **13B (Holley, Zelken et al. 2007)** **13C (Holley, Zelken et al. 2007)**	Union, N/S	Plain film radiographs	N/S Note: Time-frame of outcome assessment mean 34 months (Range 12-100, No SD reported) (Note: Time-frame of outcome assessment mean 68 months (Range 26-139, No SD reported)) Mean 65.9 months (Range 24-111, No SD reported)
16 (Ko, Lam et al. 2003)	Union, 'Fracture healing was judged by full pain-free weight-bearing ability, lack of pain on clinical stressing at the fracture site, and radiographic evidence of callus bridging the fractures'	Plain film radiographs	Mean 14.5 weeks (Range 12-16, No SD reported)
17A/B(Konan, Rayan et al. 2011)	Union, N/S	N/S '… patients were followed up clinically and radiologically.'	Mean 5.2 months (Range 3-6, No SD reported)
19 (Levine, Della Valle et al. 2008)	Union, Defined clinically as no pain on weight bearing, palpation and stressing fracture site and; Radiographically by bridging callus	Clinically and plain film radiographs	Unclear. Maximum time to union 24 weeks.

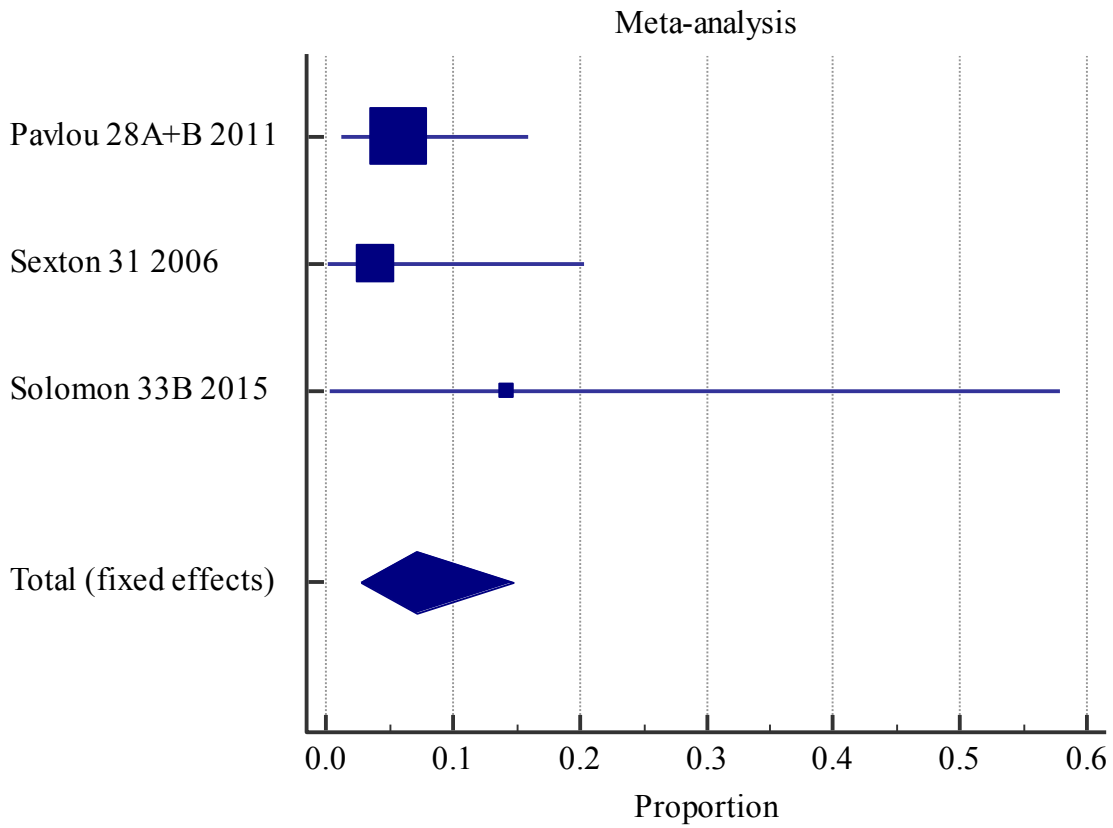
Table 10 (cont.) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
21B (Lunebourg, Mouhsine et al. 2015)	Union, N/S	Radiographs	N/S (Note: worst case by 4 months) Pooled mean observation 42 months (SD 20, 16-90)
22 (Marx, Beier et al. 2012)	Union, N/S	Post-operative radiographs	N/S (Note: Time-frame of outcomes assessment: Mean 74 months (No SD or range reported))
24A (Mukka, Mellner et al. 2016) **24B (Mukka, Mellner et al. 2016)**	Union, N/S	Plain film radiographs	N/S Follow up mean in months: 24 (Range 20-1823 days, No SD stated) 29 (Range 104-2094 days), No SD stated)
25A/25B/25C (Mukundan, Rayan et al. 2010)	Union, 'Fractures were considered to be united clinically when the patient could fully weight bear with no pain' and absence of non-union on plain film radiographs	Clinical and plain film radiographs	N/S (Note: time-frame of outcomes assessment: Minimum 2 years (no maximum reported))
26 (Munro, Garbuz et al. 2014)	Union, 'Femoral union was defined as bone bridging across the fracture site on three of four cortices.'	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled mean observation 54 months (29.8#, 24-143))
27A (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))

Table 10 (cont.) Definition of union, method of measurement and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
28A/B (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	A: Mean 5 months (SD 2.2, Range NS) B: Mean 4.26 months (SD 1.9, Range NS)
29 (Pogliacomi, Corsini et al. 2014)	Union, N/S	Plain film radiographs	N/S specific to B2s Note: Pooled mean 4.5 months (Range 3-8 months (SD N/S)
30 (Rayan, Konan et al. 2010)	Union, N/S	Clinical and plain film radiographs	N/S Minimum 2 years radiographic follow-up (Note: Pooled range 3-6 months to union)
33 (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 59 months (16-137) – excludes 2 deaths <3 months))
35 (Wu, Yan et al. 2009)	Union, N/S	Plain film radiograph	5.6 months (Range 3-9, SD NS
36 (Young, Pandit et al. 2007)	Union, N/S	Plain film radiographs	Mean 4.5 months (No SD or Range reported)

Non-union



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Pavlou 28A+B 2011	52	5.769	1.206 to 15.947	60.92	60.92
Sexton 31 2006	25	4.000	0.101 to 20.352	29.89	29.89
Solomon 33B 2015	7	14.286	0.361 to 57.872	9.20	9.20
Total (fixed effects)	84	7.121	2.711 to 14.698	100.00	100.00
Total (random effects)	84	7.121	2.700 to 13.428	100.00	100.00

Test for heterogeneity

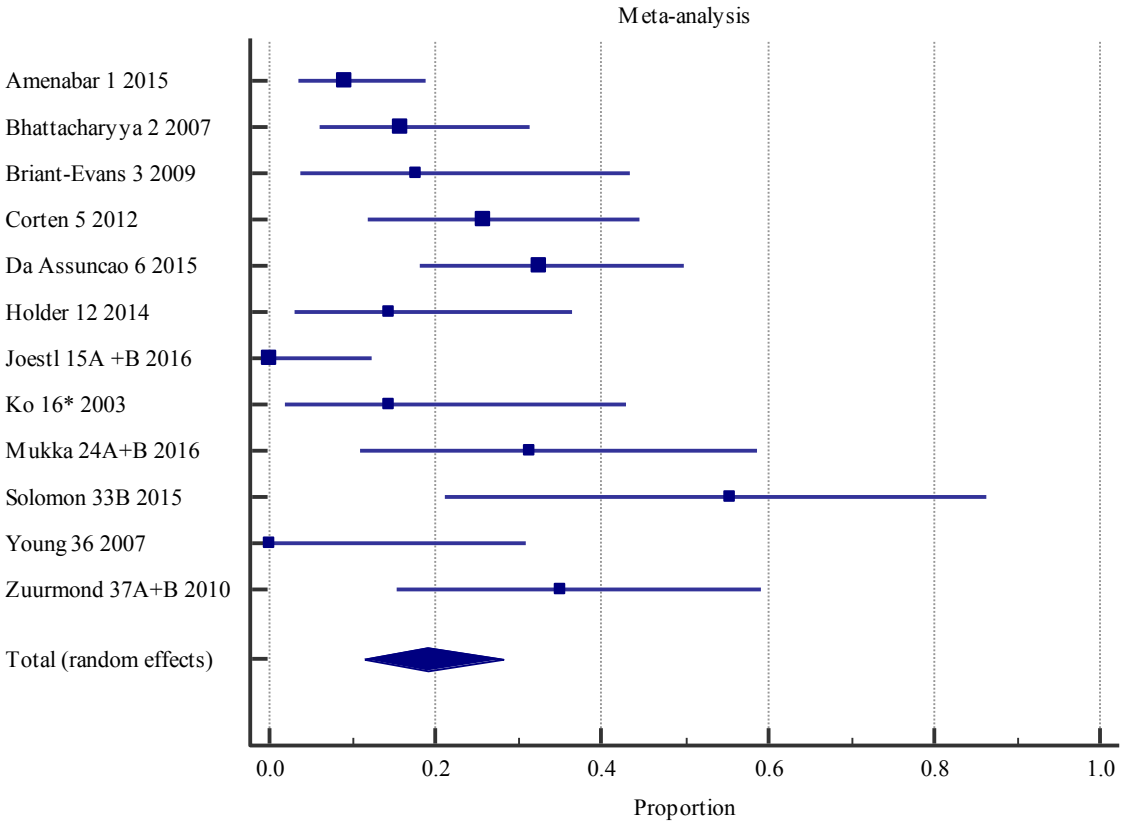
Q	1.0750
DF	2
Significance level	P = 0.5842
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 93.76

Figure 50 Non-union (overall) for Revision any.

Figure 50 shows the meta-analysis for the three studies (n=84) that reported non-union (overall) for exposure of interest. Only Pavlou and colleagues explicitly defined

non-union, being ‘Failure of a fracture to unite 12 months following fixation …’ (Pavlou, Panteliadis et al. 2011). Overall, the prevalence of non-union was 7.1% (95%CI 2.7 to 14.7). There was no important heterogeneity between the studies (I^2 = 0%).

Mortality (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	66	9.091	3.410 to 18.744	21.00	10.60
Bhattacharyya 2 2007	38	15.789	6.023 to 31.253	12.23	9.69
Briant-Evans 3 2009	17	17.647	3.799 to 43.432	5.64	7.81
Corten 5 2012	31	25.806	11.856 to 44.613	10.03	9.27
Da Assuncao 6 2015	37	32.432	18.014 to 49.785	11.91	9.64
Holder 12 2014	21	14.286	3.049 to 36.342	6.90	8.36
Joestl 15A +B 2016	28	0.000	0.000 to 12.344	9.09	9.05
Ko 16* 2003	14	14.286	1.779 to 42.813	4.70	7.29
Mukka 24A+B 2016	16	31.250	11.017 to 58.662	5.33	7.65
Solomon 33B 2015	9	55.556	21.201 to 86.300	3.13	6.06
Young 36 2007	10	0.000	0.000 to 30.850	3.45	6.35
Zuurmond 37A+B 2010	20	35.000	15.391 to 59.219	6.58	8.23
Total (fixed effects)	307	17.598	13.581 to 22.229	100.00	100.00
Total (random effects)	307	19.034	11.367 to 28.129	100.00	100.00

Test for heterogeneity

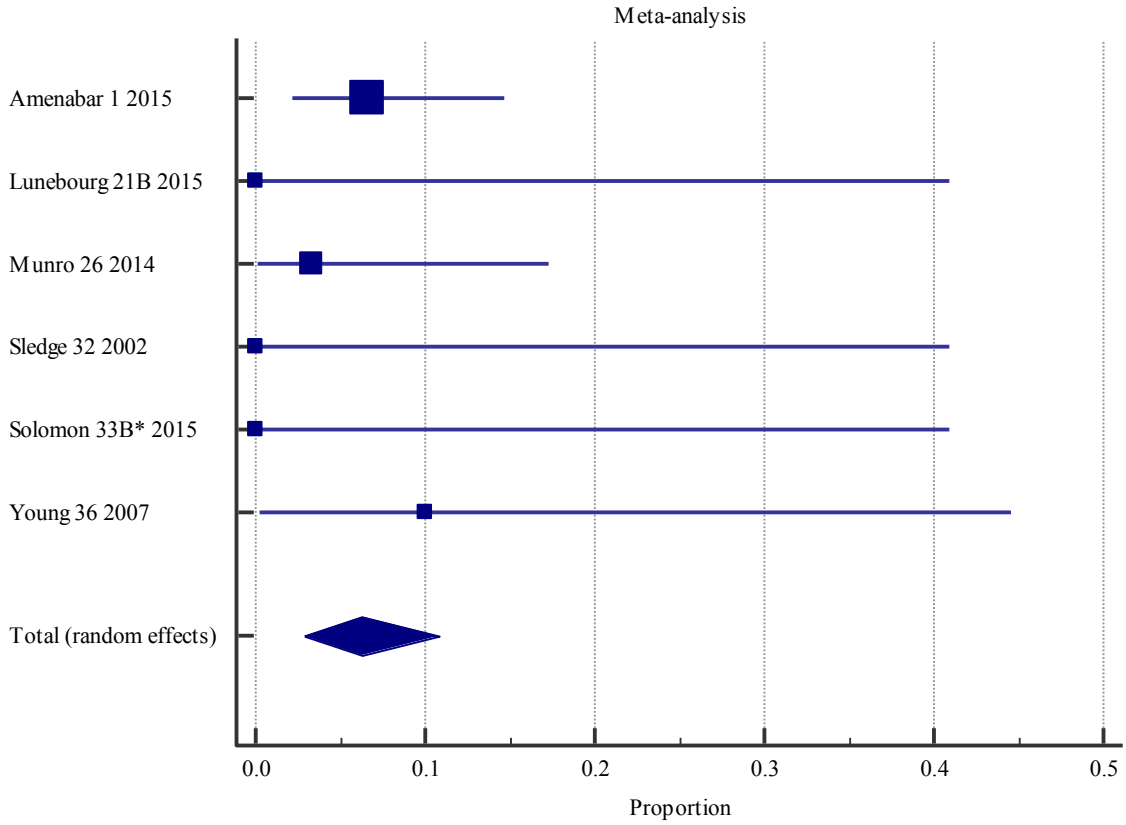
Q	38.9911
DF	11
Significance level	P = 0.0001
I^2 (inconsistency)	71.79%
95% CI for I^2	49.42 to 84.26

Figure 51 Mortality (overall) for Revision any.

Figure 51 shows the meta-analysis for the twelve studies (n=307) that reported mortality (overall) for the exposure of interest.

Overall, the prevalence of mortality was 19.0% (95%CI 11.4 to 28.1). There was a high degree of heterogeneity between the studies (I^2 = 71.8%). In studies where patients were excluded based on mortality, either directly, e.g. mortality within three months post-operatively OR in-directly, e.g. where minimum follow-up periods were applied to exclusion criteria and the reason for not reaching this time period was mortality, the patients were included in the meta-analysis. Note: raw data from Ko et al. was used for this outcome (Ko, Lam et al. 2003).

Aseptic loosening femur



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	76	6.579	2.171 to 14.689	53.85	53.85
Lunebourg 21B 2015	7	0.000	0.000 to 40.962	5.59	5.59
Munro 26 2014	30	3.333	0.0844 to 17.217	21.68	21.68
Sledge 32 2002	7	0.000	0.000 to 40.962	5.59	5.59
Solomon 33B* 2015	7	0.000	0.000 to 40.962	5.59	5.59
Young 36 2007	10	10.000	0.253 to 44.502	7.69	7.69
Total (fixed effects)	137	6.217	2.865 to 11.514	100.00	100.00
Total (random effects)	137	6.217	2.864 to 10.744	100.00	100.00

Test for heterogeneity

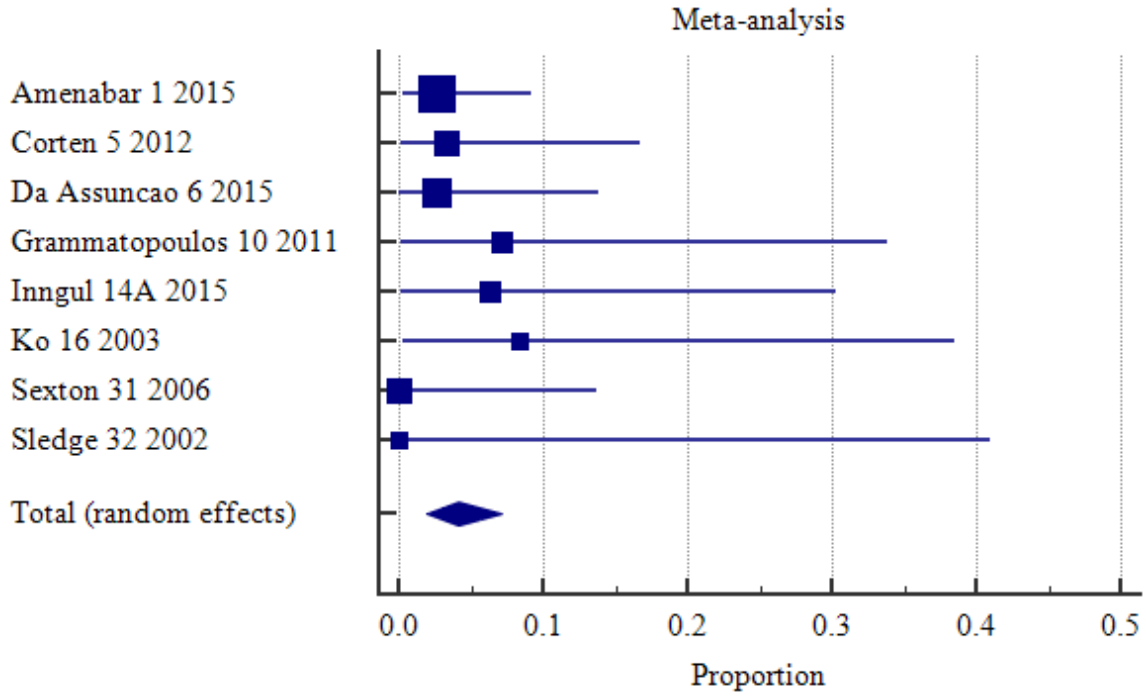
Q	1.3771
DF	5
Significance level	P = 0.9268
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 10.52

Figure 52 Aseptic loosening for Revision any.

Figure 52 shows the meta-analysis for the six studies (n=137) that reported aseptic loosening femur for the exposure of interest. Solomon and colleagues (Solomon, Hussenbocus et al. 2015) defined loosening using Harris' criteria (Harris, McCarthy et al. 1982), the remaining studies did not provide any definition. The overall assessment period across studies was similar, and up to around twelve years.

Overall, the prevalence of aseptic femoral loosening was 6.2% (95%CI 2.9 to 10.5). There was no important heterogeneity between the studies (I^2 = 0%).

Peri-prosthetic fracture post-operatively



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	76	2.632	0.320 to 9.185	33.92	33.92
Corten 5 2012	31	3.226	0.0816 to 16.702	14.10	14.10
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	17.18	17.18
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	6.61	6.61
Inngul 14A 2015	16	6.250	0.158 to 30.232	7.49	7.49
Ko 16 2003	12	8.333	0.211 to 38.480	5.73	5.73
Sexton 31 2006	25	0.000	0.000 to 13.719	11.45	11.45
Sledge 32 2002	7	0.000	0.000 to 40.962	3.52	3.52
Total (fixed effects)	219	4.162	1.964 to 7.644	100.00	100.00
Total (random effects)	219	4.162	1.958 to 7.140	100.00	100.00

Test for heterogeneity

Q	3.7303
DF	7
Significance level	P = 0.8103
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 39.80

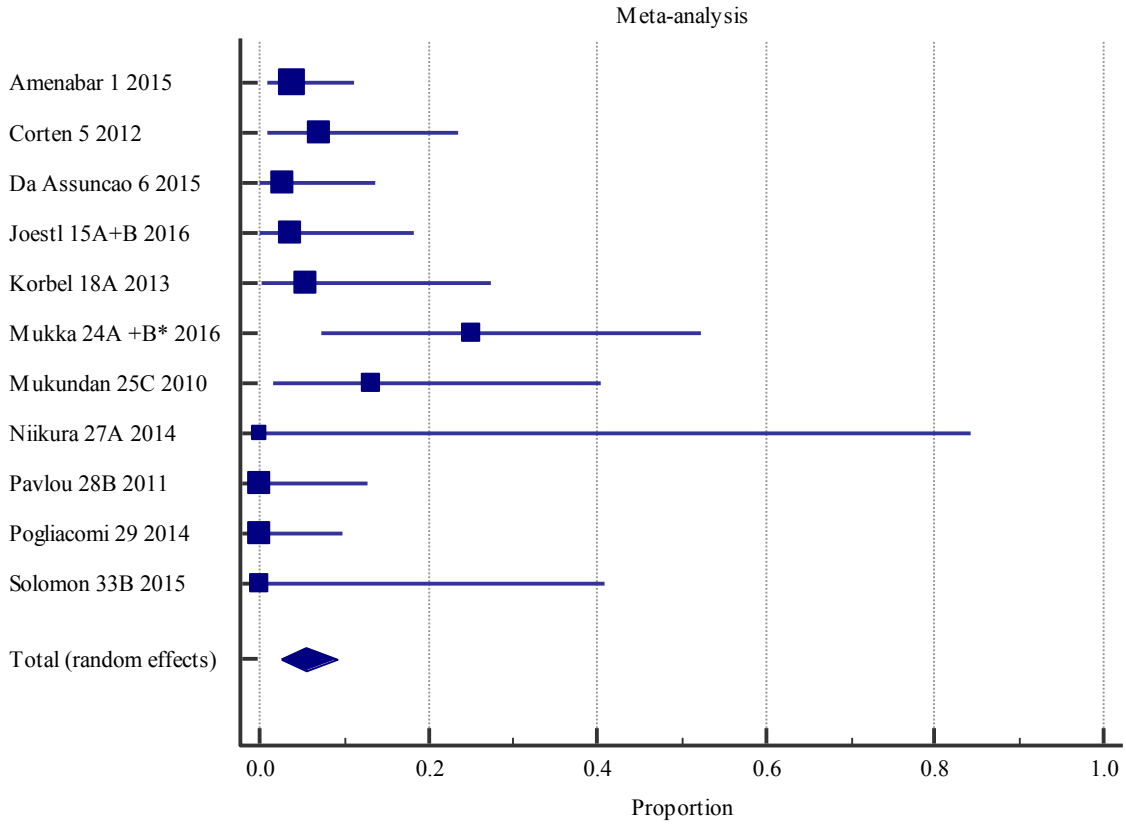
Figure 53 Peri-prosthetic femoral fracture (post-operatively) for Revision any.

Figure 53 shows the meta-analysis for the 8 studies (n=219) that reported post-operative PFF for the exposure of interest. Studies used plain film radiographs to assess

for any new post-operative fracture. The overall assessment period across studies ranged from 0 to 167 months.

Overall, the prevalence of post-operative PFF was 4.2% (95%CI 2.0 to 7.1). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Deep surgical site infection



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	76	3.947	0.822 to 11.105	25.50	17.46
Corten 5 2012	28	7.143	0.877 to 23.503	9.60	10.39
Da Assuncao 6 2015	38	2.632	0.0666 to 13.810	12.91	12.46
Joestl 15A+B 2016	28	3.571	0.0904 to 18.348	9.60	10.39
Korbel 18A 2013	18	5.556	0.141 to 27.294	6.29	7.74
Mukka 24A +B* 2016	16	25.000	7.266 to 52.377	5.63	7.12
Mukundan 25C 2010	15	13.333	1.658 to 40.460	5.30	6.80
Niikura 27A 2014	2	0.000	0.000 to 84.189	0.99	1.57
Pavlou 28B 2011	27	0.000	0.000 to 12.770	9.27	10.15
Pogliacomi 29 2014	36	0.000	0.000 to 9.739	12.25	12.09
Solomon 33B 2015	7	0.000	0.000 to 40.962	2.65	3.84
Total (fixed effects)	291	5.032	2.856 to 8.140	100.00	100.00
Total (random effects)	291	5.424	2.612 to 9.179	100.00	100.00

Test for heterogeneity

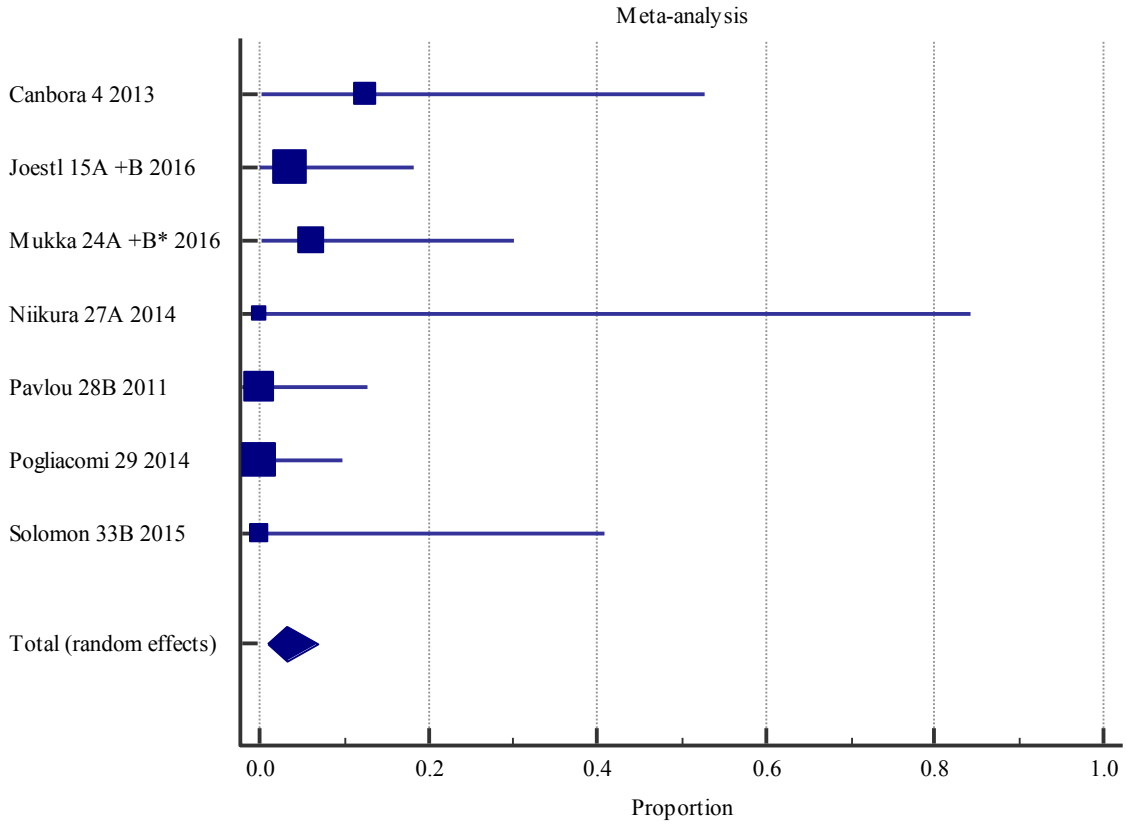
Q	14.8521
DF	10
Significance level	P = 0.1375
I^2 (inconsistency)	32.67%
95% CI for I^2	0.00 to 66.91

Figure 54 Deep surgical site infection (DSSI) for Revision any.

Figure 54 shows the meta-analysis for the eleven studies (n=291) that reported DSSI for the exposure of interest. No authors provided a definition for DSSI, however, one study (Joestl, Hofbauer et al. 2016) implies an aspiration hip joint was performed for diagnosis. The explicit time-frame of outcome measurement was not reported in any study, however, the overall assessment period across studies ranged from 0 to 167 months.

Overall, the prevalence of DSSI was 5.4% (95%CI 2.6 to 9.2). There was a moderate degree of heterogeneity between the studies (I^2 = 32.4%).

Superficial surgical site infection



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	12.500	0.316 to 52.651	6.87	6.87
Joestl 15A +B 2016	28	3.571	0.0904 to 18.348	22.14	22.14
Mukka 24A +B* 2016	16	6.250	0.158 to 30.232	12.98	12.98
Niikura 27A 2014	2	0.000	0.000 to 84.189	2.29	2.29
Pavlou 28B 2011	27	0.000	0.000 to 12.770	21.37	21.37
Pogliacomi 29 2014	36	0.000	0.000 to 9.739	28.24	28.24
Solomon 33B 2015	7	0.000	0.000 to 40.962	6.11	6.11
Total (fixed effects)	124	3.169	0.898 to 7.794	100.00	100.00
Total (random effects)	124	3.169	0.869 to 6.838	100.00	100.00

Test for heterogeneity

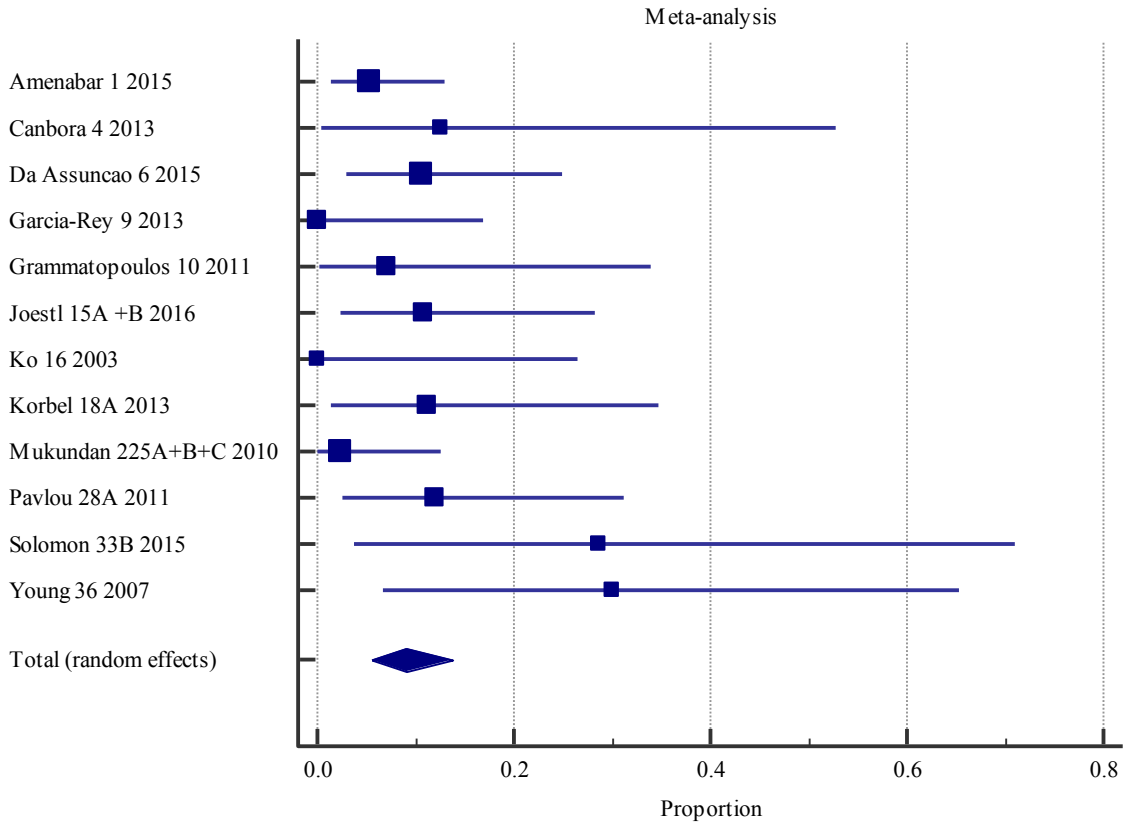
Q	5.5899
DF	6
Significance level	P = 0.4707
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 69.18

Figure 55 Superficial surgical site infection (SSSI) for Revision any.

Figure 55 shows the meta-analysis for the seven studies (n=124) that reported SSSI for the exposure of interest. No authors provided a definition for SSSI, however, one (Canbora, Kose et al. 2013) implies a wound swab was performed for diagnosis. The explicit time-frame of outcome measurement was not reported in any study, however, the overall assessment period across studies ranged from 3 months to 11 years.

Overall, the prevalence of SSSI was 3.2% (95%CI 0.9 to 7.8). There was no important heterogeneity between the studies (I^2 = 0%). Note: raw data from Mukka 24A+B (Mukka, Mellner et al. 2016) was used for this outcome.

Dislocation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Amenabar 1 2015	76	5.263	1.452 to 12.931	24.84	16.49
Canbora 4 2013	8	12.500	0.316 to 52.651	2.90	4.11
Da Assuncao 6 2015	38	10.526	2.943 to 24.805	12.58	11.88
Garcia-Rey 9 2013	20	0.000	0.000 to 16.843	6.77	7.99
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	4.84	6.23
Joestl 15A +B 2016	28	10.714	2.267 to 28.226	9.35	9.93
Ko 16 2003	12	0.000	0.000 to 26.465	4.19	5.57
Korbel 18A 2013	18	11.111	1.375 to 34.712	6.13	7.44
Mukundan 225A+B+C 2010	42	2.381	0.0603 to 12.566	13.87	12.54
Pavlou 28A 2011	25	12.000	2.547 to 31.219	8.39	9.25
Solomon 33B 2015	7	28.571	3.669 to 70.958	2.58	3.72
Young 36 2007	10	30.000	6.674 to 65.245	3.55	4.86
Total (fixed effects)	298	8.411	5.572 to 12.075	100.00	100.00
Total (random effects)	298	9.097	5.401 to 13.636	100.00	100.00

Test for heterogeneity

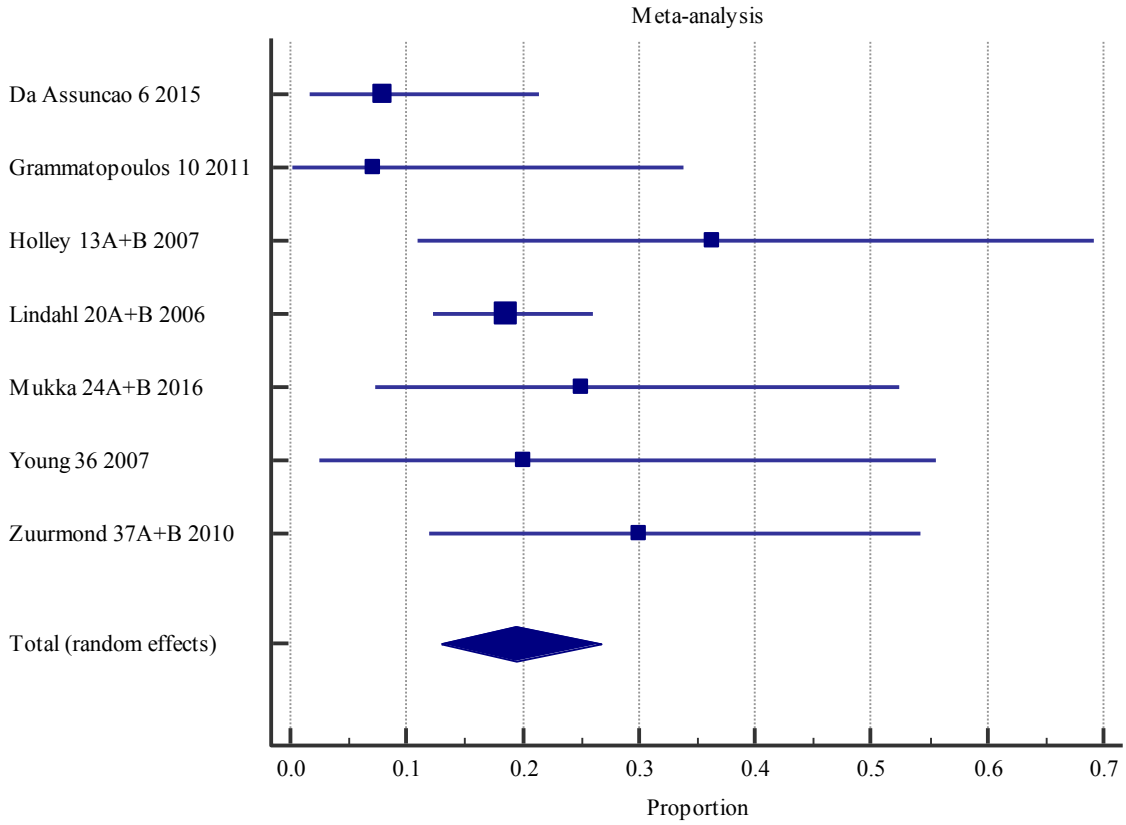
Q	16.3019
DF	11
Significance level	P = 0.1303
I^2 (inconsistency)	32.52%
95% CI for I^2	0.00 to 65.95

Figure 56 Dislocation for Revision any.

Figure 56 shows the meta-analysis for the twelve studies (n=298) that reported dislocation for the exposure of interest. No authors provided a definition for dislocation. Only one study, Solomon 33 et al., reported a time period within which dislocation occurred, which was less than 3 months post-operatively (Solomon, Hussenbocus et al. 2015). The overall assessment period across studies was similar, and up to around fourteen years. Amongst studies where events occurred, only 10% (1/10) reported a direction of dislocation.

Overall, the prevalence of dislocation was 9.1% (95%CI 5.4 to 13.6). There was a moderate degree of heterogeneity between the studies (I^2 = 32.5%).

Re-operation (any)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Da Assuncao 6 2015	38	7.895	1.659 to 21.377	15.54	18.85
Grammatopoulos 10 2011	14	7.143	0.181 to 33.868	5.98	9.57
Holley 13A+B 2007	11	36.364	10.926 to 69.210	4.78	7.97
Lindahl 20A+B 2006	135	18.519	12.357 to 26.111	54.18	33.24
Mukka 24A+B 2016	16	25.000	7.266 to 52.377	6.77	10.56
Young 36 2007	10	20.000	2.521 to 55.610	4.38	7.41
Zuurmond 37A+B 2010	20	30.000	11.893 to 54.279	8.37	12.40
Total (fixed effects)	244	18.752	14.118 to 24.139	100.00	100.00
Total (random effects)	244	19.372	12.961 to 26.718	100.00	100.00

Test for heterogeneity

Q	8.7646
DF	6
Significance level	P = 0.1873
I^2 (inconsistency)	31.54%
95% CI for I^2	0.00 to 70.85

Figure 57 Re-operation for Revision any.

Figure 57 shows the meta-analysis for the seven studies (n=244) that reported re-operation for the exposure of interest. No authors provided an explicit definition nor a time-frame for re-operation. The overall assessment period across studies was similar, and up to around twelve years.

Overall, the prevalence of Re-operation was 19.4% (95%CI 13.0 to 26.7). There was a low degree of heterogeneity between the studies (I^2 = 31.5%).

Harris hip score post-operatively

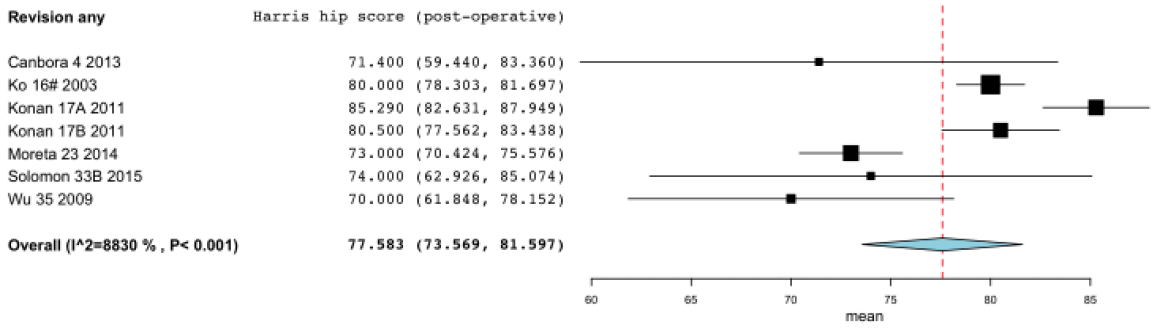


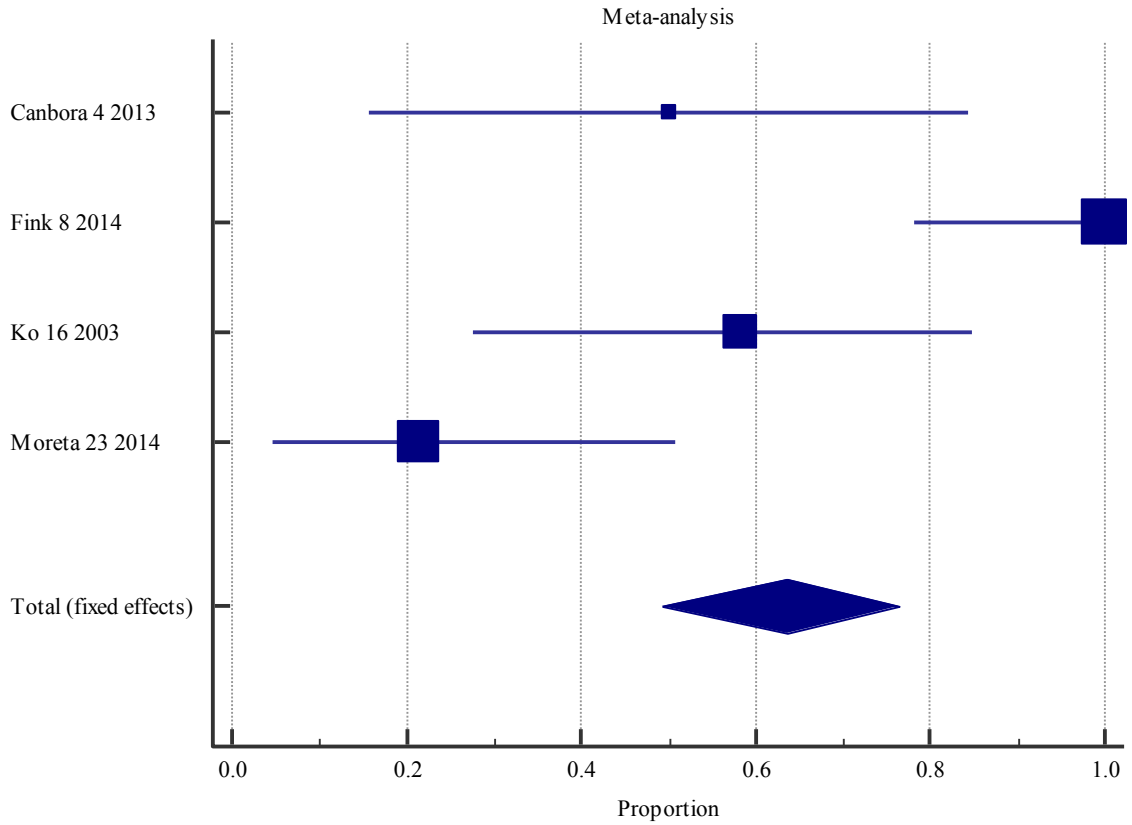
Figure 58 Harris hip score (HHS) (post-operative) for Revision any.

Figure 58 shows the meta-analysis for the seven studies (n=52) that reported post--operative HHS for the exposure of interest. The time point post-operatively at which HHS was calculated was not explicitly reported in any study, however, Canbora and colleagues and Wu and colleagues state this was conducted at final follow-up (Wu, Yan et al. 2009, Canbora, Kose et al. 2013). The overall assessment period across studies ranged from 15 to 137 months.

Overall, the mean HHS was 77.6 (95%CI 73.6 to81.6). There was a high degree of heterogeneity between the studies (I^2 = 88.3%).

Studies not included in the meta-analysis: (Sledge and Abiri 2002, Young, Pandit et al. 2007, Corten, Macdonald et al. 2012). All these studies reported on post-operative HHS, however, unfortunately did not include the standard deviation or range, hence they were excluded from this meta-analysis (see Appendix IV for individual scores).

Beals and Towers' criteria excellent outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	50.000	15.701 to 84.299	16.98	23.95
Fink 8 2014	15	100.000	78.198 to 100.000	30.19	25.57
Ko 16 2003	12	58.333	27.667 to 84.835	24.53	25.06
Moreta 23 2014	14	21.429	4.658 to 50.798	28.30	25.42
Total (fixed effects)	49	63.633	49.277 to 76.408	100.00	100.00
Total (random effects)	49	61.512	21.372 to 93.962	100.00	100.00

Test for heterogeneity

Q	28.8491
DF	3
Significance level	P < 0.0001
I^2 (inconsistency)	89.60%
95% CI for I^2	76.21 to 95.46

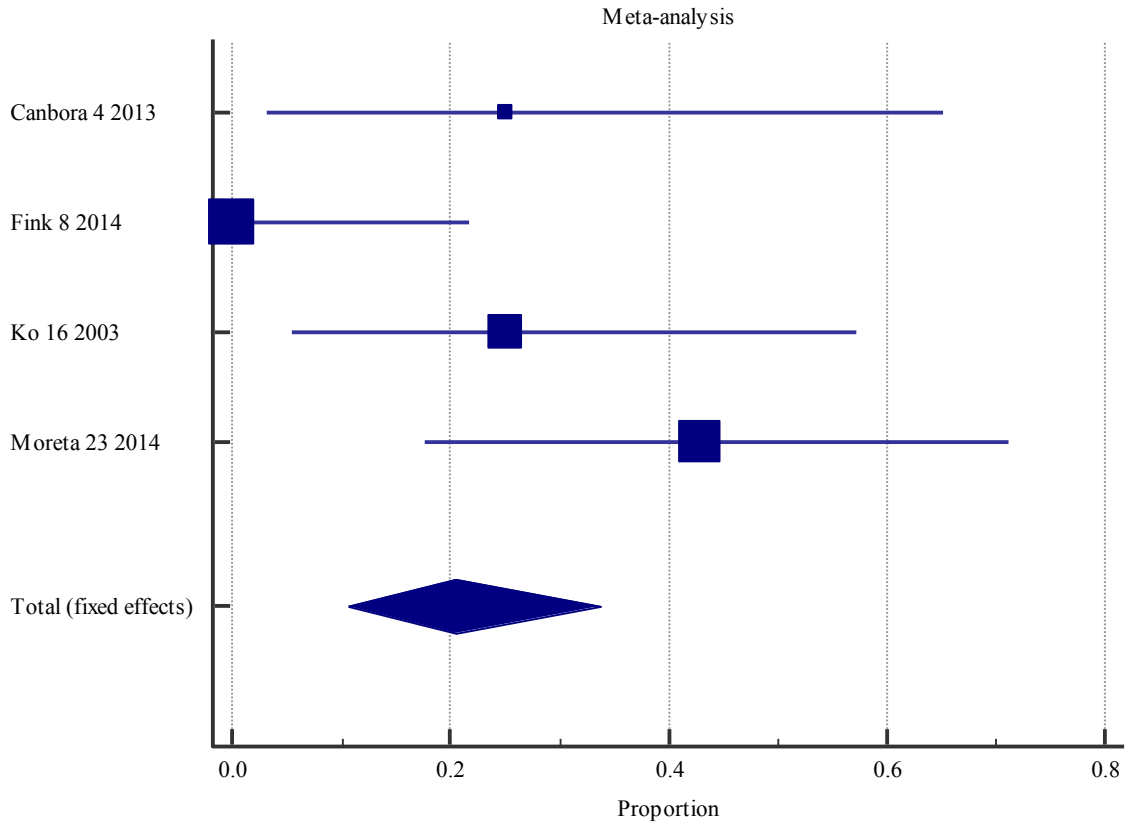
Figure 59 Beals and Towers' criteria excellent outcome for Revision any.

Figure 59 shows the meta-analysis for the four studies (n=49) that reported Beals and Towers' criteria for the exposure of interest. The time point post-operatively at which

the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues (Canbora, Kose et al. 2013) state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) and Moreta and colleagues (Moreta, Aguirre et al. 2015) that it was conducted at a minimum 10 months post-operatively. The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria excellent outcome was 63.3% (95%CI 49.3 o 76.4). There was a high degree of heterogeneity between the studies (I^2 = 90.0%).

Beals and Towers' criteria good outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	25.000	3.185 to 65.086	16.98	22.54
Fink 8 2014	15	0.000	0.000 to 21.802	30.19	26.36
Ko 16 2003	12	25.000	5.486 to 57.186	24.53	25.10
Moreta 23 2014	14	42.857	17.661 to 71.139	28.30	25.99
Total (fixed effects)	49	20.427	10.595 to 33.738	100.00	100.00
Total (random effects)	49	21.440	4.423 to 46.556	100.00	100.00

Test for heterogeneity

Q	11.7979
DF	3
Significance level	P = 0.0081
I^2 (inconsistency)	74.57%
95% CI for I^2	29.21 to 90.87

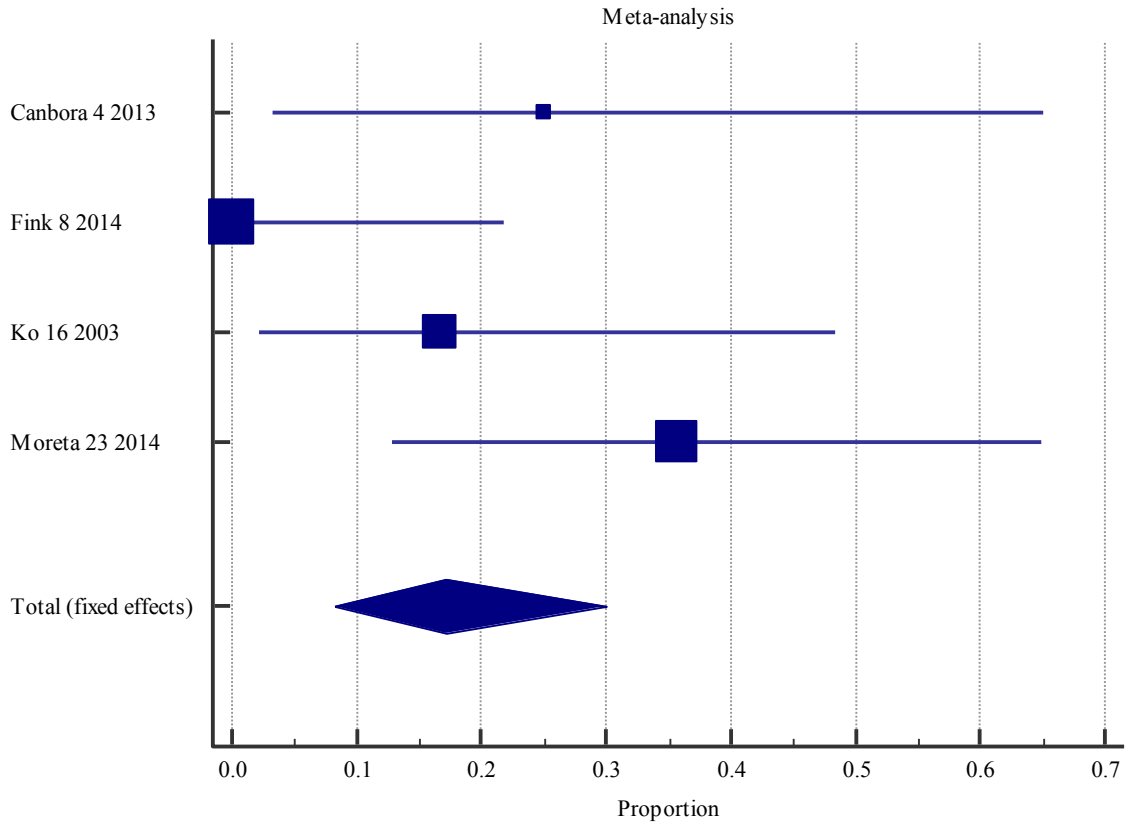
Figure 60 Beals and Towers' criteria good outcome for Revision any.

Figure 60 shows the meta-analysis for the four studies (n=49) that reported Beals and Towers' criteria for the exposure of interest. The time point post-operatively at which

the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues (Canbora, Kose et al. 2013) states this was conducted at final follow-up, mean 5 months (15-90, no SD reported) and Moreta and colleagues (Moreta, Aguirre et al. 2015) that it was conducted at minimum 10 months post-operatively. The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria good outcome was 20.4% (95%CI 10.6 to 33.7). There was a moderate degree of heterogeneity between the studies ($I^2 = 74.6\%$).

Beals and Towers' criteria poor outcome



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Canbora 4 2013	8	25.000	3.185 to 65.086	16.98	21.97
Fink 8 2014	15	0.000	0.000 to 21.802	30.19	26.71
Ko 16 2003	12	16.667	2.086 to 48.414	24.53	25.10
Moreta 23 2014	14	35.714	12.760 to 64.862	28.30	26.22
Total (fixed effects)	49	17.148	8.190 to 29.995	100.00	100.00
Total (random effects)	49	18.082	3.904 to 39.493	100.00	100.00

Test for heterogeneity

Q	9.3776
DF	3
Significance level	P = 0.0247
I^2 (inconsistency)	68.01%
95% CI for I^2	7.07 to 88.99

Figure 61 Beals and Towers' criteria poor outcome for Revision any.

Figure 61 shows the meta-analysis for the four studies (n=49) that reported Beals and Towers' criteria for the exposure of interest. The time point post-operatively at which

the Beals and Towers' criteria were assessed was not explicitly reported in any study, however, Canbora and colleagues (Canbora, Kose et al. 2013) state this was conducted at final follow-up, mean 5 months (15-90, no SD reported) and Moreta and colleagues (Moreta, Aguirre et al. 2015) that it was conducted at minimum 10 months post-operatively. The overall assessment period across studies was similar, and up to around seven years.

Overall, the prevalence of Beals and Towers' criteria poor outcome was 17.1% (95%CI 8.2 to 30.0). There was a moderate degree of heterogeneity between the studies ($I^2 = 68.0\%$).

Oxford hip score (post-operative)

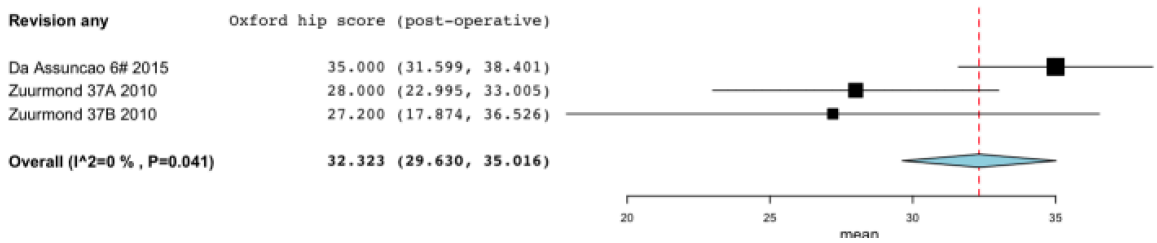


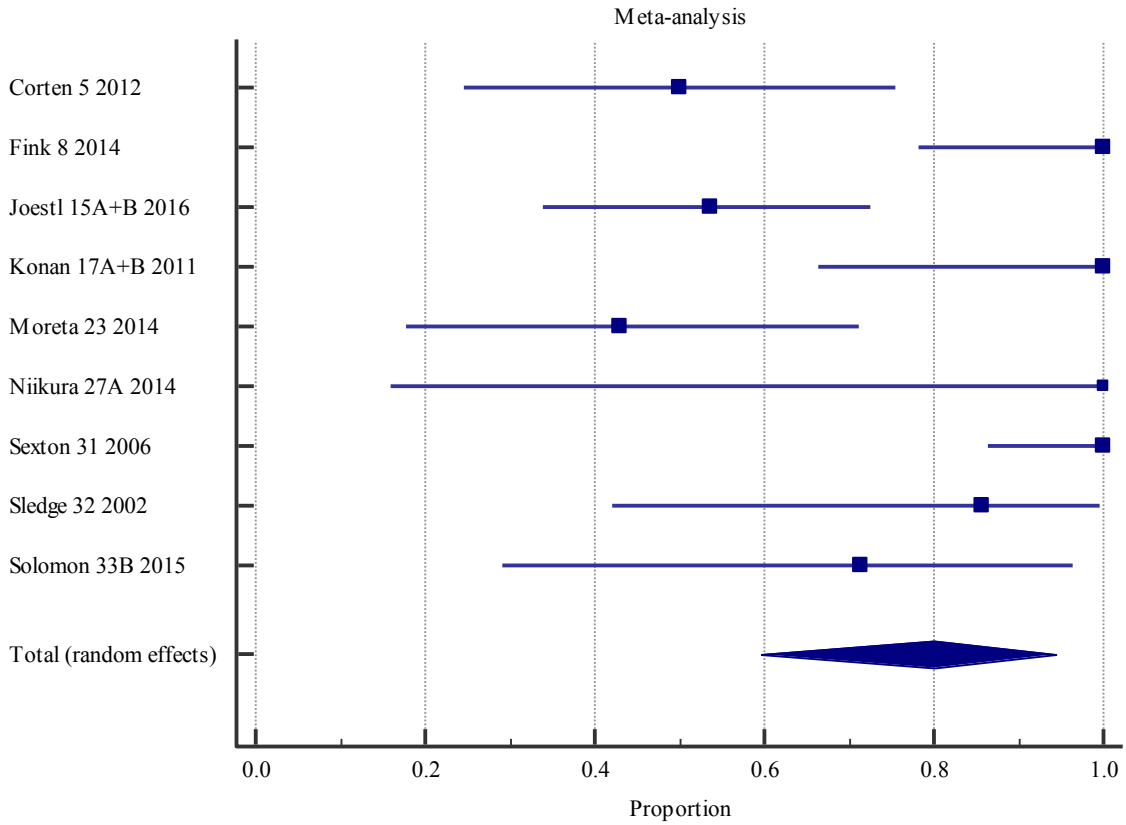
Figure 62 Oxford hip score (OHS) (post-operative) for any.

Figure 62 shows the meta-analysis for the three studies (n=36) that reported post-operative OHS for the exposure of interest. The time-frame post-operatively at which OHS was calculated was a mean of 26 months (SD NS, Range NS) and 64.9 months (Range 16–157, SD NS), for Da Assunção and Zuurmond, respectively (Zuurmond, van Wijhe et al. 2010, Da Assunção, Pollard et al. 2015).

Overall, the mean OHS was 32.3 (95%CI 29.6 to 35.0). There was no important heterogeneity between the studies (I^2 = 0%).

Studies not included in the meta-analysis: (Young, Pandit et al. 2007, Munro, Garbuz et al. 2014). Both reported OHS post-operatively (with mean scores of 74 (n=16) and 32 (n=7), respectively, however, unfortunately did not include the standard deviation or range, hence were excluded from this meta-analysis.

Attainment of pre-fracture mobility status



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Corten 5 2012	16	50.000	24.651 to 75.349	12.88	11.97
Fink 8 2014	15	100.000	78.198 to 100.000	12.12	11.88
Joestl 15A+B 2016	28	53.571	33.870 to 72.489	21.97	12.67
Konan 17A+B 2011	9	100.000	66.373 to 100.000	7.58	10.95
Moreta 23 2014	14	42.857	17.661 to 71.139	11.36	11.76
Niikura 27A 2014	2	100.000	15.811 to 100.000	2.27	7.38
Sexton 31 2006	25	100.000	86.281 to 100.000	19.70	12.55
Sledge 32 2002	7	85.714	42.128 to 99.639	6.06	10.41
Solomon 33B 2015	7	71.429	29.042 to 96.331	6.06	10.41
Total (fixed effects)	123	78.711	70.739 to 85.352	100.00	100.00
Total (random effects)	123	79.902	59.469 to 94.368	100.00	100.00

Test for heterogeneity

Q	51.1715
DF	8
Significance level	P < 0.0001
I^2 (inconsistency)	84.37%
95% CI for I^2	72.01 to 91.27

Figure 63 Attainment of pre-fracture mobility status for Revision with or without wires/cerclage/cables.

Figure 63 shows the meta-analysis for the nine studies (n=123) that reported attainment of pre-fracture mobility status for the exposure of interest. The time point post-operatively at which mobility status was assessed was only reported by Sexton and colleagues, which was 18 months post-operatively (Sexton, Stossel et al. 2006). There was no explicit reporting of how this assessment was made by authors (e.g. clinical or self-reported) except for Moreta and colleagues, who stated clinical appointment or phone interview was used for assessment (Moreta, Aguirre et al. 2015). The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of attainment pre-fracture mobility status was 79.9% (95%CI 59.5 to 94.4). There was a high degree of heterogeneity between the studies (I^2 = 84.4%).

ORIF with plate

There were eleven studies (five retrospective cohort studies and six retrospective case series) which investigated various outcomes for the interventions of ORIF with plate.

Surgical time

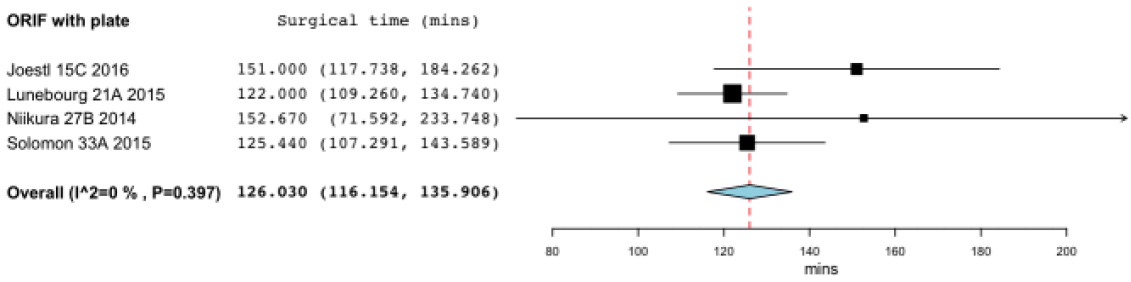


Figure 64 Surgical time (minutes) for ORIF with plate.

Figure 64 shows the meta-analysis for the four studies (n=39) that reported surgical time for the exposure of interest. Studies referred to the outcome as either 'surgical duration' (Joestl, Hofbauer et al. 2016), 'operative time' (Lunebourg, Mouhsine et al. 2015) 'operation time' (Niikura, Lee et al. 2014) or 'skin-to-skin surgical time' (Solomon, Hussenbocus et al. 2015), all of which were accepted to mean surgical time for the purposes of this meta-analysis. Only Lunebourg and colleagues explicitly defined operative time as '…the time from the incision to the dressing of the surgical wound' (as documented on the anaesthetic chart) (Lunebourg, Mouhsine et al. 2015).

Overall, the mean surgical time was 126.0 minutes (95%CI 116.2 to 135.9). There was no important heterogeneity between the studies (I^2 = 0%).

Blood loss (intra-operative)

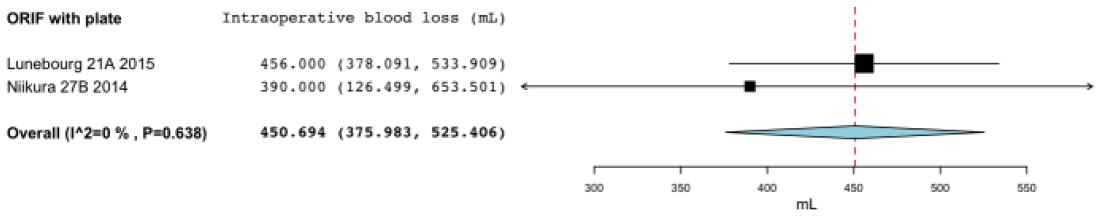


Figure 65 Blood loss (intra-operative) for ORIF with plate.

Figure 65 shows the meta-analysis for the two studies (n=19) that reported intra-operative blood loss for the exposure of interest. Neither study explicitly defined blood loss, however, Lunebourg and colleagues state it was '… found on the anaesthetic report' (Lunebourg, Mouhsine et al. 2015).

Overall, the mean blood loss was 450mL (95%CI 376 to 525). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Transfusion packed red blood cell (PRBC) requirement (units)

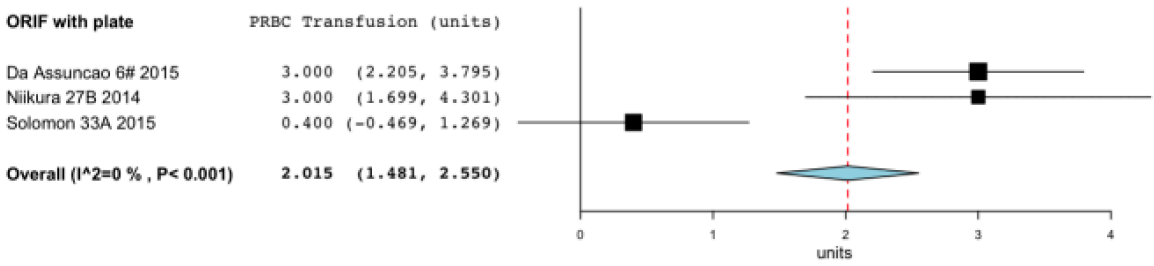


Figure 66 Transfusion packed red blood cell (PRBC) requirement for ORIF with plate.

Figure 66 shows the meta-analysis for the three studies (n=50) that reported Transfusion PRBC for the exposure of interest. The studies refer to the outcome as either 'transfusion' (6) 'intra-operative transfusion' (27B) or 'peri-operative transfusion' (33B), all of which were accepted as transfusion PRBC requirement. Overall, the mean transfusion requirement was 2.0 units (95%CI 1.5 to 2.5). There was no important heterogeneity between the studies (I^2 = 0%).

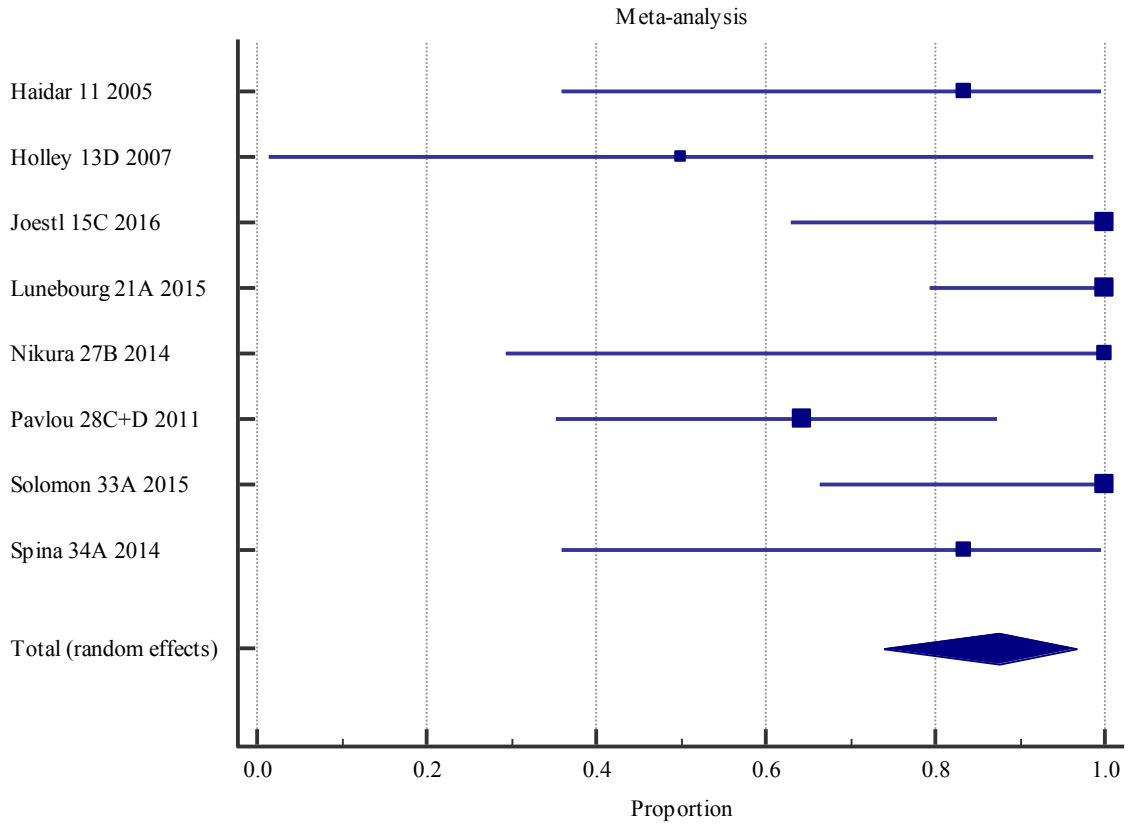
Transfusion PRBC (1 or more units required within 48 hours of surgery)

One study reported Transfusion PRBC requirement within 48 hours of surgery for ORIF with plate, exposure 15C (Joestl, Hofbauer et al. 2016), with an event rate of 63% (5/8).

Subsidence (any)

Two studies reported subsidence for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016) and exposure 33A (n=9), with no events observed in either study. While Joestl et al. did not define subsidence, Solomon and colleagues did (Solomon, Hussenbocus et al. 2015).

Union (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	83.333	35.877 to 99.579	9.72	11.82
Holley 13D 2007	2	50.000	1.258 to 98.742	4.17	6.95
Joestl 15C 2016	8	100.000	63.058 to 100.000	12.50	13.38
Lunebourg 21A 2015	16	100.000	79.409 to 100.000	23.61	17.11
Nikura 27B 2014	3	100.000	29.240 to 100.000	5.56	8.47
Pavlou 28C+D 2011	14	64.286	35.138 to 87.240	20.83	16.42
Solomon 33A 2015	9	100.000	66.373 to 100.000	13.89	14.03
Spina 34A 2014	6	83.333	35.877 to 99.579	9.72	11.82
Total (fixed effects)	64	88.388	78.666 to 94.738	100.00	100.00
Total (random effects)	64	87.444	73.763 to 96.556	100.00	100.00

Test for heterogeneity

Q	14.8052
DF	7
Significance level	P = 0.0386
I^2 (inconsistency)	52.72%
95% CI for I^2	0.00 to 78.75

Figure 67 Union (overall) for ORIF plate.

Figure 67 shows the meta-analysis for the nine studies (n=64) that reported union (overall) for exposure of interest. 3/8 (37.5%) studies explicitly defined union (Table 11) and the same proportion additionally considered clinical union. One-quarter (2/8) of studies reported a time to union. The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of union was 87.4% (95%CI 73.8 to 96.6). There was a moderate degree of heterogeneity between the studies (I^2 = 52.7%).

Table 11 Definition of union, method of measurement, and time to union among the included studies.

Study	Definition	Method of measurement	Time to union
11 (Haidar and Goodwin 2005)	Union, N/S	Clinical and plain film radiographs	at mean 4.1 months (3-5 months)
13D (Holley, Zelken et al. 2007)	Union, N/S	Plain film radiographs	N/S (Note: Time-frame of outcome assessment Mean 69.5 months (Range 57-82, No SD reported)
15C (Joestl, Hofbauer et al. 2016)	Union, 'Fracture union was defined clinically as the ability to bear weight without pain at the fracture site and radiographically as the presence of callus bridging in a minimum of three cortices on both the antero-posterior and lateral radiographs'	Clinical and plain film radiographs	N/S (Note: Time-frame of outcome assessment: Range 9-50 months)
21A (Lunebourg, Mouhsine et al. 2015)	Union, N/S	Plain film radiographs	N/S (Note: worst case by 4 months) Pooled mean observation 42 months (SD 20, 16-90)
27B (Niikura, Lee et al. 2014)	Union, N/S	Plain film radiographs	N/S (Note: time-frame for outcomes assessment: Pooled follow-up mean 18.4 months (SD 14.2, range NS))
28C/D (Pavlou, Panteliadis et al. 2011)	Union, Radiographic union defined as: '…cortical continuity on both lateral and AP (antero-posterior) radiographs.' Clinical union defined as: '…as pain-free weight bearing with or without aid.'	Clinical and plain film radiographs	Mean C: 8.8 (SD 4.0, Range NS) D: 4.4 (SD 0.51, Range NS)
33A (Solomon, Hussenbocus et al. 2015)	Union, Radiographic healing: 'no visible fracture line on all Xray views available (AP, lateral and oblique).'	Plain film radiographs	N/S (Note: Time-frame of outcomes assessment: Median 67 months (13-82) – excludes 3 deaths <3 months
34A (Spina, Rocca et al. 2014)	Union, N/S	Plain film radiographs	N/S Note: Time-frame of outcomes assessment: Pooled (n=61) range 1 to 130 months

Non-union

One study reported non-union for ORIF with plate, exposure 28C and 28D, with a prevalence of 40% (4/10) and 25% (1/4), respectively. Pavlou and colleagues defined non-union as 'Failure of a fracture to unite 12 months following fixation…' (Pavlou, Panteliadis et al. 2011).

Femoral osteolysis

One study reported femoral osteolysis for ORIF with plate, exposure 33A (n=9) (Solomon, Hussenbocus et al. 2015), with no events observed. Femoral osteolysis was defined as: a greater than 3mm diameter nonlinear demarcated lesion (recorded for each Gruen zone) (Solomon, Hussenbocus et al. 2015), however, no time-frame was stipulated. The overall assessment period across studies was similar, and up to around seven years.

Loss of reduction (fracture)

One study reported loss of reduction (fracture) for ORIF with plate, exposure 27B (n=3) (Niikura, Lee et al. 2014), with no events observed. No explicit definition of loss of reduction was reported.

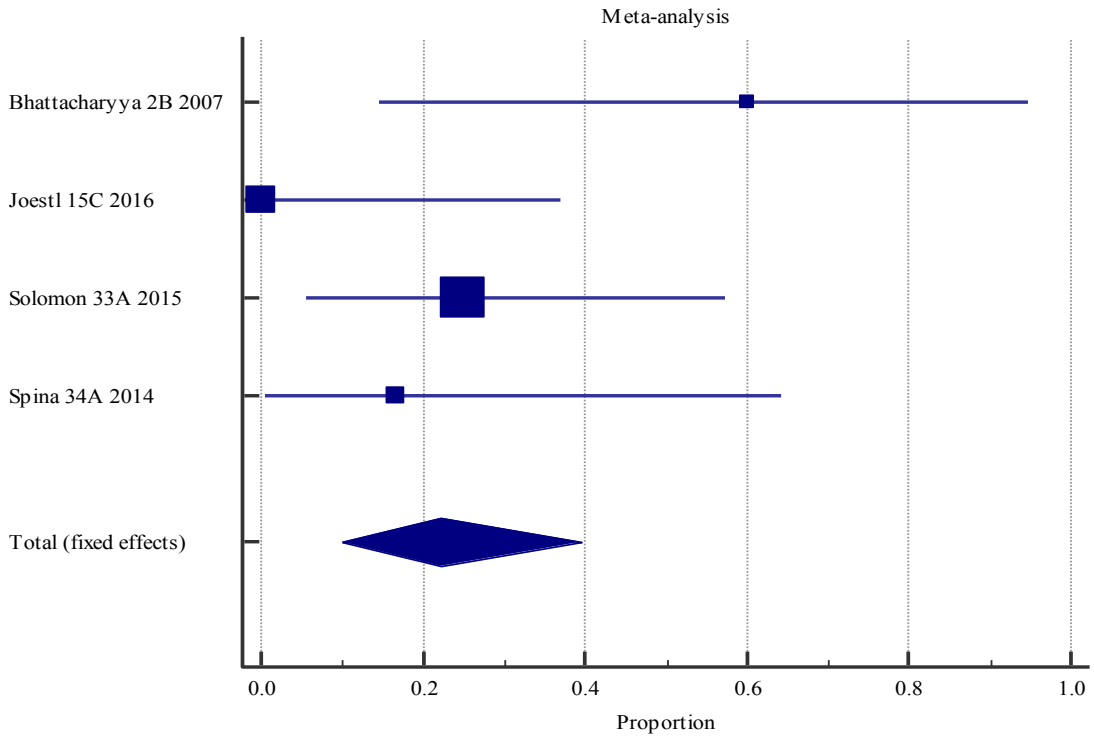
Malunion

Two studies reported malunion for ORIF with plate, exposure 21A (Lunebourg, Mouhsine et al. 2015) and 27B (Niikura, Lee et al. 2014), with event rates of 0/16 (0%) and 0/3 (0%), respectively. Malunion was defined by both authors as any angular deformity greater than 5° (in any plane).

Length of stay

One study reported length of stay for ORIF with plate, exposure 15C (n=8), (Joestl, Hofbauer et al. 2016) with a mean length of stay 26 days (SD 13). Joestl et al. specifies ‘hospital’ length of stay.

Mortality (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Bhattacharyya 2B 2007	5	60.000	14.663 to 94.726	17.14	21.56
Joestl 15C 2016	8	0.000	0.000 to 36.942	25.71	25.83
Solomon 33A 2015	12	25.000	5.486 to 57.186	37.14	29.40
Spina 34A 2014	6	16.667	0.421 to 64.123	20.00	23.21
Total (fixed effects)	31	22.175	9.940 to 39.380	100.00	100.00
Total (random effects)	31	23.161	5.561 to 48.072	100.00	100.00

Test for heterogeneity

Q	7.3208
DF	3
Significance level	P = 0.0623
I^2 (inconsistency)	59.02%
95% CI for I^2	0.00 to 86.35

Figure 68 Mortality (overall) for ORIF with plate.

Figure 68 shows the meta-analysis for the four studies (n=31) that reported mortality (overall) for the exposure of interest. Bhattacharyya was the only study to specify a time-frame for mortality, reporting cumulative deaths at 4 years. Both deaths in

the 33A Solomon study occurred within three months post-operatively (Solomon, Hussenbocus et al. 2015). The overall assessment period across the remaining studies was 9-50 months (Joestl, Hofbauer et al. 2016) and 1-130 months (Spina, Rocca et al. 2014).

Overall, the prevalence of mortality was 22.2% (95%CI 9.9 to 39.4). There was a moderate degree of heterogeneity between the studies (I^2 = 59.0%). In studies where patients were excluded based on mortality, either directly, e.g. mortality within three months post-operatively OR in-directly, e.g. where minimum follow-up periods were applied to exclusion criteria and reason for not reaching this time period was mortality, the patients were included in the meta-analysis.

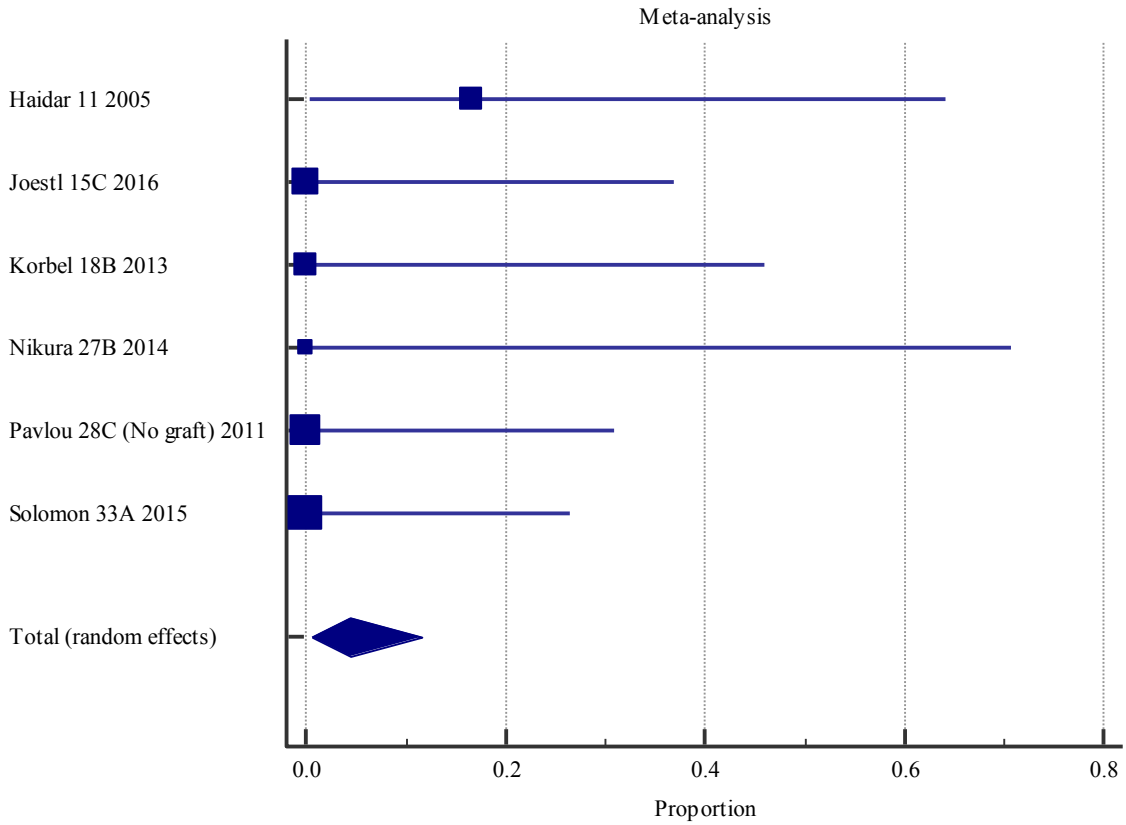
Intra-operative mortality

One study reported intra-operative mortality for ORIF with plate, exposure 27B (n=3) (Niikura, Lee et al. 2014), with no events observed.

Aseptic loosening femur

One study reported aseptic loosening femur for ORIF with plate, exposure 33A (n=9), with no events observed (Solomon, Hussenbocus et al. 2015). The term femoral loosening was used by Solomon and colleagues defined it using Harris' criteria (Harris, McCarthy et al. 1982), however, no time-frame was stipulated (Solomon, Hussenbocus et al. 2015). The overall assessment period was up to around seven years (excluding deaths within 3 months).

Deep surgical site infection



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	16.667	0.421 to 64.123	13.73	13.73
Joestl 15C 2016	8	0.000	0.000 to 36.942	17.65	17.65
Korbel 18B 2013	6	0.000	0.000 to 45.926	13.73	13.73
Nikura 27B 2014	3	0.000	0.000 to 70.760	7.84	7.84
Pavlou 28C (No graft) 2011	10	0.000	0.000 to 30.850	21.57	21.57
Solomon 33A 2015	12	0.000	0.000 to 26.465	25.49	25.49
Total (fixed effects)	45	4.397	0.637 to 14.151	100.00	100.00
Total (random effects)	45	4.397	0.547 to 11.661	100.00	100.00

Test for heterogeneity

Q	2.4788
DF	5
Significance level	P = 0.7797
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 50.29

Figure 69 Deep surgical site infection (DSSI) for ORIF with plate.

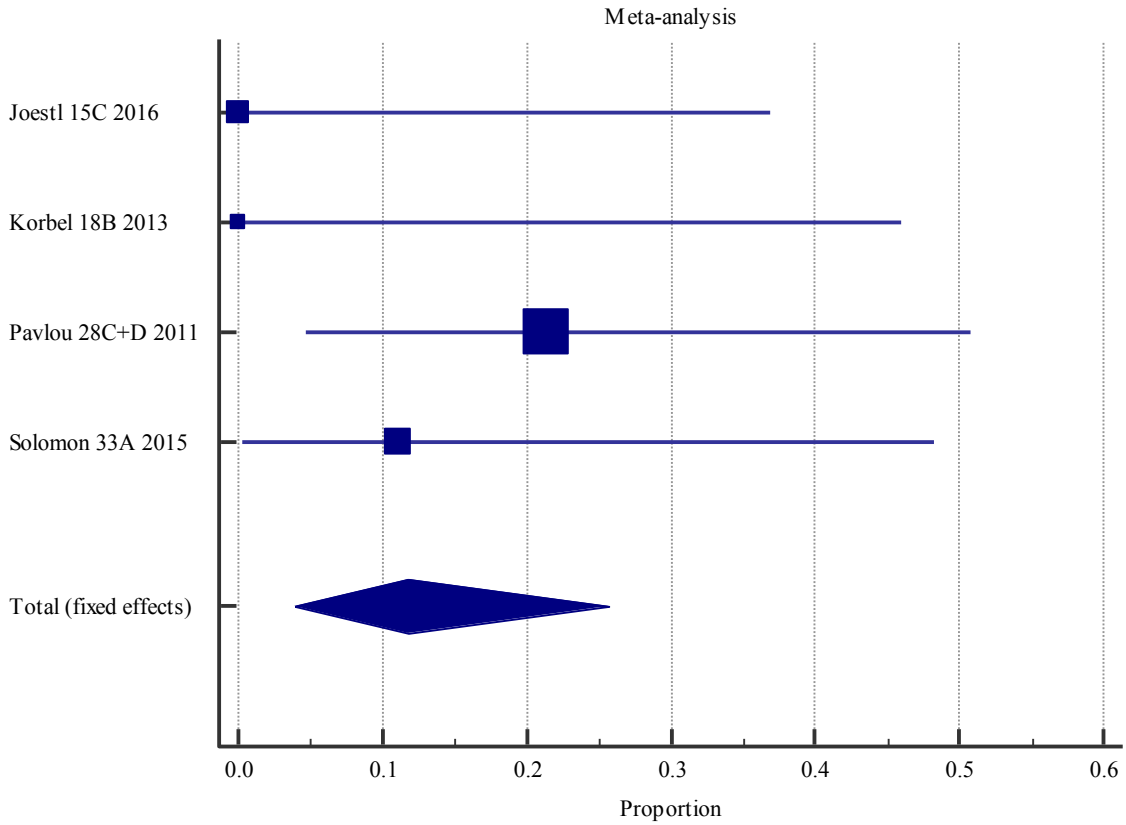
Figure 69 shows the meta-analysis for the six studies (n=45) that reported DSSI for the exposure of interest. No authors provided a definition for DSSI; only one study (Joestl, Hofbauer et al. 2016) implies an aspiration hip joint was performed for diagnosis. The explicit time-frame of the outcome measurement was not reported in any study.

Overall, the prevalence of DSSI was 4.4% (95%CI 0.5 to 11.7). There was no important heterogeneity between the studies (I^2 = 0%).

Superficial surgical site infection

Four studies reported SSSI for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016), 27B (n=3) (Niikura, Lee et al. 2014), 28C (n=10) (Pavlou, Panteliadis et al. 2011) and 33A (n=12) (Solomon, Hussenbocus et al. 2015), with no events observed. No study explicitly defined SSSI.

Dislocation overall (combined analysis)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Joestl 15C 2016	8	0.000	0.000 to 36.942	21.95	22.39
Korbel 18B 2013	6	0.000	0.000 to 45.926	17.07	17.77
Pavlou 28C+D 2011	14	21.429	4.658 to 50.798	36.59	35.20
Solomon 33A 2015	9	11.111	0.281 to 48.250	24.39	24.63
Total (fixed effects)	37	11.774	3.836 to 25.681	100.00	100.00
Total (random effects)	37	11.523	3.356 to 23.698	100.00	100.00

Test for heterogeneity

Q	3.3307
DF	3
Significance level	P = 0.3434
I^2 (inconsistency)	9.93%
95% CI for I^2	0.00 to 88.37

Figure 70 Dislocation for ORIF with plate (combined)

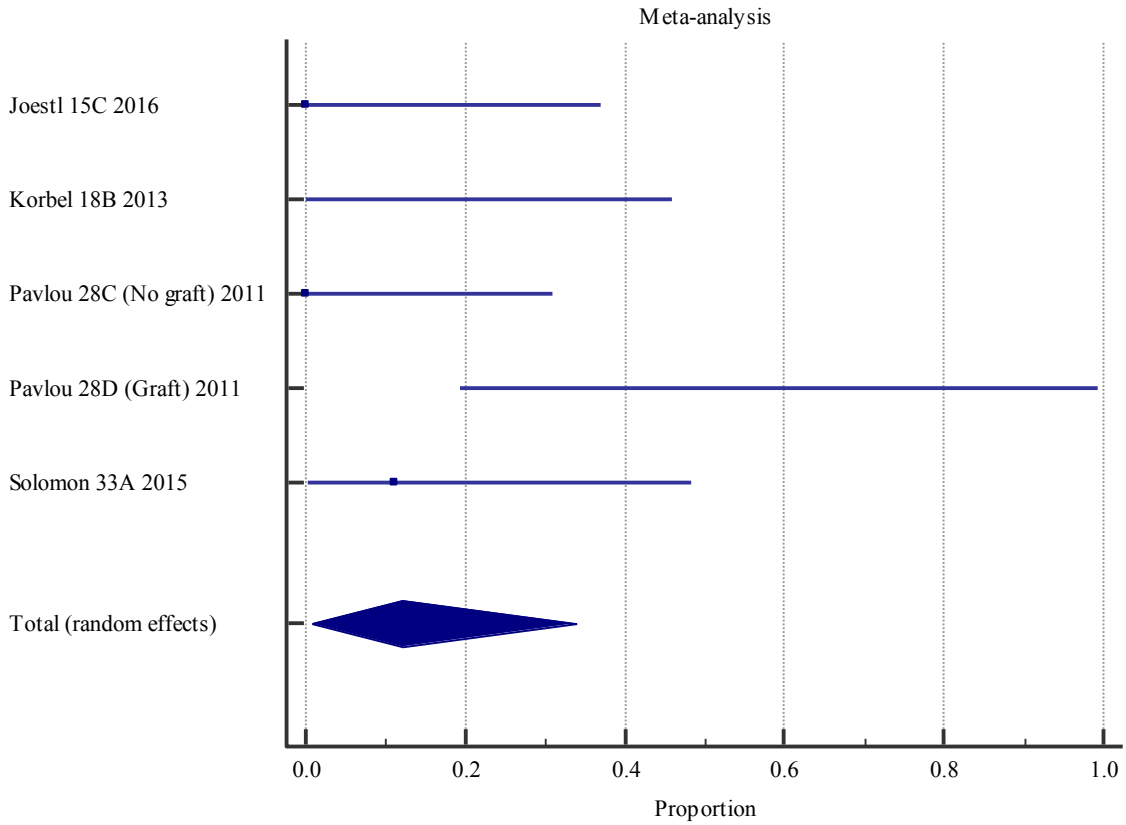
Figure 70 shows the meta-analysis for the four studies (n=37) that reported dislocation for the exposure of interest. No authors provided a definition or direction of

dislocation. Only one study (Solomon, Hussenbocus et al. 2015) reported a time period within which a dislocation occurred, which was less than 3 months post-operatively.

Overall, the prevalence of dislocation was 11.8% (95%CI 3.8 to 25.7). There was a low degree of heterogeneity between the studies (I^2 = 9.9%).

Subgroup analysis (analysis 2) was performed by separating exposure 28C (ORIF with plate without bone graft) and 28D (ORIF with plate with bone graft) to assess for any appreciable change in the meta-analysis result for dislocation (Pavlou, Panteliadis et al. 2011).

Dislocation (analysis 2)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Joestl 15C 2016	8	0.000	0.000 to 36.942	21.43	20.80
Korbel 18B 2013	6	0.000	0.000 to 45.926	16.67	19.06
Pavlou 28C (No graft) 2011	10	0.000	0.000 to 30.850	26.19	22.08
Pavlou 28D (Graft) 2011	4	75.000	19.412 to 99.369	11.90	16.57
Solomon 33A 2015	9	11.111	0.281 to 48.250	23.81	21.48
Total (fixed effects)	37	9.953	2.884 to 23.173	100.00	100.00
Total (random effects)	37	12.124	0.839 to 33.717	100.00	100.00

Test for heterogeneity

Q	11.8493
DF	4
Significance level	P = 0.0185
I^2 (inconsistency)	66.24%
95% CI for I^2	12.03 to 87.05

Figure 71 Dislocation for ORIF with plate (Analysis 2)

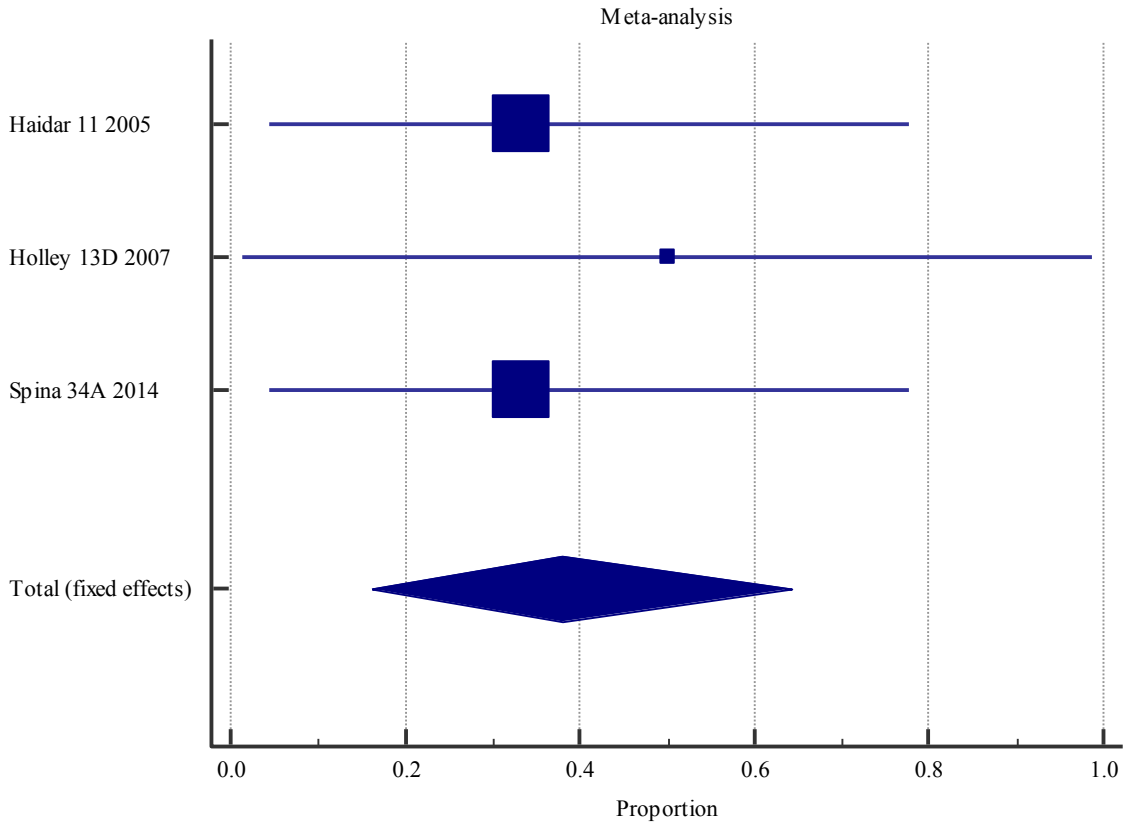
Figure 71 shows the meta-analysis for the five studies (n=37) that reported dislocation for the exposure of interest. No authors provided a definition or direction of dislocation. Only one study (Solomon, Hussenbocus et al. 2015) reported a time period within which dislocation occurred, which was less than 3 months post-operatively.

Overall, the prevalence of dislocation was 12.1% (95%CI 0.8 to 33.7). There was a moderate degree of heterogeneity between the studies (I^2 = 66.2%).

Delayed wound healing

One study reported delayed wound healing for ORIF with plate, exposure 33A, with an event rate of 0/9 (0%) (Solomon, Hussenbocus et al. 2015). No explicit definition of delayed wound healing was provided.

Re-operation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	33.333	4.327 to 77.722	41.18	41.18
Holley 13D 2007	2	50.000	1.258 to 98.742	17.65	17.65
Spina 34A 2014	6	33.333	4.327 to 77.722	41.18	41.18
Total (fixed effects)	14	38.047	16.151 to 64.237	100.00	100.00
Total (random effects)	14	38.047	17.152 to 61.592	100.00	100.00

Test for heterogeneity

Q	0.2123
DF	2
Significance level	P = 0.8993
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 68.39

Figure 72 Re-operation for ORIF with plate.

Figure 72 shows the meta-analysis for the three studies (n=14) that reported re-operation for the exposure of interest. No authors provided an explicit definition nor a

time-frame for re-operation. The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of Re-operation was 38.0% (95%CI 16.2 to 64.2). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Studies not included in the meta-analysis: (Lunebourg, Mouhsine et al. 2015). Lunebourg and colleagues reported on re-operation (by way of Revision) for Vancouver B2 PFF in their cohorts, however, unfortunately, only explicitly specified the exposure (either 21A ORIF with plate OR 21B Revision + ORIF with plate) in one out of two Revision cases and hence could not be included in our meta-analysis without introducing some uncertainty (Lunebourg, Mouhsine et al. 2015).

Deep vein thrombosis (DVT)

Two studies reported DVT for ORIF with plate, exposure 11 (Haidar and Goodwin 2005) and 15C (n=8) (Joestl, Hofbauer et al. 2016), with a prevalence of 17% (1/6) and no observed events, respectively. No authors provided an explicit definition for DVT.

Pulmonary embolism (PE)

One study reported PE for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016), with no events observed. No explicit definition of PE was provided.

Leg length discrepancy (LLD) (2cm or more)

One study reported LLD for ORIF with plate, exposure 11 (Haidar and Goodwin 2005), with an incidence of 17% (1/6). Outcome was referred to as ‘limb shortening’ by

authors, however, no explicit definition, diagnostic method, nor a time-frame for identifying LLD was provided.

Neurovascular injury

One study reported Neurovascular injury for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016), with no events observed. No explicit definition of neurovascular injury was provided.

Plate breakage

Two studies reported plate breakage for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016) and 18B (n=6) (Korbel, Sponer et al. 2013), with no observed events and a prevalence of 3/6 (50%), respectively.

Harris hip score post-operatively

One study reported post-operative Harris hip score for ORIF with plate, exposure 33A* (n=5) (Solomon, Hussenbocus et al. 2015), with a mean score of 59 (SD 22.96). The time point post-operatively at which HHS was calculated was not explicitly reported.

Harris hip pain score (post-operative)

One study reported post-operative Harris hip pain score for ORIF with plate, exposure 33A* (n=8) (Solomon, Hussenbocus et al. 2015), with a mean score of 41 (SD 8.4). The time point post-operatively at which HHS was calculated was not explicitly reported.

Beals and Towers' criteria excellent outcome

One study reported Beals and Towers' criteria excellent outcome for ORIF with plate, exposure 34A, with a prevalence of 50% (3/6) (Spina, Rocca et al. 2014). The time

point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Beals and Towers' criteria good outcome

One study reported Beals and Towers' criteria good outcome for ORIF with plate, exposure 34A (Spina, Rocca et al. 2014), with a prevalence of 16.7% (1.6). The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Beals and Towers' criteria poor outcome

One study reported Beals and Towers' criteria excellent outcome for ORIF with plate, exposure 34A (Spina, Rocca et al. 2014), with a prevalence of 33% (2/6). The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Parker mobility score (post-operative)

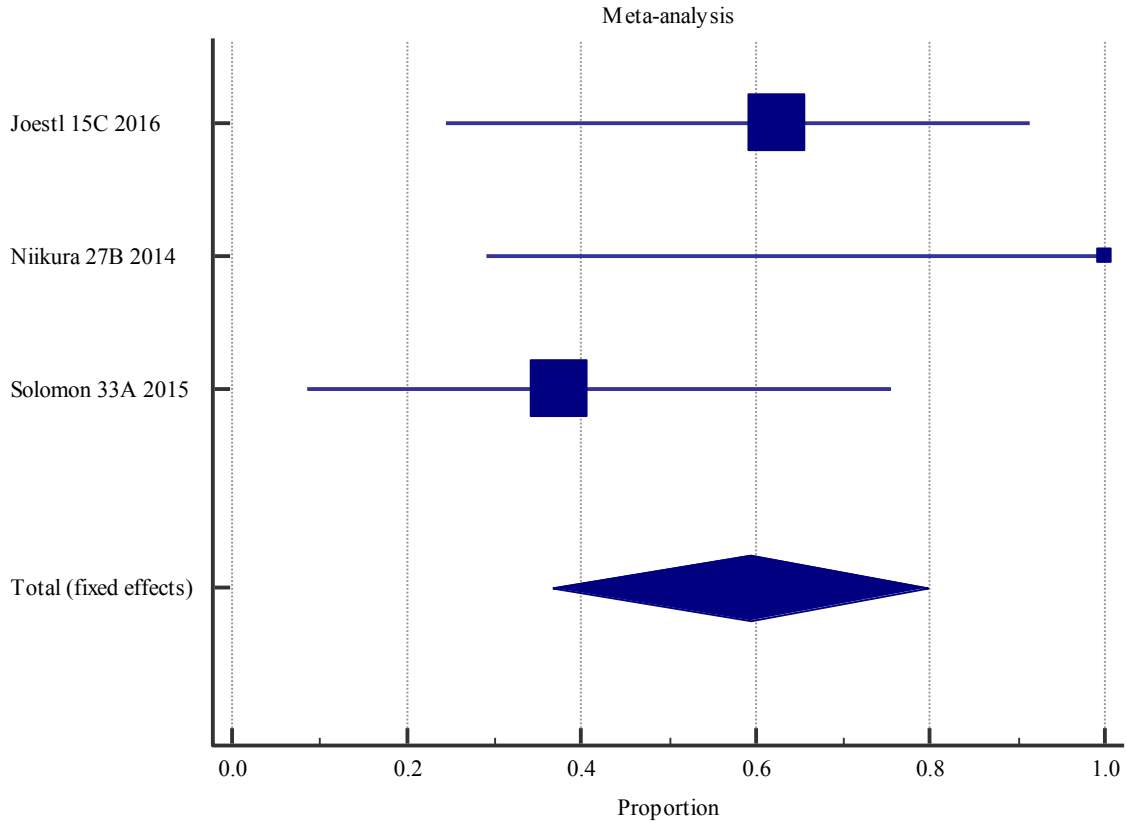
Two studies reported post-operative Parker mobility score for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016) and 27B (n=3) (Niikura, Lee et al. 2014) with mean scores of 6.6 (SD 2) and 2 (SD 2.7), respectively. Note, for reference, mean pre-operative Parker mobility score for exposure 15C (n=8) (Joestl, Hofbauer et al. 2016) and 27B (n=3) were 7 (SD 1.2) and 2 (SD 2.7), respectively.

Ambulatory status (post-operative)

Two studies reported post-operative ambulatory status for ORIF with plate, exposure 27B (Niikura, Lee et al. 2014), with 66% (2/3) non-ambulatory and 33% (1/3)

mobilising with crutch, and exposure 34A with 40% (2/5) mobilising without aids (Spina, Rocca et al. 2014).

Attainment of pre-fracture mobility status



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Joestl 15C 2016	8	62.500	24.486 to 91.477	40.91	37.35
Niikura 27B 2014	3	100.000	29.240 to 100.000	18.18	25.29
Solomon 33A 2015	8	37.500	8.523 to 75.514	40.91	37.35
Total (fixed effects)	19	59.463	36.700 to 79.584	100.00	100.00
Total (random effects)	19	63.088	31.380 to 89.515	100.00	100.00

Test for heterogeneity

Q	4.5050
DF	2
Significance level	P = 0.1051
I^2 (inconsistency)	55.60%
95% CI for I^2	0.00 to 87.33

Figure 73 Attainment pre-fracture mobility status for ORIF with plate.

Figure 73 shows the meta-analysis for the three studies (n=19) that reported Attainment pre-fracture mobility status for the exposure of interest. There was no explicit reporting of how this assessment was made by authors (e.g. clinical or self-reported). The overall assessment period for Joestl et al. (Joestl, Hofbauer et al. 2016) and Solomon et al.

(Solomon, Hussenbocus et al. 2015) studies ranged from 9 to 82 months Niikura and colleagues (Niikura, Lee et al. 2014) study reported a pooled mean follow-up time of 18.4 months (no range provided).

Overall, the prevalence of Attainment pre-fracture mobility status was 59.5% (95%CI 36.7 to 79.6). There was a moderate degree of heterogeneity between the studies (I^2 = 55.6%).

Attainment of pre-fracture social status

One study reported attainment of pre-fracture social status for ORIF with plate, exposure 27B (Niikura, Lee et al. 2014), with a prevalence of 100% (3/3), one patient returning home independently, one patient returning home with caregiver and one patient returning to nursing home.

Pain free (self-assessment)

One study reported pain free (self-assessment) status for ORIF with plate, exposure 32A, with an event rate of 4/6 (66%) (Sledge and Abiri 2002). The time point post-operatively at which the outcome was assessed was not reported by study authors.

Quality of Life (self-assessment) post-operatively (1 (poor) – 10 (excellent))

One study reported perceived post-operative quality of life, exposure 34A (n=6) (Spina, Rocca et al. 2014), with a mean score of 6 (SD NS, range NS). Note: pre-operative mean score was 8 (SD NS, range NS). The time point post-operatively at which the outcome was assessed was not reported by study authors.

ORIF with wires/cerclage/cables

There were two cohort studies which investigated various outcomes for the interventions of ORIF with wires/cerclage/cables.

Union

Two studies reported union for ORIF with wires/cerclage/cables, exposure 24C (Mukka, Mellner et al. 2016) and 34B (Spina, Rocca et al. 2014), with a prevalence of 100% (2/2) and no events observed, respectively. Neither study defined union, nor provided a time-frame for its observation.

Mortality (overall)

One study reported mortality for ORIF with wires/cerclage/cables, exposure 24C (Mukka, Mellner et al. 2016) (n=2) with no events observed.

Deep surgical site infection

One study reported DSSI for ORIF with wires/cerclage/cables, exposure 24C (Mukka, Mellner et al. 2016) (n=2) with no events observed.

Re-operation

Two studies reported re-operation for ORIF with wires/cerclage/cables, exposure 24C (n=2) (Mukka, Mellner et al. 2016) and 34B (n=1) (Spina, Rocca et al. 2014), with no events observed in either study.

Beals and Towers' criteria excellent outcome

One study reported Beals and Towers' criteria excellent outcome for ORIF with wires/cerclage/cables, exposure 34B (Spina, Rocca et al. 2014), with a prevalence of 0%

(0/1). The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Beals and Towers' criteria good outcome

One study reported Beals and Towers' criteria good outcome for ORIF with wires/cerclage/cables, exposure 34B (Spina, Rocca et al. 2014), with a prevalence of 0% (0/1). The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Beals and Towers' criteria poor outcome

One study reported Beals and Towers' criteria excellent outcome for ORIF with wires/cerclage/cables, exposure 34B (Spina, Rocca et al. 2014), with a prevalence of 100% (1/1). The time point post-operatively at which the Beals and Towers' criteria were assessed was not explicitly reported.

Ambulatory status (post-operative)

One study reported post-operative ambulatory status for ORIF with wires/cerclage/cables, exposure 34B (Spina, Rocca et al. 2014) with a prevalence of 0% (0/1) mobilising without aids. The time point post-operatively at which the outcome was assessed was not reported by study authors.

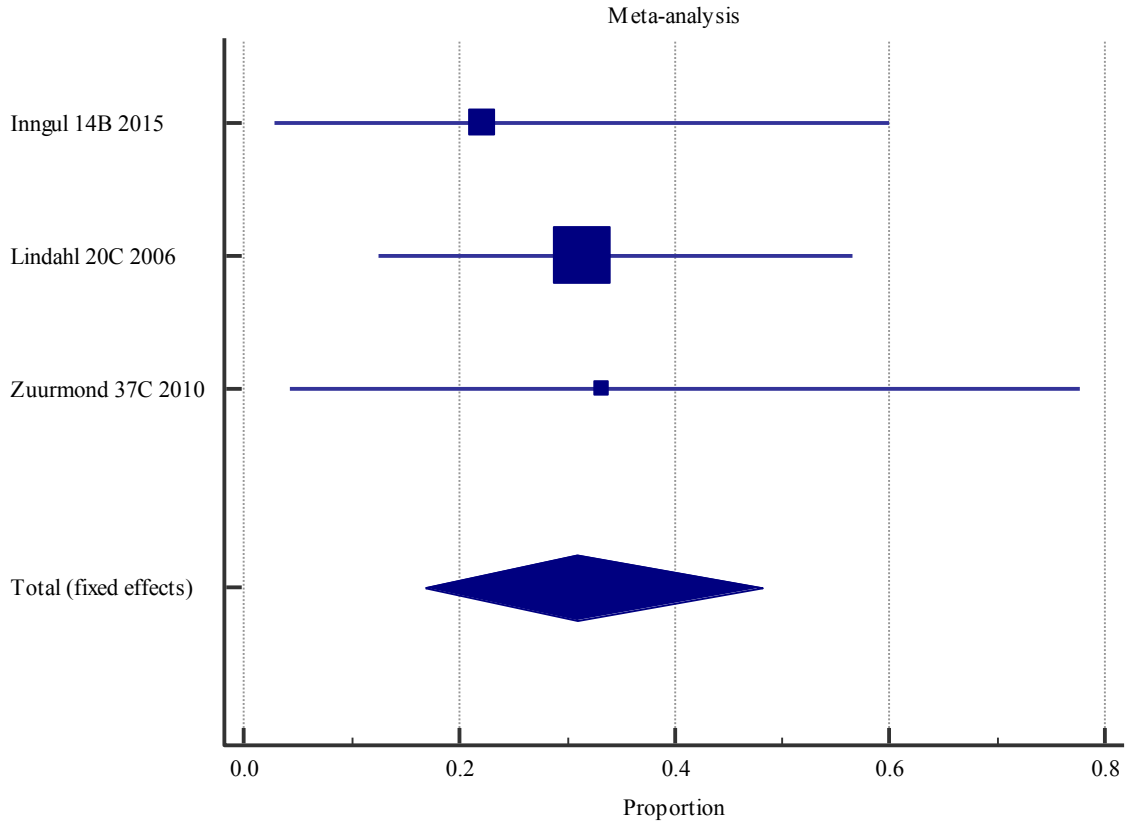
Pain free (self-assessment)

One study reported pain free (self-assessment) status for ORIF with wires/cerclage/cables, exposure 32B (n=1), with no events observed (Sledge and Abiri 2002). The time point post-operatively at which the outcome was assessed was not reported by study authors.

ORIF mixed methods/unspecified

There were three studies (two cohort studies and one retrospective case series) which investigated various outcomes for the interventions of ORIF mixed methods/unspecified.

Re-operation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Inngul 14B 2015	9	22.222	2.814 to 60.009	27.03	27.03
Lindahl 20C 2006	19	31.579	12.576 to 56.550	54.05	54.05
Zuurmond 37C 2010	6	33.333	4.327 to 77.722	18.92	18.92
Total (fixed effects)	34	30.917	16.806 to 48.219	100.00	100.00
Total (random effects)	34	30.917	17.264 to 46.534	100.00	100.00

Test for heterogeneity

Q	0.2750
DF	2
Significance level	P = 0.8715
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 75.60

Figure 74 Re-operation for ORIF mixed methods/unspecified.

Figure 74 shows the meta-analysis for the three studies (n=34) that reported re-operation for the exposure of interest. No authors provided an explicit definition or a time-frame for re-operation.

Overall, the prevalence of re-operation was 30.9% (95%CI 16.8 to 48.2). There was no important heterogeneity between the studies (I^2 = 0%).

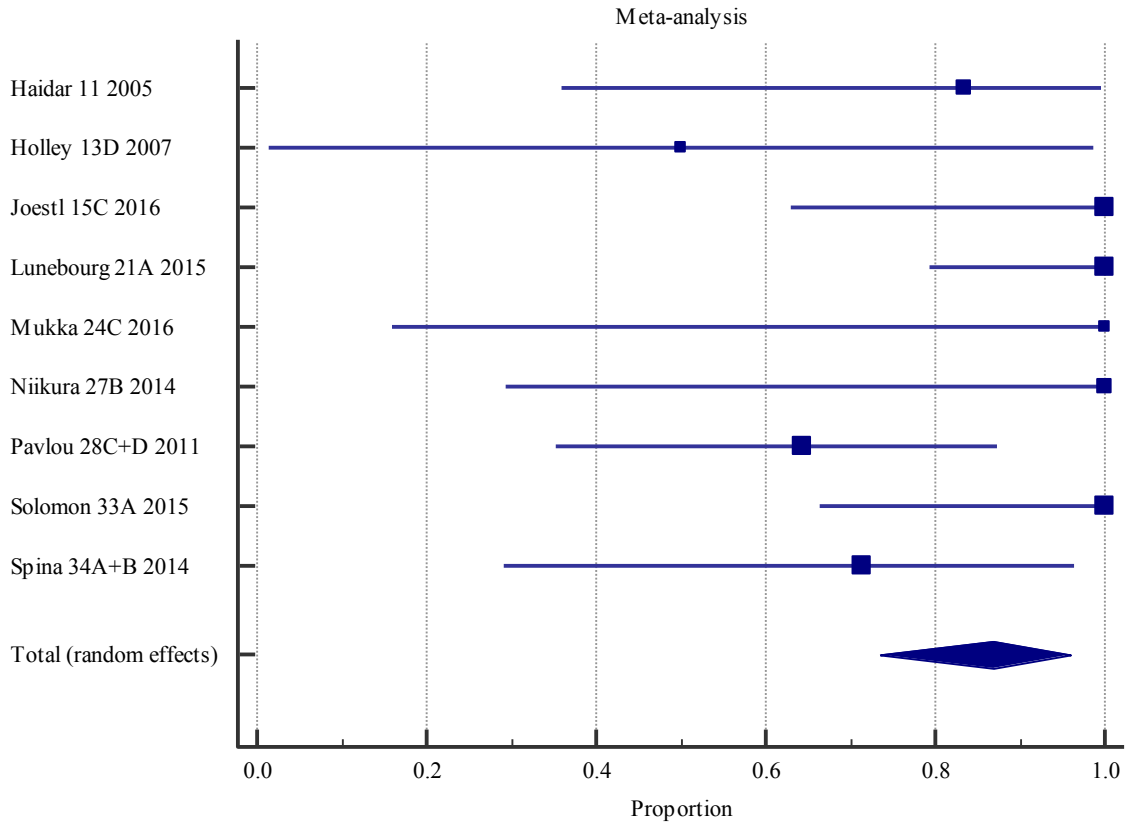
Oxford hip score (post-operatively)

One study reported mortality for ORIF mixed methods/unspecified, exposure 37C (n=6), with a mean of 23.8 (SD 7.9) (Zuurmond, van Wijhe et al. 2010). The overall assessment period across studies was similar, and up to around thirteen years.

ORIF any

There were thirteen studies (seven cohort studies and six retrospective case series) which investigated various outcomes for the interventions of ORIF mixed methods/unspecified.

Union (overall)



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	83.333	35.877 to 99.579	9.21	10.95
Holley 13D 2007	2	50.000	1.258 to 98.742	3.95	6.42
Joestl 15C 2016	8	100.000	63.058 to 100.000	11.84	12.42
Lunebourg 21A 2015	16	100.000	79.409 to 100.000	22.37	15.92
Mukka 24C 2016	2	100.000	15.811 to 100.000	3.95	6.42
Niikura 27B 2014	3	100.000	29.240 to 100.000	5.26	7.84
Pavlou 28C+D 2011	14	64.286	35.138 to 87.240	19.74	15.27
Solomon 33A 2015	9	100.000	66.373 to 100.000	13.16	13.03
Spina 34A+B 2014	7	71.429	29.042 to 96.331	10.53	11.73
Total (fixed effects)	67	87.591	78.024 to 94.040	100.00	100.00
Total (random effects)	67	86.719	73.443 to 95.870	100.00	100.00

Test for heterogeneity

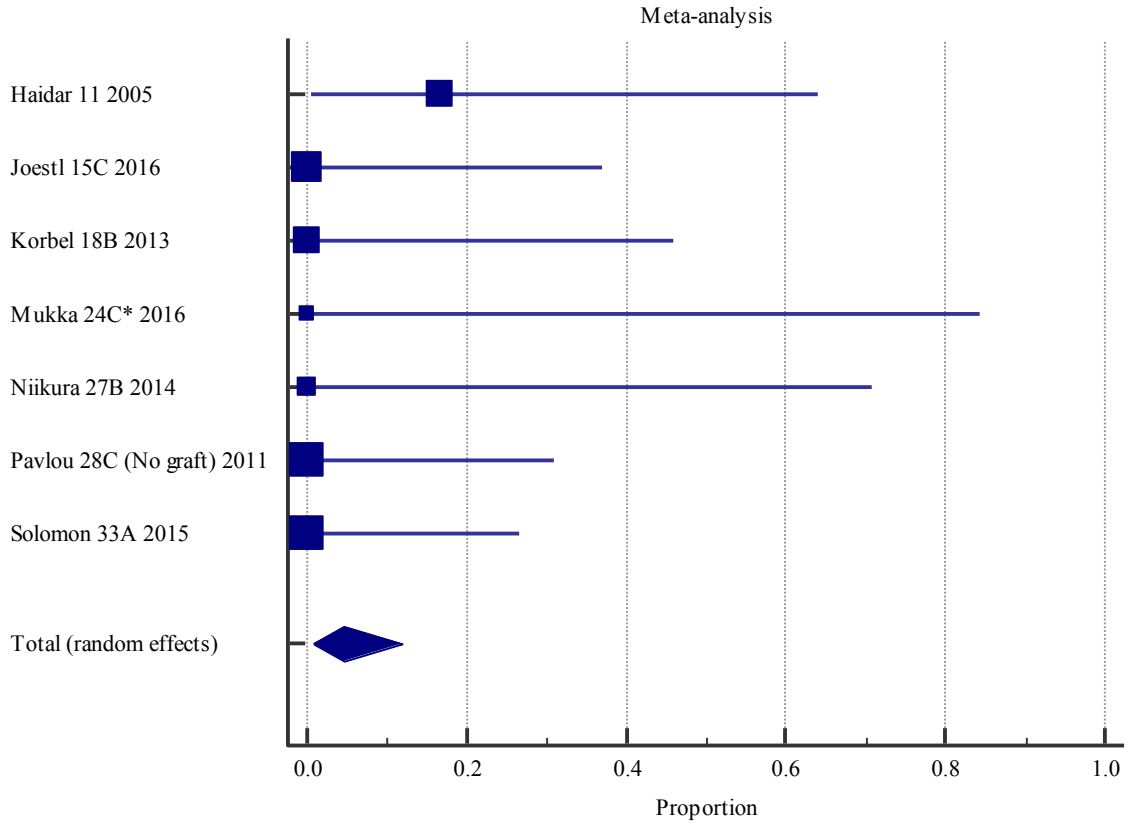
Q	16.2185
DF	8
Significance level	P = 0.0394
I^2 (inconsistency)	50.67%
95% CI for I^2	0.00 to 76.93

Figure 75 Union (overall) for ORIF any).

Figure 75 shows the meta-analysis for the nine studies (n=67) that reported union (overall) for exposure of interest. One third of the studies 3/9 explicitly defined union and 22% (2/9) of studies reported a time to union. The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of union was 86.7% (95%CI 73.4 to 95.9). There was a moderate degree of heterogeneity between the studies (I^2 = 50.7%).

Deep surgical site infection



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	16.667	0.421 to 64.123	12.96	12.96
Joestl 15C 2016	8	0.000	0.000 to 36.942	16.67	16.67
Korbel 18B 2013	6	0.000	0.000 to 45.926	12.96	12.96
Mukka 24C* 2016	2	0.000	0.000 to 84.189	5.56	5.56
Niikura 27B 2014	3	0.000	0.000 to 70.760	7.41	7.41
Pavlou 28C (No graft) 2011	10	0.000	0.000 to 30.850	20.37	20.37
Solomon 33A 2015	12	0.000	0.000 to 26.465	24.07	24.07
Total (fixed effects)	47	4.620	0.774 to 14.074	100.00	100.00
Total (random effects)	47	4.620	0.692 to 11.757	100.00	100.00

Test for heterogeneity

Q	2.5843
DF	6
Significance level	P = 0.8589
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 33.35

Figure 76 Deep surgical site infection (DSSI) for ORIF any.

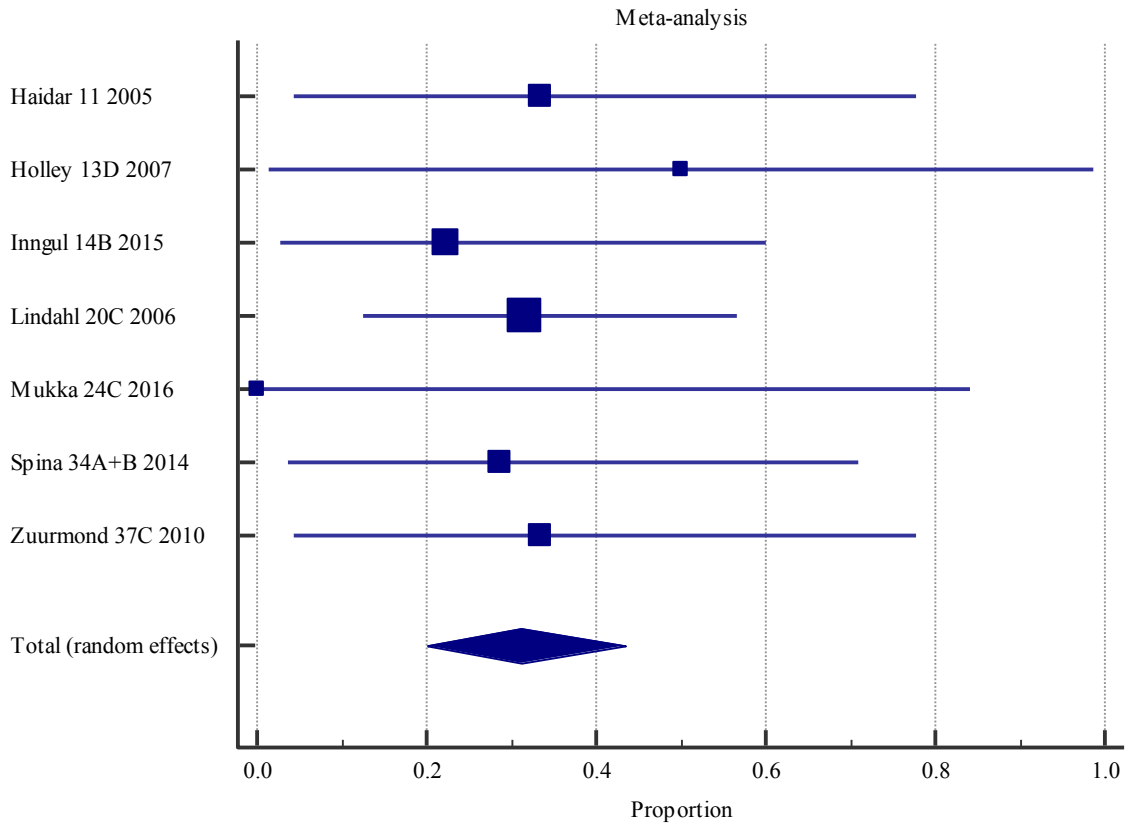
Figure 76 shows the meta-analysis for the seven studies (n=47) that reported DSSI for the exposure of interest. No authors provided a definition for DSSI, only one study (Joestl, Hofbauer et al. 2016) implies an aspiration hip joint was performed for diagnosis. The explicit time-frame of outcome measurement was not reported in any study.

Overall, the prevalence of DSSI was 4.6% (95%CI 0.7 to 11.8). There was no important heterogeneity between the studies (I^2 = 0%).

Superficial surgical site infection

Five studies reported SSSI for ORIF with plate, exposure 15C (n=8) (Joestl, Hofbauer et al. 2016), 24C (n=2) (Mukka, Mellner et al. 2016), 27B (n=3) (Niikura, Lee et al. 2014), 28C (n=10) (Pavlou, Panteliadis et al. 2011) and 33A (n=12) (Solomon, Hussenbocus et al. 2015), with no events observed. No authors provided an explicit definition for SSSI.

Re-operation



Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Haidar 11 2005	6	33.333	4.327 to 77.722	12.07	12.07
Holley 13D 2007	2	50.000	1.258 to 98.742	5.17	5.17
Inngul 14B 2015	9	22.222	2.814 to 60.009	17.24	17.24
Lindahl 20C 2006	19	31.579	12.576 to 56.550	34.48	34.48
Mukka 24C 2016	2	0.000	0.000 to 84.189	5.17	5.17
Spina 34A+B 2014	7	28.571	3.669 to 70.958	13.79	13.79
Zuurmond 37C 2010	6	33.333	4.327 to 77.722	12.07	12.07
Total (fixed effects)	51	31.077	19.574 to 44.588	100.00	100.00
Total (random effects)	51	31.077	19.920 to 43.480	100.00	100.00

Test for heterogeneity

Q	1.7557
DF	6
Significance level	P = 0.9407
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 1.89

Figure 77 Re-operation for ORIF with plate.

Figure 77 shows the meta-analysis for the seven studies (n=51) that reported re-operation for the exposure of interest. No authors provided an explicit definition or a

time-frame for re-operation. The overall assessment period across studies was similar, and up to around eleven years.

Overall, the prevalence of re-operation was 31.1% (95%CI 19.9 to 43.5). There was no important heterogeneity between the studies ($I^2 = 0\%$).

Non-operative

Only one case series evaluated non-operative intervention.

Union

One study reported union for non-operative intervention, exposure 27C (Niikura, Lee et al. 2014), with a prevalence of 100% (1/1). Union was not defined nor a time-frame of assessment given by authors.

Ambulatory status (post-injury)

One study reported post-operative ambulatory status for non-operative intervention, exposure 27C (Niikura, Lee et al. 2014), with 100% (1/1) mobilising with cane. The explicit time-frame of the outcome measurement was not reported in any study.

Summary of findings (Grade)

Table 12 Summary of Findings (Grade).

Revision, with or without wires/cerclage/cables compared to ORIF with plate in the management of Vancouver B2 periprosthetic femoral fractures in patients with a hemi or total hip arthroplasty

Bibliography:

Outcomes	№ of participants (studies) Follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with ORIF with plate	Risk difference with Revision, with or without wires/cerclage/cables
Surgical time [a]	46 (3 observational studies) [b,c]	⨁◯◯◯ VERY LOW [d,e]	-	The mean surgical time was **0** minutes	MD **50.3 minutes more** (22.7 more to 77.9 more)
Transfusion packed red blood cell (units)	24 (2 observational studies) [f,g]	⨁◯◯◯ VERY LOW [d,e]	-	The mean transfusion packed red blood cell (units) was **0** Units	MD **2.6 Units more** (1.2 more to 4.1 more)
Union (overall) assessed with: Radiographically or clinically [h]	70 (4 observational studies) [i,j]	⨁◯◯◯ VERY LOW [d,e]	**RR 1.17** (0.90 to 1.53)	79 per 100	**13 more per 100** (8 fewer to 42 more)
Dislocation	118 (4 observational studies) [k,l]	⨁◯◯◯ VERY LOW [d,e]	**RR 1.26** (0.47 to 3.39)	10 per 100	**3 more per 100** (5 fewer to 24 more)
Attainment of pre-fracture mobility status	56 (3 observational studies) [m,n]	⨁◯◯◯ VERY LOW [d,e]	**RR 1.10** (0.71 to 1.72)	58 per 100	**6 more per 100** (17 fewer to 42 more)
Mortality	57 (2 observational studies) [o]	⨁◯◯◯ VERY LOW [d,e]	not estimable	150 per 1,000	**150 fewer per 1,000** (150 fewer to 150 fewer)
Reoperation	10 (1 observational study) [p]	⨁◯◯◯ VERY LOW [d,e]	not estimable	500 per 1,000	**500 fewer per 1,000** (500 fewer to 500 fewer)

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **MD:** Mean difference; **RR:** Risk ratio

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. Note: Only Surgical time analysis 1 was used for our Grade Summary of Findings table for simplicities sake (surgical time analysis 2 yielded almost identical results)
b. Joestl et al 2016, Niikura et al 2014, Solomon et al 2015
c. Two retrospective cohort studies and one retrospective case series
d. Studies did not identify and/or account for confounding
e. Most studies had imprecise estimates which are related to their small sample sizes
f. Niikura et al 2014, Solomon et al 2015
g. One retrospective cohort study and one retrospective case series
h. See description of studies tables for assessment method
i. Holley et al 2007, Niikura et al 2014, Pavlou et al 2011, Solomon et al 2015
j. Two retrospective cohort studies and two retrospective case series
k. Joestl et al 2016, Korbel et al 2013, Pavlou et al 2011, Solomon et al 2015
l. 1 retrospective cohort study and 3 retrospective case series
m. Joestl et al 2016, Niikura et al 2014, Solomon et al 2015.
n. Two retrospective cohort studies and one retrospective case series
o. Joestl et al 2016, Solomon et al 2015.
p. Holley et al 2007

Table 13 Summary of Findings (Grade).

Revision by any method compared to ORIF by any method in the management of Vancouver B2 periprosthetic femoral fractures in patients with a hemi or total hip arthroplasty

Bibliography:

Outcomes	№ of participants (studies) Follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with ORIF by any method	Risk difference with Revision by any method
Surgical time [a]	71 (4 observational studies) [b,c]	⨁◯◯◯ VERY LOW [d,e]	-	The mean surgical time was **0** minutes	MD **64.4 minutes more** (43.9 more to 85 more)
Union	103 (5 observational studies) [f,g]	⨁◯◯◯ VERY LOW [d,e]	**RR 1.04** (0.85 to 1.30)	86 per 100	**3 more per 100** (13 fewer to 26 more)
Mortality	83 (3 observational studies) [h,i]	⨁◯◯◯ VERY LOW [d,e]	**RR 1.95** (0.72 to 5.30)	15 per 100	**15 more per 100** (4 fewer to 66 more)
Reoperation	218 (4 observational studies) [c,j]	⨁◯◯◯ VERY LOW [d,e]	**RR 0.61** (0.34 to 1.09)	31 per 100	**12 fewer per 100** (20 fewer to 3 more)
Deep surgical site infection (DSSI)	102 (5 observational studies) [k,l,m]	⨁◯◯◯ VERY LOW [d,e]	not estimable	0 per 100	**0 fewer per 100** (0 fewer to 0 fewer)
Superficial surgical site infection (SSSI)	78 (4 observational studies) [k,n,o]	⨁◯◯◯ VERY LOW [d,e]	not estimable	0 per 1,000	**0 fewer per 1,000** (0 fewer to 0 fewer)

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **MD:** Mean difference; **RR:** Risk ratio

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. Note: Only Surgical time analysis 1 was used for our Grade Summary of Findings table for simplicities sake (surgical time analysis 2 yielded almost identical results)
b. Joestl et al 2016, Lunebourg et al 2015, Niikura et al 2014, Solomon et al 2015
c. Two retrospective cohort studies and two retrospective case series
d. Studies did not identify and/or account for confounding
e. Most studies had imprecise estimates which are related to their small sample sizes
f. Holley et al 2007, Lunebourg et al 2015, Niikura et al 2014, Pavlou et al 2011, Solomon et al 2015
g. Two retrospective cohort studies and three retrospective case series
h. Joestl et al 2016, Solomon et al 2015, Zuurmond et al 2010
i. Three retrospective cohort studies
j. Holley et al 2007, Inngul et al 2015, Lindahl et al 2006, Zuurmond et al 2010.
k. Note: Effect estimates could not be calculated due to zero event rate in ORIF any method intervention arm
l. Joestl et al 2016, Korbel et al 2013, Mukka et al 2016, Niikura et al 2014, Solomon et al 2015
m. One prospective cohort study, two retrospective cohort studies and two retrospective case series
n. Joestl et al 2016, Mukka et al 2016, Niikura et al 2014, Solomon et al 2015
o. One prospective cohort study, two retrospective cohort studies and one retrospective case series.

Chapter 4 – Discussion and final considerations

Summary of findings

Overall, no management strategies have been shown to be consistently superior for the outcomes included in this systematic review. Comparative meta-analysis revealed small differences between management strategies across different outcomes. While the surgical time was shorter and the transfusion requirement was less for ORIF with plate vs Revision +/- wires, cerclage and cables, pre and post-operative Parker mobility scores, subsidence, union, mortality, dislocation and infection rates were similar. Regarding Revision via any method vs ORIF any method, union, malunion and infection rates were similar, however, mortality rates were lower for ORIF and re-operation rates were lower for Revision. The section below presents a detailed discussion about the clinical significance of the main findings of this systematic review and meta-analysis according to outcomes.

Mortality

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=8 patients=155), Revision any method (studies=12 patients=307), ORIF with plate (studies=4 patients=31) revealed a prevalence of mortality of 21.6% (95%CI 9.0 to 38.0), 19.0% (95%CI 11.4 to 28.1) and 22.2% (95%CI 9.9 to 39.4), respectively. It should be noted that the observational time-frame ranged from 6 months to 6 years, 3 months to 9 years and 0 months to 10 years, for Revision with or without wires/cerclage/cables, Revision any method and ORIF with plate, respectively.

Comparative meta-analysis for three studies (Joestl, Hofbauer et al. 2016, Solomon, Hussenbocus et al. 2015, Zuurmond, van Wijhe et al. 2010) including 83 patients revealed a 12% increase in the prevalence of mortality for Revision any method

compared with ORIF any method. These results were not statistically significant. It should be noted that the time-frame for mortality varied between studies and between the exposures within the same study, however, there was no significant trend observed (see Appendix IV for further details).

Although mortality is a critically important outcome, in light of our findings it should not influence the decision-making when choosing between ORIF with plate and Revision any method.

Re-operation

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=7 patients=38), Revision any method (studies=7 patients=244), ORIF with plate (studies=3 patients=14) and ORIF any method (studies=7, patients=51) revealed a prevalence of re-operation of 15.9% (95%CI 9.3 to 23.7), 19.4% (95%CI 13.0 to 27.2), 38.0% (95%CI 15.2 to 64.2) and 31.1% (95%CI 19.9 to 43.5), respectively. It should be noted that the observational time-frame ranged from 3 months to 12 years and 1 month to 11 years, Revision any method and ORIF any method, respectively.

Comparative meta-analysis for four studies (Lindahl, Garellick et al. 2006, Holley, Zelken et al. 2007, Zuurmond, van Wijhe et al. 2010, Inngul and Enocson 2015) including 218 patients revealed a 12% lower prevalence for re-operation for Revision any method compared with ORIF any method. It should be noted that the time-frame for re-operation assessment varied between studies and between the exposures within the same study, however, there was no significant trend observed (see Appendix IV for further details).

Although there was no statistically significant difference in the prevalence of re-operation between the exposures, our findings suggest a trend towards Revision any method being protective against re-operation when compared to ORIF any method. A previous systematic review on this topic reported that there was no difference between ORIF any method and Revision any method (Khan, Grindlay et al. 2017). Nevertheless, our meta-analysis for re-operation only included two out of the four studies included by the previous systematic review. Interestingly, this review included the study by Solomon et al., in their meta-analysis for the outcome of re-operation and we did not (Solomon, Hussenbocus et al. 2015). Despite this, we could not identify reporting of re-operation in Solomon's study publication, and also upon review of their de-identified raw data. Therefore, we are not able to confirm whether this outcome was assessed in the above-mentioned study. Solomon did however report that closed reduction was performed to manage patients with post-operative hip dislocations, but no further details were provided regarding whether this was performed in the operating theatre or in the emergency department. In addition, the previous systematic review included the study by Lunebourg and colleagues for the re-operation meta-analysis, which was not included in our meta-analysis. Lunebourg and colleagues reported two re-operations (referred to as Revision surgery by authors) for the Vancouver B2 PFF cohort (n=23), however, only one of these re-operations was explicitly stated to have undergone internal fixation (ORIF any equivalent) at the time of original management for PFF (Lunebourg, Mouhsine et al. 2015). The remaining Vancouver B2 PFF case undergoing re-operation was not explicitly declared by authors to belong to either the ORIF with plate plus revision (Revision any method equivalent) or the ORIF with plate alone exposure group (ORIF any equivalent). As such, we could not justify the inclusion of this study in the meta-analysis for the outcome of re-operation. Finally, we included two studies which were not included by

Khan and colleagues (Lindahl, Garellick et al. 2006, Holley, Zelken et al. 2007). It is possible that these two studies did not meet the inclusion criteria of the previous systematic review. Nevertheless, the study by Lindahl et al., 2006 accounted alone for over half of the total weight in our meta-analysis for this outcome (Lindahl, Garellick et al. 2006). Despite the differences between the two meta-analyses, both of them showed similar results, with a non-statistically significant trend towards Revision any method being protective for re-operation compared to ORIF any method.

Union

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=17 patients=278), Revision any method (studies=24 patients=418), ORIF with plate (studies=9 patients=64) and ORIF any method (studies=9, patients=67) revealed a prevalence of union of 97.0% (95%CI 94.5 to 98.7), 96.6% (95%CI 94.5 to 98.1), 87.4% (95%CI 73.8 to 96.6) and 86.7% (95%CI 73.4 to 95.9), respectively.

Comparative meta-analysis for four studies (Holley, Zelken et al. 2007, Pavlou, Panteliadis et al. 2011, Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015) (13, 27, 28, 33) including 70 patients revealed a 14% increase in the prevalence of union for Revision with or without wires/cerclage/cables compared with ORIF with plate. In addition, comparative meta-analysis including five studies (Holley, Zelken et al. 2007, Pavlou, Panteliadis et al. 2011, Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015) on 103 patients comparing Revision any method vs ORIF any method revealed a 3% increase in the prevalence of union reported for Revision any method. All of these results were not statistically significant.

Stratified analyses were conducted for the presence/absence of bone graft as an adjunct to ORIF with plate (28C/28D) (Pavlou, Panteliadis et al. 2011). The analyses yielded similar results, with no statistically significant difference between union rates, however, there was a modest trend toward higher union rates with Revision with or without wires/cerclage/cables. However, they suggested that the addition of bone graft to ORIF with plate intervention may neutralise this difference almost completely.

Overall, less than half of the studies explicitly defined union, with radiographic assessment being the diagnostic method of choice in the majority of studies. Furthermore, less than a quarter of studies provided a time to union. This reflects a global deficiency in the quality of outcome definition and reporting, which reduces the overall methodological quality of the included studies. Within the limitations of this systematic review, our findings suggest that no surgical management strategy is superior with regards to promoting union. Therefore, this outcome should not influence the decision-making when choosing between ORIF and Revision or any of its subcategories. However, bone graft augmentation of ORIF with plate should be investigated further, as it has shown to slightly increase union rates in one comparative study.

Dislocation

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=11 patients=214), Revision any method (studies=12 patients=298) and ORIF with plate (studies=4 patients=37) revealed a prevalence of dislocation of 10.4% (95%CI 5.8 to 16.2), 9.1% (95%CI 5.4 to 13.6) and 11.8% (95%CI 3.8 to 25.7), respectively.

Comparative meta-analysis for four studies (Pavlou, Panteliadis et al. 2011, Korbel, Sponer et al. 2013, Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016) including 118 patients revealed that the prevalence of dislocation was 5% higher for Revision with or without wires/cerclage/cables, in comparison with ORIF with plate. Nevertheless, this result was not statistically significant.

Stratified analyses were conducted for the presence/absence of bone graft as an adjunct to ORIF with plate (28C/28D) (Pavlou, Panteliadis et al. 2011) to assess for any appreciable change in meta-analysis results for dislocation. The analyses yielded similar results with no statistically significant difference in the prevalence of dislocation between the two surgical approaches. Nevertheless, only 4 out of 118 patients included in the meta-analysis received bone graft, and further research should be conducted in order to investigate the potential protective role of ORIF with plate and bone graft with regards to dislocation.

In light of current results, similar to the outcome of union, our findings suggest that no surgical management strategy is superior with regards to preventing dislocation. Therefore, this outcome should not influence the decision-making when choosing between ORIF with plate and Revision with or without wires/cerclage/cables.

Surgical time

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=4 patients=70), Revision any method (studies=5 patients=77) and ORIF with plate (studies=4 patients=39) revealed a mean surgical time of 177.5 (95%CI 157.0 to 198.0), 182.2 (95%CI 162.2 to 202.1) and 126.0 (95%CI 116.2 to 135.9) minutes, respectively.

Comparative meta-analysis for three studies (Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016) including 46 patients revealed that surgical time was 50 minutes longer for Revision with or without wires/cerclage/cables, in comparison with ORIF with plate. In addition, comparative meta-analysis including four studies (Niikura, Lee et al. 2014, Lunebourg, Mouhsine et al. 2015, Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016) on 71 patients comparing Revision any method vs ORIF any method revealed a mean difference of around one hour, with a longer duration reported for Revision any method. All of these results were statistically significant. None of the studies explicitly defined surgical time and refer to the outcome as either 'surgical duration' (Joestl, Hofbauer et al. 2016), 'operation time' (Niikura, Lee et al. 2014) or 'skin-to-skin surgical time' (Solomon, Hussenbocus et al. 2015), all of which were accepted to mean surgical time for the purposes of this meta-analysis. In this context, the most meaningful reporting for surgical time would be 'skin-to-skin' surgical time as it represents the operative time from incision to the dressing of the surgical wound, which most accurately reflects time spent performing each surgical management strategy (i.e. Revision with or without wires/cerclage/cables). The clinical and practical implications of an additional 50-minute surgical time are significant, with prolonged anaesthetic exposure for the patient and greater economic burden on the health system. Therefore, ORIF with plate represents a more efficient management strategy and may impart a harm and cost minimisation when compared to Revision with or without wires/cerclage/cables. The same holds true for ORIF any method vs Revision any method.

Transfusion PRBC

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=2 patients=11), ORIF with plate (studies=3 patients=50) revealed a mean of 3.1 (95%CI 1.9 to 4.2) and 2.0 (95%CI 1.5 to 2.5) units PRBC, respectively.

Comparative meta-analysis for two studies (Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015) including 24 patients revealed greater transfusion requirement for Revision with or without wires/cerclage/cables of 2.6 units PRBC, in comparison with ORIF with plate. Although these results were statistically significant, the sample size was small, even after combining the two studies. Therefore, these results should be interpreted with caution, and further research is required to confirm these findings. Nevertheless, an additional two and a half units PRBC transfusion requirement per patient is of clinical importance, given the risks of transfusion to the patient and the cost involved with its provision. In this sense, ORIF with plate would represent a risk minimisation to the patient and would reduce the overall cost of the surgery.

Attainment of pre-fracture mobility status

Single study meta-analysis performed for Revision with or without wires/cerclage/cables (studies=6 patients=86), Revision any method (studies=9 patients=123) and ORIF with plate (studies=3, patients=19), revealed a prevalence of attainment of pre-fracture mobility status of 88.8% (95%CI 66.6 to 99.6), 79.9% (95%CI 59.4 to 94.4) and 59.5% (95%CI 36.7 to 79.6), respectively.

Comparative meta-analysis for three studies (Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015, Joestl, Hofbauer et al. 2016) including 56 patients revealed a 6%

increase in the prevalence of attainment of pre-fracture mobility status for Revision with or without wires/cerclage/cables compared with ORIF with plate. This result was not statistically significant.

It should be noted that there was no explicit reporting by authors of how or at which time point post-operatively this assessment was made (e.g. clinical or self-reported). Future studies should include this and other patient-reported measures when evaluating surgical management strategies for Vancouver B2 PPF.

Parker mobility scores pre and post-operatively

Comparative meta-analysis for two studies (Niikura, Lee et al. 2014, Joestl, Hofbauer et al. 2016) including 41 patients revealed no statistically significant difference in the difference in Parker mobility score pre and post-operatively for Revision with or without wires/cerclage/cables compared with ORIF with plate. Both sub-groups revealed patients had modestly lower scores post-operatively with 0.49 (95%CI 0.40 to 1.38) points (lower post-operatively) for Revision with or without wires/cerclage/cables sub-group compared with 0.33 (95%CI 1.18 to 1.84) points (lower post-operatively) in the ORIF with plate sub-group.

Limitations of the systematic review

Quality of the evidence

Overall the methodological quality of the included studies was low and this is consistent with the field of orthopaedics research in general (Fayaz, Haas et al. 2013). In addition, the majority of studies lack the appropriate level of evidence, adequate sample sizes and often do not present a clear and systematic definition of exposures and outcomes. Furthermore, the studies lack sophisticated statistical techniques to handle confounding bias on most occasions. Despite these limitations, the current systematic review presents results based on the best available evidence on the effectiveness of surgical management strategies for Vancouver B2 PFF. The main methodological issues of the included studies in the current systematic review are reported below:

Definition of the population and exposure

Grouping patients into one single cohort based purely on their fracture classification as Vancouver B2 is useful to assess management strategies. However, there are variations within this type of fracture that may contribute to prognosis and response to treatment that should be considered in the evaluation of the surgical management strategy. These factors are related to the patients themselves, the implants used in the surgery, the performance of the surgical intervention itself and the after-care regime. Patient factors would include the indication for the index procedure (e.g. hip hemi-arthroplasty for a fractured neck of the femur vs primary total hip replacement for hip osteoarthritis) and age. Index procedure details, including arthroplasty construct (THA vs HA), femoral stem geometry and fixation principle (e.g. cemented vs uncemented systems) are important considerations in planning for subsequent management in the event of a PFF. The experiential level of the surgeon performing the intervention may

affect the outcomes of the surgery, and some of the included studies had more experienced surgeons concentrated in one intervention arm. Similarly, the after-care regime may also have an impact on the outcomes of the surgery. These include for example the weight-bearing, surgical antibiotic prophylaxis, and the venous thromboembolism prophylaxis protocols employed by surgeons. Table 14 shows the proportion of studies included in the review which reported these factors.

Table 14 Proportion of characteristics related to the exposure reported by the included studies.

Population	
Indication of index procedure	19% (7/37)
Age	84% (31/37)
Index procedure details	
Index arthroplasty construct (THA/HA)	51% (19/37)
Index femoral stem type	19% (7/37)
Index femoral stem fixation (cemented/cementless)	68% (25/37)
Exposure	
Experiential level of surgeon	24% (9/37)
Allocation of exposure	62% (23/37) out of which 65% was surgeon preference
After-care regime	
Weight-bearing regime	62% (23/37)
Surgical antibiotic prophylaxis protocol	22% (8/37)
Venous thromboembolism prophylaxis protocol	22% (8/37)

It should be noted that our intention for sub-group analysis, including patient age and surgeon experiential level, was not able to be executed due to the lack of reported data on either as evidenced by the Table above.

Definition of the outcomes

The explicit definition of outcome measures, their method and time-frame of measurement is important in orthopaedic research in order to effectively inform surgical decision-making and patient information on expected risks and benefits of proposed interventions (which may be non-operative or operative) along with their probable time-frames. The absence of strict definitions or criterion for an outcome measure makes interpretation of intra-study comparisons challenging as there may be multiple patients within a cohort exhibiting a similar clinical picture whom are inconsistently allocated to an outcome because of disparities between the assessor's (surgeon's) definition and its application to the clinical scenario. This potential for intra-assessor variability is further complicated by the fact that commonly multiple surgeons will participate in providing orthopaedic care within a given unit and unanimous opinion is variably observed which will lead to inter-assessor variability.

Furthermore, the method of measurement will impact on outcome assessment in terms of accuracy and precision of outcome detection. Additionally, the time-frame for its identification is vital in informing practice and counselling patients. Using an example from our study, the single study meta-analysis for Revision with or without wires/cerclage/cables for union outcome; 56% (10/18) studies provided a definition for union, however, although these definitions generally included radiographic assessment of cortical bridging usually 2 or 3 out of four times to satisfy a diagnosis of union, none of these definitions were exactly the same. 100% (18/18) reported a method of detection by way of a plain film radiograph with a further 17% (3/18) additionally considering clinical examination to support a diagnosis of union. Additionally, the time to union was only reported in half (9/18) of the studies.

In the case of complications, beyond the detection method and time-frame, the reporting of their management outcomes is also important to consider. In the case of prosthetic hip dislocation, it is relatively simple with a continuum between complete joint congruency, subluxation, where some articular contact is present, and dislocation, where no articular contact is observed. This may be identified clinically with a patient exhibiting a shortened and externally or internally rotated lower limb (depending on direction of dislocation) and inability to weight bear and can be further correlated with a plain film radiograph. In our single study meta-analysis of Revision with or without wires/cerclage/cables for dislocation outcome, 0% (0/11) study authors provided a definition or direction of dislocation. Dislocations are seldom left without treatment as the patient would be rendered unable to mobilise on that limb. In terms of the implication of a dislocation, if medical staff perform a reduction manoeuvre under sedation or anaesthesia to restore the normal joint enlocation this may or may not be considered as a re-operation depending on whether or not this was performed in the Emergency Department resuscitation room or in the operating theatre. As discussed above, Solomon et al. reported multiple dislocations and closed reductions being performed; however, none of these were reported as re-operations. If these dislocations were interpreted as re-operations, this would read as a re-operation rate (for dislocation) of 11% (1/9) for exposure 33A ORIF with plate and 29% (2/7) for 33B Revision with or without wires/cerclage/cables (Niikura, Lee et al. 2014, Solomon, Hussenbocus et al. 2015). This may change our view on either intervention depending on its size of effect and clinical relevance. Regardless of whether or not the dislocation event results in reporting as ‘re-operation’, an unstable joint articulation will impart much morbidity upon the patient with recurrent dislocations resulting in repeated hospital presentation and possible requirement for Revision surgery to improve arthroplasty construct to improve stability. It is clear that

depending on a studies definition of re-operation, important data may or may not be reported which would likely impact on the surgeon's decision-making and provision of expected outcomes to patients.

Beyond the detection method and time-frame, the concept of a threshold for an outcome being considered a reality is important to consider. Relevant to dislocation, subsidence of the femoral stem is a commonly reported outcome which may lead to altered stability of a hip arthroplasty construct by way of a stem migrating within the femoral canal and altering the dynamic at the prosthetic head and acetabular interface. The amount of subsidence which surgeons tolerate prior to labelling as such, varied amongst studies, however, generally 5mm or less was accepted to be within acceptable limits. For this reason we performed two single study meta-analyses for Subsidence for Revision with or without wires/cerclage/cables which included; Subsidence (any) where any subsidence was considered to represent its existence regardless of distance and Subsidence greater than 5mm **or** requiring Revision surgery, (with the latter thought to be somewhat more meaningful from a clinical perspective), for if 5mm or less subsidence is identified in a patient it would be unlikely to cause clinically detectable symptoms and ultimately, if any degree of subsidence is tolerated by the patient without causing symptoms or complications necessitating revision, it is likely to be clinically unimportant. For subsidence in any meta-analysis, a definition of subsidence was provided in 88% (7/8) studies, however, only 63% (5/8) explicitly reported their measurement method.

This uncertainty impacts not only our single study meta-analyses but our comparative meta-analyses. An example is our meta-analyses of Re-operation for Revision any method vs ORIF any method where 0% (0/4) study authors provided an explicit definition for re-operation. Additionally, they did not provide an explicit time-

frame within which re-operation was observed, with the only guidance being the overall time-frame for outcome assessment published by authors.

Furthermore, when considering comparisons between studies such as our comparative analysis section, an important limitation is the variable time-frames of outcome assessment. Upon review of these time-frames for outcomes assessed, most study ranges did not vary considerably (see Appendix IV for further details). In addition, all studies reported outcomes for clinically relevant observational time periods. For example, for the outcome of union, the critical period of evaluation is within the first year post-surgery, as union is generally achieved within 9 to 12 months after surgery.

Study protocols must establish strict definitions for outcome measures and their detection method and time-frame of assessment to ensure results are consistent and interpretable clinically. Beyond this, inter-study comparisons rely on these protocols in being explicit to ensure that outcomes observed are indeed comparable. Indeed, practice varies across units, health networks, states and nations. Herein lies a limitation to our meta-analyses.

Potential confounding bias

The included studies did not take age into account in their analysis, and this could be a potential source of confounding bias. Age is associated with both the assignment of surgical management strategy (older patients are more likely to receive ORIF with plate than Revision) and with the outcomes of transfusion, with older individuals being more likely to need transfusion; union, with older patients is less likely to progress to union due

to biological deficiencies; mortality, with older patients more likely to die, and re-operation, where a surgeon's inclination to offer re-operation after a Vancouver B2 PFF management strategy fails, may be less likely if the patient originally underwent ORIF as opposed to Revision.

There is also a potential of bias associated with the review process, such as the inclusion of studies published in English only. In addition, the title and abstract screening was performed by one reviewer only. Therefore, it is possible that some studies were missed in this process.

Strengths of the systematic review

This systematic review was born out of the absence of high quality, randomised controlled studies in the published literature to advise management of Vancouver B2 PFFs, which is an ever-more prevalent orthopaedic diagnosis. Regardless of the low quality of studies included, it represents the best available body of evidence to advise practice. It is the only systematic review on the topic which was guided by a published systematic review protocol (Ianunzio, Munn et al. 2017) and that included searching grey literature databases (in addition to published literature). Our systematic review's rigour and comprehensiveness is highlighted by drawing comparisons with the recently published systematic review by Khan and colleagues, whereby our study encompasses 37 studies including 926 patient fracture cases, representing over 250% greater content than that of Khan and colleagues (Khan, Grindlay et al. 2017).

Concluding statement

Overall, no management strategies have been shown to be consistently superior for the outcomes included in this systematic review and meta-analyses. This best body of evidence does not provide support for one intervention method over another except to say that;

- Revision with or without wires/cerclage/cables compared with ORIF with plate
    - ORIF with plate exposes patients to shorter surgical times and lower transfusion requirements
    - Outcomes of union, dislocation, attainment of pre-fracture mobility status and Parker mobility score should not be used to advise surgical management decision-making
- ORIF any method compared with Revision any method
    - ORIF any method exposes patients to shorter surgical times
    - A non-statistically significant trend towards Revision any method being protective against re-operation exists and requires further investigation.
- Outcomes of mortality and union should not be used to advise surgical management decision-making.

Future Directions

Future studies require larger, prospective, preferably randomised studies with more precise reporting of population and exposure, outcome definitions and observational time-frames, along with acknowledgement and control of age as a potential confounder.

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Appendices

Appendix I: Appraisal instruments

JBI Critical Appraisal Checklist for Randomised Controlled Trials

	Yes	No	Unclear	Not applicable
1. Was true randomisation used for assignment of participants to treatment groups?	☐	☐	☐	☐
2. Was allocation to treatment groups concealed?	☐	☐	☐	☐
3. Were treatment groups similar at the baseline?	☐	☐	☐	☐
4. Were participants blind to treatment assignment?	☐	☐	☐	☐
5. Were those delivering treatment blind to treatment assignment?	☐	☐	☐	☐
6. Were outcomes assessors blind to treatment assignment?	☐	☐	☐	☐
7. Were treatments groups treated identically other than the intervention of interest?	☐	☐	☐	☐
8. Was follow-up complete, and if not, were strategies to address incomplete follow-up utilised?	☐	☐	☐	☐
9. Were participants analysed in the groups to which they were randomized?	☐	☐	☐	☐
10. Were outcomes measured in the same way for treatment groups?	☐	☐	☐	☐
11. Were outcomes measured in a reliable way?	☐	☐	☐	☐
12. Was appropriate statistical analysis used?	☐	☐	☐	☐
13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?	☐	☐	☐	☐

JBI Critical Appraisal Checklist for Quasi-Experimental

	Yes	No	Unclear	Not applicable
1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	☐	☐	☐	☐
2. Were the participants included in any comparisons similar?	☐	☐	☐	☐
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	☐	☐	☐	☐
4. Was there a control group?	☐	☐	☐	☐
5. Were there multiple measurements of the outcome/conditions both pre and post the intervention/exposure?	☐	☐	☐	☐
6. Was follow-up complete, and if not, was follow-up adequately reported and strategies to deal with loss to follow-up employed?	☐	☐	☐	☐
7. Were the outcomes of participants included in any comparisons measured in the same way?	☐	☐	☐	☐
8. Were outcomes measured in a reliable way?	☐	☐	☐	☐
9. Was appropriate statistical analysis used?	☐	☐	☐	☐

JBI Critical Appraisal Checklist for Cohort Studies

	Yes	No	Unclear	Not applicable
1. Were the two groups similar and recruited from the same population?	☐	☐	☐	☐
2. Were the exposures measured similarly to assign people to both exposed and unexposed groups?	☐	☐	☐	☐
3. Was the exposure measured in a valid and reliable way?	☐	☐	☐	☐
4. Were confounding factors identified?	☐	☐	☐	☐
5. Were strategies to deal with confounding factors stated?	☐	☐	☐	☐
6. Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?	☐	☐	☐	☐
7. Were the outcomes measured in a valid and reliable way?	☐	☐	☐	☐
8. Was the follow-up time reported and sufficient to belong enough for outcomes to occur?	☐	☐	☐	☐
9. Was follow-up complete, and if not, were the reasons to loss to follow-up described and explored?	☐	☐	☐	☐
10. Were strategies to address incomplete follow-up utilised?	☐	☐	☐	☐
11. Was appropriate statistical analysis used?	☐	☐	☐	☐

JBI Critical Appraisal Checklist for Case Control Studies

	Yes	No	Unclear	Not applicable
1. Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?	☐	☐	☐	☐
2. Were cases and controls matched appropriately?	☐	☐	☐	☐
3. Were the same criteria used for identification of cases and controls?	☐	☐	☐	☐
4. Was exposure measured in a standard, valid and reliable way?	☐	☐	☐	☐
5. Was exposure measured in the same way for cases and controls?	☐	☐	☐	☐
6. Were confounding factors identified?	☐	☐	☐	☐
7. Were strategies to deal with confounding factors stated?	☐	☐	☐	☐
8. Were outcomes assessed in a standard, valid and reliable way for cases?	☐	☐	☐	☐
9. Was the exposure period of interest long enough to be meaningful?	☐	☐	☐	☐
10. Was appropriate statistical analysis used?	☐	☐	☐	☐

JBI Critical Appraisal Checklist for Analytical Cross Sectional Studies

	Yes	No	Unclear	Not applicable
1. Were the criteria for inclusion in the sample clearly defined?	☐	☐	☐	☐
2. Were the study subjects and the setting described in detail?	☐	☐	☐	☐
3. Was the exposure measured in a valid and reliable way?	☐	☐	☐	☐
4. Were objective, standard criteria used for measurement of the condition?	☐	☐	☐	☐
5. Were confounding factors identified?	☐	☐	☐	☐
6. Were strategies to deal with confounding factors stated?	☐	☐	☐	☐
7. Were the outcomes measured in a valid and reliable way?	☐	☐	☐	☐
8. Was appropriate statistical analysis used?	☐	☐	☐	☐

JBI Critical Appraisal Checklist for Case Series

	Yes	No	Unclear	Not applicable
1. Were there clear criteria for inclusion in the case series?	☐	☐	☐	☐
2. Was the condition measured in a standard, reliable way for all participants included in the case series?	☐	☐	☐	☐
3. Were valid methods used for identification of the condition for all participants included in the case series?	☐	☐	☐	☐
4. Did the case series have consecutive inclusion of participants?	☐	☐	☐	☐
5. Did the case series have complete inclusion of participants?	☐	☐	☐	☐
6. Was there clear reporting of the demographics of the participants in the study?	☐	☐	☐	☐
7. Was there clear reporting of clinical information of the participants?	☐	☐	☐	☐
8. Were the outcomes or follow-up results of cases clearly reported?	☐	☐	☐	☐
9. Was there clear reporting of the presenting site(s)/clinic(s) demographic information?	☐	☐	☐	☐
10. Was statistical analysis appropriate?	☐	☐	☐	☐

Appendix II: Data extraction instrument

JBI Data Extraction Form for Experimental / Observational Studies

Reviewer _ Date _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Author _ Year _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Journal _ Record Number _ _ _ _ _ _ _ _ _ _ _ _ _ _

Study Method

RCT ☐ Quasi-RCT ☐ Longitudinal ☐

Retrospective ☐ Observational ☐ Other ☐

Participants

Setting

Population

Sample size

Group A _____ Group B _____

Interventions

Intervention A

Intervention B

Authors Conclusions:

Reviewers Conclusions:

Study results

Dichotomous data

Outcome	**Intervention ( )** **number/total number**	**Intervention ( )** **number/total number**

Continuous data

Outcome	**Intervention ( )** **number/total number**	**Intervention ( )** **number/total number**

Appendix III: List of excluded studies after full-text reading.

Reason for exclusion: Study included mixed exposures and pooled outcomes (n=39)

1. Abdel MP, Lewallen DG, Berry DJ. Periprosthetic femur fractures treated with modular fluted, tapered stems. *Clin Orthop Relat Res*. 2014;472:599-603.
2. Al-Ajlouni JM. Early results of femoral reconstruction with a tapered, cementless, modular stem. *Jordan Medical Journal*. 2014;48:81-92.
3. Artiaco S, Boggio F, Titolo P, Zoccola K, Bianchi P, Bellomo F. Clinical experience in femoral revision with the modular Profemur R stem. *Hip Int*. 2011;21(1):39-42.
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6. Colman M, Choi L, Chen A, Crossett L, Tarkin I, McGough R. Proximal femoral replacement in the management of acute periprosthetic fractures of the hip: a competing risks survival analysis. *J Arthroplasty.* 2014;29:422-7.
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13. Fink B, Grossmann A, Singer J. Hip revision arthroplasty in periprosthetic fractures of Vancouver type B2 and B3. *Journal of orthopaedic trauma*. 2012;26(4):206-11.

14. Griffiths EJ, Cash DJ, Kalra S, Hopgood PJ. Time to surgery and 30-day morbidity and mortality of periprosthetic hip fractures. *Injury*. 2013;44(12):1949-52.

15. Haddad FS. Clinical and biomechanical assessment of the treatment of type b periprosthetic fractures of the femur [Ph.D.]. Ann Arbor: University of London, University College London (United Kingdom); 2012.

16. Hernandez-Vaquero D, Fernandez-Lombardia J, de los Rios JL, Perez-Coto I, Iglesias-Fernandez S. Treatment of periprosthetic femoral fractures with modular stems. *Int Orthop*. 2015;39(10):1933-8.

17. Kinov P, Volpin G, Sevi R, Tanchev PP, Antonov B, Hakim G. Surgical treatment of periprosthetic femoral fractures following hip arthroplasty: our institutional experience. *Injur*y. 2015;46(10):1945-50.

18. Langenhan R, Trobisch P, Ricart P, Probst A. Aggressive Surgical Treatment of Periprosthetic Femur Fractures Can Reduce Mortality: Comparison of Open Reduction and Internal Fixation versus a Modular Prosthesis Nail. *Journal of orthopaedic trauma.* 2012;26:80-5.

19. Lindahl H, Malchau H, Oden A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. *J Bone Joint Surg Br*. 2006;88(1):26-30.

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Reason for exclusion: Study was not written in English (n=20)

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Reason for exclusion: study did not present a classification for PFF (n=18)

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Reason for exclusion: Study did not have the design of interest (n=16)

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Reason for exclusion: Study did not include the population of interest (n=13)

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Reason for exclusion: Study did not adopt the Vancouver classification (n=10)

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Reason for exclusion: No outcomes presented (n=4)

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Reason for exclusion: Study did not include the intervention of interest (n=1)

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Reason for exclusion: Study did not include PFF (n=1)

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Appendix IV Description of Studies
Cohort studies

First author/ year	Cohort characteristics	Participants characteristics	Exposure	Outcomes	Statistical analysis	Results	Limitations and conclusions (Authors')	Limitations and conclusions (Reviewers')
Bhattacharyya 2007 (2A/B)	**Study design** Retrospective cohort study n=106 **Data source:** Local trauma registry, medical records, social security database for mortality	**Participants** Mixed cohort of patients with PFF, n=43 Vancouver B2 **Sampling:** Unclear **Recruitment:** 2000-2005 **Indication index** NS **Index implant details** NS **Mechanism injure** Minor trauma 103/106 (97.2%) Motor vehicle accident 3/106 (2.8%) **Fracture diagnosis method** Radiographs and intra-operative assessment **Setting** Multi-centre**.** Two tertiary trauma centres Boston, Massachusetts, USA **Inclusion criteria** Patients with a PFF treated operatively **Exclusion criteria** Nil	**Exposure A Revision +/- W/C/C (n=38)** (Revision long stem, uncemented, posterior approach, implant NS, Zimmer) **Exposure B ORIF with plate (n=5)** (lateral locking plate, implant NS, company NS) **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	Mortality	Adopted Chi-square to test difference in mortality between groups (Exposure A and B)	**Mortality** A: 6/38 (15.8%) B: 3/5 (60%) cumulative at 4 years – p=0.054	Revision is associated with lower mortality rate compared with ORIF plate, which maybe in part be attributed to early weight bearing with revision. Authors acknowledge selection bias exists i.e. it may be that more medically fit patients were chosen to undergo revision.	Patients were allocated to Revision or ORIF based on surgeon preference. For the association under study there was no attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to receive ORIF and are more likely to die). The association between higher mortality and ORIF is potentially confounded by factors such as age and comorbidities, which were not controlled for.
Joestl 2016 (15A/B/C)	**Study design** Retrospective cohort study n=32 **Data source** Local trauma registry, medical records	**Participants** Cohort of patients with Vancouver B2 PFF, n=32 **Sampling** Consecutive **Recruitment** 2000-2014 **Indication index** NS **Index implant details** THA (see later) **Mechanism injury** Low energy fall	**Exposure A Revision +/- W/C/C (n=14)** (Revision uncemented distally fixed long stem and cables, anterolateral approach, Helios, Biomet) **M:F** 3:11 **Mean age in years:** 81 (SD 9) **Index implant Cemented: Uncemented** 1:13 **Exposure B Revision +/- W/C/C (n=14)** (uncemented	-Attain pre-fracture mobility status -Dislocation/ -Infection (DSSI +/- SSSI)	Descriptive statistics used for all outcomes with the exception of:	**Attain pre-fracture mobility status** A: 8/14 (57.1%) B: 7/14 (50%) C: 5/8 (62.5%) **Dislocation** A: 1/14 (7.1%) B: 2/14 (14.3%) C: 0/8 (0%) **Infection (DSSI or SSSI)** A: 1/14 (7.1%) B: 1/14 (7.1%) C: 0/8 (0%)	ORIF utilizing the LCP-system is a valid treatment option for Vancouver B2 PFF following THA.	Patient allocation to Revision or ORIF was NS. For the associations under study there was no attempt to account for presence of confounding factors (e.g. older/frail patients

		Fracture diagnosis method Trauma surgeon (author) **Setting** Single-centre Tertiary hospital Vienna, Austria **Inclusion criteria** Patients with a Vancouver B2 PFF around a THA **Exclusion criteria** Pathological fractures Index procedure hip HA	distally fixed long stem and cables, anterolateral approach Hyperion, Biomet) **M:F** 6:8 **Mean age in years:** 80 (SD 9) **Index implant Cemented/ uncemented** 1:13 **Exposure C ORIF with plate (n=8)** (Locking compression plate (4.5mm LCP, Synthes) **M:F** 1:7 **Mean age in years:** 85 (SD 8) **Index implant Cemented/ uncemented:** 0:8 **Allocation of exposure:** NS **Surgeon experiential level** NS **Weight bearing status** **For Exposure A and B** Early mobilization with two crutches or walker **OR** Partial **OR** full weight bearing immediately post-operatively (no protocol specified) **For Exposure C** Partial weight bearing (20kg) with 2 crutches or walker for 6 weeks, then in absence or pain and XR supportive of healing upgraded to full weight bearing **Venous thromboembolism prophylaxis** Low molecular weight heparin until full weight bearing **Surgical antibiotic prophylaxis** Cefuroxim for 5 days	-Length of stay - Mortality - Neurovascular injury -Parker mobility score (pre and post op) -Subsidence - Surgical time -Transfusion -Union (15C only) -Venous thromboembolism (DVT or PE) **Time-frame of outcomes assessment:** Exposure A: 10-103 months Exposure B: 9-27 months Exposure C: 9-50 months	Surgical time and length of stay (ANOVA was used to compare means between Exposure A, B and C)	**Infection DSSI** A: 1/14 (7.1%) B: Not reported C: 0/8 (0%) **Infection SSSI** A: Not reported B: 1/14 (7.1%) C: 0/8 (0%) **Length of stay (days)** A: 26 (SD 14, Range 11-55) B: 29 (SD 16, Range 19-70) C: 26 (SD 13, Range 11-49) p-value=0.4748 **Mortality overall** A: 0/14 (0%) B: 0/14 (0%) C: 0/8 (0%) **Neurovascular injury** A: 0/14 (0%) B: 0/14 (0%) C: 0/8 (0%) **Parker mobility score post-operatively** A: 6.5 (SD 2, Range 4-9) B: 6.35 (SD 2, Range 4-9) C: 6.62 (SD 2, Range 4-9) p-value=0.2940 ***Note: Parker mobility score pre-operatively** A: 6.8 (SD 1.7, Range 4-9) B: 6.99 (SD 1, Range 5-9) C: 7 (SD 1.2, Range 4-9) p-value=0.6513 **Subsidence** A: 0/14 (0%) B: 0/14 (0%) C: 0/8 (0%) **Surgical time ('surgical duration' mins)** A: 190 (SD 47, Range 135-355) B: 191 (SD 35, Range 130-260) C: 151 (SD 48, Range 90-205) p-value=0.1025 **Transfusion (1 or more units PRBC required within 48 hours surgery)** A: 12/14 (85.7%) B: 6/14 (42.8%) C: 5/8 (62.5%) p-value=0.0754 **Union (overall)** A: NS B: NS C: 8/8 (100%)	The key to a successful outcome is anatomical fracture reduction of the femoral shaft in order to ensure stem stability to the bone and to avoid secondary migration of the prosthesis.	are more likely to receive ORIF and are more likely to die). The study did not present an analysis on anatomical fracture reduction to support their conclusions on this matter. In addition, the statistical approach to test the differences in binary outcomes e.g. transfusion was NS, although p-values were presented. Overall, the study reported that there was no difference for outcomes between exposure groups. Nevertheless, the lack of a statistically significant difference could be related to the small sample size.

						Venous thromboembolism **DVT** A: 0/14 (0%) B: 0/14 (0%) C: 0/8 (0%) **PE** A: 0/14 (0%) B: 0/14 (0%) C: 0/8 (0%)		
Lindahl 2006 (20A/B/C)	**Study design** Retrospective cohort study n=321 (Full assessment for n=217, re-operation outcome for n=321) **Data source** National joint registry, National population registry for mortality	**Participants** Mixed cohort of patients with PFF, n=158 Vancouver B2 **Sampling** NS **Recruitment** 1999-2000 **Indication index** NS **Index implant details** THA **Primary:Revision** 230:91 **Cemented:Uncemented** 318:3 **Mechanism injury** Not explicit - minor trauma 70-80% **Fracture diagnosis method** Radiographs (surgeon and radiologist) **Setting** Multi-centre (central and rural) Sahlgrenska University Hospital, Göteborg University, Göteborg, and the Department of Orthopaedics, NU-sjukvården, Uddevalla, Sweden **Inclusion criteria** Patients with a PFF around THA reported in national joint register **Exclusion criteria** Nil	**Exposure A Revision +/- W/C/C (n=49)** (Majority cemented long stem, approach NS, no implant specified) **Exposure B Revision mixed methods/unspecified (n=86)** (Majority cemented long stem, ORIF technique NS, no implant specified) **Exposure C ORIF mixed methods/unspecified (n=19)** (Technique NS although authors state common practice single plate fixation, no implant specified) **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific implant usage for Exposure groups, globally available exposure data advises 144/193 (75%) of revision procedures were performed with a cemented long stem implant and 49/193 (25%) of revision procedures were performed with an uncemented long stem distally fixed implant. Only 2 patients treated with only strut allografts.	-Re-operation **Time-frame of outcomes assessment:** Pooled mean 5 years (3.8-6 years, SD N/S)	Utilised descrip-tive statistics for re-operation outcome for Exposure groups	**Re-operation** A: 5/49 (10.2%) B: 20/86 (23.3%) C: 6/19 (31.6%)	Authors report a high frequency of repeat surgery after treatment of Vancouver type B2 fractures with ORIF alone.	The purpose of this study was to determine the demographics, incidence, and results of treatment of periprosthetic fractures. For the association of type of treatment and re-operation, authors did not attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to receive ORIF and may be at higher risk of developing complications resulting in the need for re-operation (e.g. malnutrition my lead to non-union, which may necessitate re-operation). Additionally, the ORIF technique utilised in Exposure group B and C was not explicitly described, which limits the interpretation of the results.
Mukka 2016 (24A/B/C)	**Study design** Prospective cohort study n=26* **Data source**	**Participants** Mixed cohort of patients with PFF, n= 18 Vancouver B2 **Sampling** Consecutive **Recruitment** 2009-2015	**Exposure A Revision (n=8)** (Revision same length or longer stem, cemented or uncemented and cerclage, direct lateral, no implant specified)	-Union -Mortality -Infection (DSSI/SSSI) -Re-operation	Utilised descrip-tive statistics for	**Union*** A: 8/8 (100%) B: 8/8 (100%) C: 2/2 (100%) **Mortality overall*** A: 4/8 (50%) B: 2/8 (25%) C: 0/2 (0%)	Authors do not give conclusions specific to management	The purpose of this study was to compare the prevalence and incidence rate of

	Local medical and surgical database	**Indication index** NS **Index implant details** THA:HA 3:15 **Primary:Revision** 18:0 **Stem** All CPT (Cemented, polished tapered stems) **Mechanism injury** NS **Fracture diagnosis method** Radiographs (Senior revision hip surgeon) **Setting** Multi-centre Two tertiary centres Danderyd Hospital Stockholm and Sundsvall Hospital, Sweden **Inclusion criteria** Patients 80 years and older sustaining a PFF within 24 months of primary THA or HA for displaced femoral neck fracture **Exclusion criteria** Intra-operative PFFs	**M:F** 3:5 **Mean age in years:** 84.6 (Range 80.73-90.36, No SD) **Time from index to fracture in years:** 1.27 (9 days to 1748, No SD) **Index implant** THA:HA 2:6 **Stem** All cemented CPT **Follow up mean in months:** 24 (Range 20-1823 days, No SD stated) **Exposure B** **Revision + ORIF plate (n=8)** (Revision same length or longer stem, cemented and ORIF plate, direct lateral approach, no implant specified) **M:F** 3:5 **Mean age in years:** 86.35 (Range 80.97-92.63, No SD) **Time from index to fracture in years:** 1.05 (37 days to 1251, No SD) **Index implant** THA:HA 1:7 **Stem** All cemented CPT **Follow up mean in months:** 29 (Range 104-2094 days), No SD stated) **Exposure C ORIF with W/C/C (n=2)** (ORIF with cerclage only, approach NS, no implant specified) **M:F** NS **Mean age in years:** 94.2 (Range 94.1-94.3, No SD) **Time from index to fracture in years:** 2.3 (Range 762-926, No SD) **Index implant** THA:HA 0:2 **Stem** All cemented CPT **Follow up mean in months:** 14.6 (Range 158-732 days), No SD stated) **Allocation of exposure** NS **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS	**Time-frame of outcomes assessment:** See follow-up	outcomes for Exposure groups	**Mortality within 1 year*** A: 3/8 (37.5%) B: 2/8 (25%) C: 0/2 (0%) **Infection (DSSI or SSSI)*** A: 3/8 (37.5%) B: 2/8 (25%) C: 0/2 (0%) **Infection DSSI*** A: 2/8 (25%) B: 2/8 (25%) C: 0/2 (0%) **Infection SSSI*** A: 1/8 (12.5%) B: 0/8 (0%) C: 0/2 (0%) **Re-operation*** A: 2/8 (25%) B: 2/8 (25%) C: 0/2 (0%)	of Vancouver B2 PFF in this publication.	PFFs in an octogenarian THA/HA cohort. The study indicates that there was no difference for between exposure groups for union. Mortality, re-operation and infection rates favoured ORIF (exposure C), however, given the small sample size and low incidence of these outcomes it is difficult to interpret.

			Surgical antibiotic prophylaxis NS					
Mukundan 2010 (25A/B/C)	**Study design** Retrospective cohort n=72 **Data source** Local database	**Participants** Mixed cohort of patients with PFF, n= 42 Vancouver B2 **Sampling** Unclear **Recruitment** 1995-2005 **Indication index** NS **Index implant details** THA:HA 58:14 **Primary:Revision** 56 (:15 **Cemented:Uncemented** 55 (40 primary THA, 15 revision THA):17 (14 HA, 3 primary THA) **Stem** NS **Mechanism injury** All simple falls **Fracture diagnosis method** Radiographs and intra-operative notes **Setting** Single-centre Tertiary hospital Leeds, United Kingdom **Inclusion criteria** Patients sustaining a PFF following THA or HA managed by a single surgeon at their institution **Exclusion criteria** NS	**Exposure A Revision +/- W/C/C (n=19)** (Revision long stem, cemented/uncemented NS, approach NS, implant NS, company NS) **Exposure B Revision + ORIF plate (n=8)** (Revision long stem with ORIF Dynamic compression plate, cemented/uncemented NS, approach NS, implant NS, company NS) **Exposure C Revision +/- W/C/C (n=15)** (Revision with distally locked long stem, cemented/uncemented NS, approach NS, implant NS, company NS) **Allocation of exposure** Not explicit (Implies Vancouver algorithm used) **Surgeon experiential level** Consultant (single surgeon) **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	Subsidence/ Union/ Infection DSSI/ Dislocation/ Modified Charnley-D'Aubigne Postel score **Time-frame of outcomes assessment:** Minimum 24 months (pooled)	Utilised descript-tive statistics for outcomes for Exposure groups	**Subsidence** A: Not reported B: Not reported C: 3/15 (20%) **Union** A: 19/19 (100%) B: 8/8 (100%) C: 14/15 (93.3%) **Infection DSSI** A: Not reported B: Not reported C: 2/15 (13.3%) **Dislocation** A: 0/19 (0%) B: 0/8 (0%) C: 1/15 (6.7%) **Modified Charnley-D'Aubigne Postel score proportion of excellent outcome** A: 14/19 (73.7%) B: 5/8 (62.5%) C: 6/15 (40%) **Modified Charnley-D'Aubigne Postel score proportion of poor outcome** A: 0/19 (0%) B: 3/8 (37.5%) C: 6/15 (40%)	Authors made no specific conclusions regarding management of Vancouver B2 PFFs except for noting all but one patient's fracture united.	The purpose of this study was to present a single surgeon's series of PFF management. For the outcomes of subsidence and deep surgical site infection no conclusions can be drawn as authors only published outcome data for exposure group C. Regardless of exposure, the incidence rates of union and dislocation were similar. For the outcome of Modified Charnley D'Aubigne Postel score, Revision long stem (exposure A) group was positively associated with proportion of excellent outcomes when compared with Revision ORIF with plate (exposure B) and Revision with distally locked long stem (exposure C).
Pavlou 2011 (28A/B/C/D)	**Study design** Retrospective cohort study (n=202) **Data source** Local records	**Participants** Mixed cohort of patients with PFFs, n=52 B2 **Sampling** Unclear (appears consecutive) **Recruitment** 1995-2007 **Indication index** NS **Index implant details** NS	**Exposure A Revision +/- W/C/C (n=25)** (Revision stem only, approach NS, implant NS, company NS) **Exposure B Revision mixed methods/unspecified (n=27)** (Revision stem and cortical strut OR impaction allograft,	-Union -Time to union -Non-union -Dislocation -Infection -DSSI/SSSI	Adopted ANOVA to test mean time for union between groups	**Union overall** A: 23/25 (92%) B: 26/27 (96.2%) C: 6/10 (60%) D: 3/4 (75%) **Time to union (months)** A: 5 (SD 2.2, Range NS) B: 4.26 (SD 1.9, Range NS) p-value=0.218 **Time to union (months)**	Fixation with or without bone grafting for Vancouver B2 PFFs rarely has a role as the	The aim of this study was to evaluate treatment methods of PFF with respect to stem revision and grafting.

		Mechanism injury NS **Fracture diagnosis method** Not explicit **Setting** Multi-centre Two arthroplasty centres, UK (note no explicit location specified) **Inclusion criteria** Patients with a PFF around a THA treated operatively **Exclusion criteria** Lost to follow-up or deceased for reasons not related to surgery (19/202 including; 15/81 (18.5%) B2, 3/18 (16.7%) B1, 1/107 (0.93%) B3)	approach NS, implant NS, company NS) **Exposure C ORIF with plate (without bone grafting) (n=10)** Single or double plating, no implant specified, no company specified) **Exposure D ORIF with plate (with bone grafting) (n=4)** Single or double plating, with bone grafting, no implant specified, no company specified) **Allocation of exposure** NS (although implies Vancouver algorithm) **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided pooled data published Sex M:F 76:145 Age at surgery (mean): 75 (Range 33-90, no SD given)	**Time-frame of outcomes assessment:** Assessed until union OR 12 months	(Exposure A, B, C, D), alpha error <0.05 statistically significant. Adopted OR 95% CI for non-union rates Utilised descriptive statistics for Dislocation and Infection outcomes for groups (Exposures A, B, C, D)	A: 4.3 (SD 1.9, Range NS) C: 8.8 (SD 4.0, Range NS) p-value=0.038 **Time to union (months)** A: 4.3 (SD 1.9, Range NS) D:4.4 (SD 0.5, Range NS) p-value=0.736 **Time to union (months)** B: 5 (SD 2.2, Range NS) C: 8.8 (SD 4.0, Range NS) p-value=0.067 **Time to union (months)** B: 5 (SD 2.2, Range NS) D: 4.4 (SD 0.5, Range NS) p-value=0.298 **Time to union (months)** C: 8.8 (SD 4.0, Range NS) D: 4.4 (SD 0.51, Range NS) p-value=0.043 **Non-union overall** A: 2/25 (8%) B: 1/27 (3.7%) C: 4/10 (40%) D: 1/4 (25%) **Non-union A vs B** OR 2.26 (0.19-26.6 95%CI) p-value=0.517 **Non-union A vs C** OR 7.7 (1.12-52.32 95% CI) **p-value=0.038** **Non-union A vs D** OR 3.83 (0.26-56.2, 95% CI) p-value=0.327 **Non-union B vs C** OR 17.3 (1.63-184.4, 95%CI) **p-value=0.018** **Non-union B vs D** OR 8.7 (0.43-177.3, 95%CI) p-value=0.1 **Non-union D vs C** OR 2 (0.15-26.7 95%CI) p-value=0.6 **Dislocation** A: 3/25 (12%) B: Not reported C: 0/10 (0%) D: 3/4 (75%)	non-union rates are unacceptably high, however, elderly patients with B2 fractures deemed unsuitable for prolonged procedure may selectively be considered for palliative fixation. Stem revision is becoming increasingly advised over fixation for PFF management. When stem revision is indicated for management, cases should be referred to highly specialised arthroplasty centres.	Revision appears to be protective against non-union when compared to ORIF plate, with or without bone grafting, however, potential confounders were not controlled for by study authors. Although this study reports statistically significant differences in time to union (shorter), and non-union (lower incidence) for Revision stem (exposure group A) and ORIF plate without bone graft (exposure group C), and non-union (lower incidence) for Revision stem and cortical strut or impaction allografting (exposure group B) and ORIF plate without bone graft), there was no attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to receive ORIF and are more likely to be exhibit poor healing potential and thus a higher propensity for non-union and delayed union). This makes interpretation

						Infection (DSSI or SSSI) A: 2/25 (8%) B: 0/27 (0%) C: 0/10 (0%) D: 1/4 (25%) **Infection DSSI** A: Not reported B: 0/27 (0%) C: 0/10 (0%) D: Not reported **Infection SSSI** A: Not reported B: 0/27 (0%) C: 0/10 (0%) D: Not reported		of union, time to union and non-union difficult. Additionally, the influence of bone graft utilisation it self may confound comparisons between Revision and ORIF given the absence of a statistically significant between exposure groups B and D for outcome of non-union. Study authors did not state why 14 Vancouver type B2 PFFs underwent ORIF despite them implying usage of Vancouver algorithm, authors imply one indication for such ORIF is patients whom are deemed unsuitable for lengthy operation. For the outcomes of Dislocation there appears to be higher rates in ORIF plate with bone graft (exposure group D) compared with remaining exposure groups. For the outcome of surgical site infection, given authors inconsistently specified Deep vs Superficial location

								across exposure groups it makes drawing conclusions difficult.
Solomon 2015 (33A/B)	**Study design** Retrospective cohort study n=21 **Data source** Local records	**Participants** Cohort of patients with Vancouver B2 PFF, n= 21 **Sampling** Unclear **Recruitment** 2000-2010 **Indication index** NS **Index implant details** See exposure **Mechanism injury** NS **Fracture diagnosis method** Radiographs, ERBA **Setting** Single-centre Tertiary hospital Adelaide, South Australia **Inclusion criteria** Patients with a Vancouver B2 PFF (assessed as loose at stem-cement interface only (except for major fracture lines), with anatomical reduction deemed possible) around cemented, collarless polished tapered femoral stem treated operatively **Exclusion criteria** Death pre-operatively (1), concomitant acetabular revision for loosening (1)	**Exposure A ORIF with plate (n=12)** (ORIF cable ready plate with non-locking screws, lateral approach to femur, Zimmer) **M:F** 7:5 **Mean age in years:** 79 (Range 57-89, No SD reported) **ASA** 2:4/12 (33%), 3:5/12 (42%), 4:3/12 (25%) **Time from index to fracture in years median:** 2.4 (Range 0.08-16, No SD) **Primary:Revision** 12:0 **Cemented:Uncemented** 12:0 **Stem** CPT: 6, Exeter: 6 **Lost to follow-up** n=3 Exposure group A (death prior to 3 months post op due to medical causes unrelated to surgery – excluded from published data, reported here) **Exposure B Revision +/- W/C/C (n=9)** (Revision long stem, cemented with cables (4) or Revision distally fixed long stem, uncemented with cables (5), posterior approach, implant NS, company NS. **M:F** 4:5 **Mean age in years:** 71 (Range 39-88, No SD reported) **ASA** 2:3/9 (33%), 3:4/9 (44%), 4:2/9 (22%) **Time from index to fracture in years median:** 0.96 (Range 0.03-17, No SD) **Primary:Revision** 7:2 **Cemented:Uncemented** 9:0 **Stem** CPT: 4, Exeter: 5 **Lost to follow-up** n=2 Exposure group B (death prior to 3 months post op due to	-Surgical time -Transfusion -Subsidence -Union/Non-union (33A) -Femoral osteolysis -Aseptic loosening femur -Infection DSSI/SSSI -Dislocation -Delayed wound healing -Harris Hip Score -Harris pain score (post-op) -Attain pre-fracture mobility status - Mortality* **Time-frame of outcomes assessment:** Exposure A Overall: median 67 months (13-82) – excludes 3 deaths <3 months Exposure B Overall: median 59 months (16-137) – excludes 2	Adopted Mann-Whitney U test to test differ-ence in outcomes operating room time, skin-to-skin surgical time and trans-fusion units required between groups (Expo-sure A and B). Utilised descript-tive statistics for remain-ing outcomes for exposure groups.	**Surgical time - Skin to skin median (Wasko and Kaminski)** A: 122 (SD not stated, Range 80-165) B: 200 (SD not stated, Range 142-285) **p-value=0.002** **Surgical time - Skin to skin mean (Wasko and Kaminski) (generated by author JI)** A: 125.4 (SD 27.8, 80-165) B: 196 (SD 51.4, 142-285) **Surgical time - Operating theatre time median (Wasko and Kaminski)** A: 183 (SD not stated, 143-239) B: 270 (SD not stated, 206-352) **p-value=0.002** **Surgical time – Operating theatre time mean (Wasko and Kaminski) (generated by author JI)** A: 199 (SD 33.2, 143-239) B: 275 (SD 50.1, 206-352) **Transfusion – Number packed red blood cells required median (units)** A: 0 (SD not stated, 0-4) B: 3 (SD not stated, 0-5) **p-value=0.008** **Transfusion – Number packed red blood cells required mean (units) (generated by author JI)** A: 0.4 (1.33, 0-4) B: 3 (SD 1.74, 0-5) **Subsidence 6mm or more** A: 0/9 (0%) B: 1/7 (14.3%) **Union** A: 9/9 (100%) B: 6/7 (85.7%)* (raw data, not published)	Authors conclude ORIF is a viable alternative to Revision when loosening is present only at stem-cement interface and anatomical reduction achieved when managing Vancouver B2 PFFs. Additionally, authors conclude that ORIF reduces operative risks, operating and anaesthesia times, as well as the direct cost of the procedure. It should be emphasized that achieving anatomical reduction is a prerequisite for treatment of these fractures with	The aim of this study was to determine the operative risks, post-operative complications, and radiographic and functional outcomes in two cohorts of Vancouver B2 femoral fractures around CCPT stems treated either by ORIF alone or revision surgery. For the sub-group of Vancouver B2 PFF around CCPT stems the study demonstrates shorter time in operating theatre and skin to skin surgical time. Having said this, authors did not account for confounders such as method of anaesthesia (general anaesthetic vs spinal anaesthesia vs regional anaesthesia), BMI and positioning procedure, which may have impacted durations for both outcomes. Their conclusion regarding anaesthesia time is difficult to make as

			medical causes unrelated to surgery – excluded from published data, reported here) **Allocation of exposure** NS **Surgeon experiential level** Exposure A – Consultant surgeon or trainee under direct supervision by consultant. Exposure B – Consultant surgeon experienced in hip revision **Weight bearing status** Exposure A – Partial weightbearing 20kg for first six weeks progressing to full weightbearing Exposure B – Uncemented - as for exposure A. Cemented – weight bear as tolerated immediately after surgery **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	deaths <3 months		**Non-union** A: 0/9 (0%) B: Not reported **Femoral osteolysis** A: 0/9 (0%) B: 0/7 (0%) **Infection (DSSI or SSSI)** A: 0/9 (0%) B: 0/7 (0%) **Infection DSSI** A: 0/9 (0%) B: 0/7 (0%) **Infection SSSI** A: 0/9 (0%) B: 0/7 (0%) **Dislocation** A: 1/9 (11%) B: 2/7 (28.6%) **Delayed wound healing** A: 0/9 (0%) B: Not reported **Harris Hip Score mean (post op) at latest follow-up** A: 59 (SD 23, 36-96) **n=5** B: 72 (SD 11.3, 36-96) **n=4** **Harris Pain score mean (post op) at latest follow-up** A: 40.5 (SD 8.4, 20-44) **n=8** B: 31.1 (SD 15.2, 10-44) **n=7** **Attain pre-fracture mobility status** A: 3/8 (37.5%) B: 5/7 (72%) **Mortality within 3months*** A: 3/12 (25%) B: 2/9 (22%) **Mortality overall*** A: 3/12 (25%) B: 5/9 (55.5%)	ORIF. If anatomical reduction cannot be achieved, stem revision is indicated. The return to pre-injury mobility of the ORIF cohort at latest follow-up was poorer than those in the revision cohort, although the self reported Harris pain scores were better in the ORIF group. Authors' report study limitations including small sample size, relatively short follow-up, absence of control for age and presence of co-morbidities.	it was not explicitly studied or how the anaesthetic time was estimated from the two available outcome variables. Although study authors conclude ORIF reduces direct cost of the procedure, they have not provided economic analysis to validate this. Authors conclude that ORIF is attracts lower operative risks when compared with Revision, however, it is not clear which of their outcome variables they are referring to. Transfusion requirement of packed red blood cells was lower in the ORIF group compared with Revision, however, the authors did not account for presence or absence of other transfusion approaches such as use of cell saver intra-operatively. Functional outcomes including Harris Hip Score and Harris Pain Score were conflicting with ORIF having superior pain scores post-operatively, however, Revision

								group having superior Harris hip scores. Furthermore, the revision cohort was associated with a higher incidence of attaining pre-fracture mobility status. It would appear that revision promoted superior functional outcomes however, in the absence of pre-operative Harris hip and pain scores it is difficult to make such a conclusion. It is unclear why the authors did not conduct statistical analysis beyond descriptive statistics for these outcomes. Mortality within 3 months was similar between the ORIF group compared with Revision group, however, mortality overall was higher in ORIF group. This may be reflected by the ORIF group being older (mean age 8 years greater in ORIF group) or given they received ORIF they are likely frailer and thus more likely to die. Regardless of exposure, the incidence rates of union, femoral

								osteolysis, infection (DSSI or SSSI), dislocation and delayed wound healing were similar.
Spina 2014 (34A/B)	**Study design** Retrospective cohort study n=61 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=7 B2 **Sampling** Unclear **Recruitment** 1998-2012 **Indication index** NS **Index implant details** NS **Mechanism injury** Mostly minor trauma **Fracture diagnosis method** Radiographs **Setting** Single-centre, Tertiary hospital, Verona, Italy **Inclusion criteria** Patients admitted to local hospital with a PFF managed operatively **Exclusion criteria** Non-operatively managed PFF **Lost to follow-up** 1 patient died prior to follow-up	**Exposure A ORIF with plate (n=6)** (ORIF plate and cerclage, approach NS, predominantly cable ready plate, no company specified) **Index implant details** 4 straight stem (3 cemented) 2 anatomic stem (not stated cemented or uncemented) **Exposure B ORIF with W/C/C (n=1)** (ORIF cerclage wires only, approach NS, implant NS, company NS **Allocation of exposure** Vancouver algorithm with deviation based on age and surgeon experiential level **Surgeon experiential level** NS **Weight bearing status** Assisted and delayed weight bearing for a mean of 40 days post-operatively **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided pooled data published **Age at surgery (mean)**: 75.5 (no SD or Range reported)	-Transfusion -Mortality -Aseptic loosening femur -Re-operation -Union -Complications -Beals and Towers' Criteria -Ambulatory status post-operatively -Pain free (self assessed) -Pre op and Post op (self) perceived Quality of Life **Time-frame of outcomes assessment:** Nil specific to B2. Pooled (n=61) range 1 to 130 months	Utilised descript-tive statistics for remain-ing outcomes for exposure groups	**Transfusion** **A+B: Pooled results only** 3.6 units packed red blood cells per patient **Mortality** A: 1/6 B: Not reported **Aseptic loosening femur** A: Incomplete reporting B: Not reported **Re-operation** A: 2/6 (33%) [0/4 (0%) straight stem, 2/2 (100%) anatomic stem] B: 0/1 (0%) **Union** A: 5/6 (83%) [4/4 (100%) straight stem, 1/2 (50%) anatomic stem B]: 0/1 (0%) **Complications** A: 3/6 (50%) [1/4 (25%) straight stem, 2/2 (100%) anatomic stem] B: 0/1 (0%) **Beals and Towers' criteria proportion of excellent outcome** A: 3/6 (50%) [3/4 (75%) straight stem, 0/2 (0%) anatomic stem] B: 0/1 (0%) **Beals and Towers' criteria proportion of good outcome** A: 1/6 (16.7%) [1/4 (25%) straight stem, 0/2 (0%) anatomic stem] B: 0/1 (0%) **Beals and Towers' criteria proportion of poor outcome** A: 2/6 (33%) [0/4 (0%) straight stem, 2/2 (100%) anatomic stem] B: 1/1 (100%) **Ambulatory status post-operatively – proportion**	In Vancouver B2 fractures… according to the results of the current study, ORIF can still be an adequate treatment for fractures on cementless straight stems (Fig. 3). As the straight stem does not need to fit and fill the femoral canal, but relies on a press fit concept, it can reach a new stable position…	The study aimed to report the causes of failure in 61 PPFs. The utility of this study is limited by its small sample size. ORIF of anatomic stems - terrible outcome 100% re-operation rate. Unclear if these are cemented or not. Avoid ORIF in patients with PFF around anatomic femoral stem.

						mobilising independently without aids A: 2/5 (40%) B: 0/1 (0%) **Pain free post op** (self assessed) A: 4/6 (66%) B: 0/1 (0%) **Pre-op and post op perceived Quality of life (self assessed)** A: Mean 8 pre-op, Mean 6 post op B: Not reported		
Young 2007 (36)	**Study design** Retrospective cohort study n=54 **Data source** Local database	**Participants** Mixed cohort of patients with PFF, n= 10 B2 **Sampling** Unclear **Recruitment** 1999-2004 **Indication index** OA 33/54 (61%), NOF # 15/54 (28%), DDH 3/54 (5.5%), Other 3/54 (5.5%) **Index implant details** NS **Mechanism injury** Minor trauma: 46/54 (85%), Major trauma: 2/54 (4%), Spontaneous: 6/54 (11%) **Fracture diagnosis method** Radiographs (two independent reviewers) **Setting** Single-centre Tertiary hospital Auckland, New Zealand. **Inclusion criteria** Patients suffering a post-operative PFF around a THA treated at local institution **Exclusion criteria** Intra-operative PFFs **Lost to follow-up** 21 patients not assessed due to 20 deaths and 1 patient leaving region	**Exposure Revision +/- W/C/C (n=10)** Revision long stem uncemented (9), cemented (1), with or without cerclage. In 2/10 cases Acetabular cup revised, approach NS, implant NS, company NS. **Allocation of exposure** NS, implies Vancouver algorithm **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	-Union -Heterotopic ossification -Aseptic loosening femur -Dislocation -Re-operation -Repeat revision femoral component -Harris hip score (post-operative) -Oxford hip score (post-operation) - Mortality **Time-frame of outcomes assessment:** 1 to 3 years	Utilised descript-tive statistics for remain-ing outcomes for exposure groups	**Union** 10/10 (100%) **Heterotopic ossification** 1/10 (10%) **Aseptic loosening femur** 1/10 (10%) **Dislocation** 2/10 (20%) **Re-operation** 2/10 (20%) **Repeat revision femoral component** 0/10 (0%) **Harris hip score (post-operative) mean** 69.1 (No SD reported) n=8 **Oxford hip score (post-operation)** 31.7 (No SD reported) n=7 **Mortality within 6 months post-operatively** 0/10 (0%)	Type B2 fractures require revision of the implant to a long-stem prosthesis, with additional support as needed in the form of cerclage wires and cortical onlay grafts	The objective of this study was to review all periprosthetic fractures at a single institution to identify injury and treatment patterns and their associated clinical outcomes. This study has not tested for the stated conclusion regarding Vancouver B2 PFF management. Small sample size. No conclusions drawn from reviewers.
Zuurmond 2010* (37A/B/C)	**Study design** Retrospective cohort study n=71 (note OHS data	**Participants** Mixed cohort of patients with PFF, n=26 B2 **Sampling** Unclear **Recruitment** 1993-2006	**Exposure A Revision +/- W/C/C (n=11)** Revision same length stem, cemented/uncemented NS, approach NS, implant NS,	-Mortality -Complications -Re-operation	Utilised descript-tive statistics for	**Mortality overall** A: 4/11 (36%) B: 3/9 (33%) C: 1/6 (17%)	Nil specific to B2 fractures.	The purpose of this observational study was to determine the clinical results of the

	prospectively collected) **Data source** Local records at two hospitals	**Index implant details** **Primary:Revision** 44:27 **Cemented:Uncemented** 67:9 **Stem** NS **Fracture diagnosis method** Radiographs and intra-operative assessment **Setting** Multi-centre, Two tertiary hospitals Goningen and Zwolle, Netherlands **Inclusion criteria** Patients with a PFF treated at either centre with complete medical records and radiographs available **Exclusion criteria** Nil. Note: 8 patient records incomplete hence not included 35/71 lost to follow-up (32 deaths, 1 migration, 2 cognitively impaired couldn't answer)	company NS **M:F** 9:2 **Mean age in years:** 71.4 (Range 47-90, No SD reported) **Time from index to fracture in years mean:** 7.7 (Range 1-14, No SD reported) **Indication index** OA 8/11 (73%), NOF # 2/11 (18%), AVN 1/11 (0.9%) **Cemented:Uncemented** NS **Mechanism injury** Minor trauma 11/11 (100%) **Exposure B Revision mixed methods/unspecified (n=9)** Revision stem (length NS), cemented/ uncemented NS, ORIF with plate OR cerclage, approach NS, implant NS, company NS **M:F** 1:8 **Mean age in years:** 78.1 (Range 67-86, No SD reported) **Time from index to fracture in years mean:** 9 (Range 0.75-17.3, No SD reported) **Indication index** OA 6/9 (67%), NOF # 2/9 (22%), RA 1/9 (11%) **Cemented:Uncemented** NS **Mechanism injury** Minor trauma 9/9 (100%) **Exposure C ORIF mixed methods/unspecified (n=6)** ORIF, technique NS, implant NS, company NS **M:F** 2:4 **Mean age in years:** 68.8 (Range 50-82, No SD reported) **Time from index to fracture in years mean:** 3.8 (Range 0.08-10.8, No SD reported) **Indication index** OA 6/6 (100%) **Cemented:Uncemented** NS **Mechanism injury** Minor trauma 5/6 (83%), Major trauma 1/6 (17%)	-Oxford hip score (post-operatively) **Time-frame of outcomes assessment:** Nil specific to B2 Global 0.25-12 years	remain-ing outcomes for exposure groups	**Complications** A: 6/11 (55%) B: 4/9 (44%) C: 4/6 (67%) **Re-operation** A: 3/11 (27%) B: 3/9 (33%) C: 2/6 (33%) **Oxford hip score (post-operatively)** A: 28 (SD 8.5, 18-39) **n=7** B: 27 (SD 10.6, 19-42) **n=5** C: 23.8 (SD 7.9, 17-34) **n=6**		operative treatment of periprosthetic femoral fractures over a long period of time. Authors state re-operation outcome (2/6 (33%)) amongst Vancouver B2 PFFs undergoing ORIF may have been better if the Vancouver algorithm was not deviated from. Mortality rate overall was lower in the ORIF exposure arm, however, this could in part be explained by the fact the mean age was approximately 9.3 years less than exposure B and 2.6 years less than exposure A Regardless of exposure, the incidence rates of complications, re-operation and mean Oxford hip scores were similar. For the association under study there was no attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to receive ORIF and are more likely to die)

			Allocation of exposure Vancouver algorithm with some deviation) **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS					

Note: In mixed cohorts of PFF, on most occasions demographic data (sex and age) was not stratified by fracture type and therefore global data presented in the table.
# Denotes SD estimated by method of Hozo
*Raw data utilised NS: Not specified

Table 2. Description of included case series studies

Amenabar 2015 (1)	**Study design** Retro-spective case series n=76 **Data source** Surgical database	**Participants** Mixed cohort of patients with PFF, n=66 (87%) B2 **Sampling** Unclear **Recruitment** 2000-2012 **Indication index** NS **Index implant details** THA:HA NS **Primary:Revision** 63:13 **Cemented:Uncemented** NS **Index stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs pre-op and intra-operative assessment by senior surgeon **Setting** Single-centre Tertiary hospital Santiago, Chile **Inclusion criteria** Vancouver B2 or B3 PFF undergoing Revision THA with minimum 2 years follow-up **Exclusion criteria**Tumour disease or Active/previous surgical site infection**.** Non-operative or ORIF management **Lost to follow-up** 5 excluded as <2 year follow-up	**<u>Exposure A</u> Revision mixed methods/unspecified (n=66)** Revision longer stem (distal press fit), uncemented +/- cerclage, +/- cortical strut allograft (n=18/76) +/- acetabular revision (if cup loose) (n=24/76), lateral approach, ETO, ZMR cone type modular stem (for B2), Zimmer **Allocation of exposure** Not explicit (Implies Vancouver algorithm) **Surgeon experiential level** Experienced arthroplasty surgeons **Weight bearing status** Touch weight bear 8-10 weeks then full weight bear with cane further 6 weeks **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided pooled data published: Sex M:F 28:48 Age at surgery (mean): 75.7 (SD 12.4, 41-97)	-Mortality -Implant survival -Failure -Aseptic loosening femur -PFF post-op -Infection DSSI -Complications -Dislocation -SF-12 (Mental score) -SF-12 (Physical score) **Time-frame of outcomes assessment:** Pooled mean 74.4 months (SD 42.9, 24-167)	Adopted Kaplan-Meier survival curve 95% CI for in implant survival Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Mortality overall at 2 years (B2 only)** 6/66 (10%) **Implant survival** **5 yr (failure endpoint)** 89.6% (82.2-97 95% CI) n=29 at risk **Failure (any complication requiring revision surgery)** 7/76 (9.2%) **Aseptic loosening femur** 5/76 (6.6%) **PFF post-op** 2/76 (2.6%) **Infection DSSI** 3/76 (3.9%) **Complications** 4/76 (5.3%) **Dislocation** 4/76 (5.3%) **SF-12 (Mental score) Mean** 55 (SD 8.1, 31-68) **SF-12 (Physical score) Mean** 37.4 (SD 9.4, 15-55)	Failure rate was low. Our study has some limitations. First, it is a retrospective series with a relatively small number of patients. Second, it presents the results of periprosthetic femoral fractures treated in a tertiary hospital by experienced arthroplasty surgeons, therefore the outcomes may not be extrapolated.	The purpose of the study was to report results and quality of life following revision THA for Vancouver B2 and B3 fractures. Population too small for KM survival curve.

Briant-Evans 2009 (3)	**Study design** Retro-spective case series n=23 **Data source** Local hip registry	**Participants** Mixed cohort of patients with PFF, n=17 B2 **Sampling** Unclear **Recruitment** 1995-2005 **Indication index** NS **Index implant details** THA:HA NS **Primary:Revision** 14:9 **Cemented:Uncemented** NS **Index stem** Exeter polished taper stem 22/23 (96%) Charnley 1/23 (4%) **Mechanism injury** NS **Fracture diagnosis method** Radiographs and intra-operative assessment (bone-cement interface stable except for main fracture lines) **Setting** Single-centre Tertiary hospital Portsmough, United Kingdom **Inclusion criteria** Patient's with PFF undergoing cement in cement revision arthroplasty **Exclusion criteria** Unable to attend clinic beyond 6 weeks due to frailty (1) Death <6 months post op (prior to union) (3)	**Exposure A Revision mixed methods/unspecified (n=17)** Revision same or longer stem, cement in cement, +/- Cerclage OR cables alone (n=10/17) +/- ORIF plate (n=7/17) incl 3 with autologous bone graft, extended posterior approach, Exeter stem, Stryker **Allocation of exposure** Surgeon selection based on age, comorbidities, radiographic and intra op appearance bone-cement interface **Surgeon experiential level** NS **Weight bearing status** NS (Note globally (n=23) mean time to partial weight bear 3.6 days, full weight bear 31 days (no range given) **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided pooled data published ASA 1: 1/23 (4.3%), 2: 13/23 (57%), 3: 7/23 (30%), 4: 2/23 (8.7%) Time from index to fracture years (mean): 6 (SD 5.65#, 0.4-23)	-Union -Mortality **Time-frame of outcomes assessment:** Union 2-11 months Mortality not-specified Overall mean 3 years (Range 0.3-9)	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Union (B2)** 12/13 (92%) (Note 4 not assessed as deceased (3) and not available (1)) **Mortality overall** 3/17 (17.6%)	The results suggest that there is a valid role for the use of the cement-in-cement revision technique for periprosthetic fractures (B2 and B3) Authors recommend technique especially for sick patients not suitable for long proceedure, with simple, reducible fractures with well fixed cement mantle. Authors acknowledge small sample size.	Authors note cement extrusion risk for non-union. For the association under study there was no attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to receive cement-in-cement revision and are more likely to die) No specific conclusions to add.
Canbora 2013* (4)	**Study design** Retro-spective case series n=17 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=8 B2 **Sampling** Convenience **Recruitment** 2000-2009 **Indication index** NS **Fracture diagnosis method** Pre-op radiographs and intra-operative notes **Setting** Single-centre Tertiary hospital Istanbul, Turkey **Inclusion criteria** Patients with Vancouver B2 or B3 PFF undergoing revision hip arthroplasty **Exclusion criteria** NS	**Exposure A Revision +/- W/C/C (n=8)** (Revision distally fixed long stem, uncemented extensively pourous coated +/- cup revision if loose +/- conversion to THA for pre-existing bipolar HA, posterolateral approach, implant not specific (Eschelon, Smith and Nephew 12/17, ZMR, Zimmer 5/17) **M:F** 5:3 **Mean age in years:** 71.5 (Range 49-87, No SD reported) **Time from index to fracture in years mean:** 3.5 (Range 0.17-12, No SD reported) **Index implant details** THA:HA	-Subsidence -Union -Dislocation -Infection SSSI -Harris Hip Score (post-operative) -Barthel ADLs index -Beals and Towers' Criteria **Time-frame of outcomes assessment:**	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Subsidence <6mm** 0/8 (0%) **Union** 8/8 (100% **Dislocation** 1/8 (12.5%) **Infection SSSI** 1/8 (12.5%) **Harris Hip Score (post-operative) mean** 71.4 (SD 17, 40-85) **Barthel ADLs index mean** 73.8 (SD 25, 30-100) **Beals and Towers' Criteria proportion of excellent outcome** 4/8 (50%) **Beals and Towers' Criteria proportion of good outcome** 2/8 (25%)	Vancouver B2 (and B3) PPFs require difficult reconstructive surgeries to manage. Uncemented distally locked long femoral stems offer successful treatment.	The purpose of this study was to evaluate the clinical results of femoral revision using an uncemented extensively porous-coated long femoral stems… for Vancouver

			4 (2 cemented, 2 uncemented):4 (3 cemented and 1 uncemented) **Primary:Revision** NS **Index stem** NS **Mechanism injury** Minor trauma: 4/8 (50%) Major trauma: 1/8 (12.5%) Spontaneous: 3/8 (37.5%) **Allocation of exposure** NS **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	Mean 39 months (Range 15-90, SD not reported)		**Beals and Towers' Criteria proportion of poor outcome** 2/8 (25%)		B2 and B3 PFFs No specific conclusions to add.
Corten 2012 (5)	**Study design** Retro-spective case series n=31 **Data source** Local records	**Participants** Cohort of patients with Vancouver B2 PFF, n=31 **Sampling** Unclear **Recruitment** 1996-2007 **Indication index** NS **Index implant details** THA:HA 25(NS):6 (Austin Moore (AM)) **Primary: Revision** 28(90%):3(10%) **Cemented:Uncemented** 19:12 **Index stem** NS except AM **Mechanism injury** Minor trauma: 18/31 (58%) Spontaneous: 4/13 (13%) Unclear traumatic event: 9/31 (29%) **Fracture diagnosis method** Pre-op radiographs **Setting** Single-centre Tertiary hospital Ontario, Canada **Inclusion criteria** Patients with Vancouver B2 PFF undergoing cemented long stem revision arthroplasty with or without allograft or plate fixation **Exclusion criteria** NS **Loss to follow-up** n=11/31(35%) (8 deaths <6 months, 3 lost after 3 months post op – reason NS)	**Exposure A Revision mixed methods/unspecified (n=31)** (Revision long stem, cemented, direct lateral approach +/- cortical strut allografts n=24/31 (77%) +/- ORIF plate n=1/31 (3.2%) +/- Acetabular cup revision n=6/25 (24%) +/- Acetabular poly exchange n=2/25 (8%), implant Endurance, Depuy (23/31(74%)), OR Eschelon, Smith and Nephew (8/31(26%)) **M:F** 11:20 **Mean age in years:** 81.8 (SD 9.25#, 56-93) **ASA** 2: 7/31 (23%), 3: 24/31 (77%) **Time from index to fracture in years mean:** 8.6 (SD 7.2#, 0.25-29) **Allocation of exposure** Surgeon preference – if limited life expectancy, e.g. >80 years old with ASA 2 or more (n=27) OR Expected to be non-compliant with non-weight bearing (e.g. dementia or psychiatric diagnoses prohibiting (n=4) **Surgeon experiential level** NS **Weight bearing status** Protected weight bear as tolerated with walker **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	-Mortality -PFF post-op -Infection DSSI -Union -SF-12 score -Harris Hip Score (post-operatively) -Womac pain/function/ /stiffness scores -Attain pre-fracture mobility status -Subsidence -Cortical strut ingrowth **Time-frame of outcomes assessment:** Mean 33 months (SD 33#, 0-132) Specified if available in Outcome column	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Mortality within 6 months post op** 8/31 (26%) **PFF post-op** 1/31 (3.2%) **Infection DSSI** 2/28 (7%) **Union (in patients with 1 year or more follow-up)** 14/16 (87.5%) **SF-12 Score** Incomplete – does not state mental or physical **Harris Hip Score (post-operatively) mean** 77.5 (No SD or range reported) **Womac scores (mean) at minimum 1 year follow-up (n is unclear)** **Pain** 3 (No SD or range reported) **Function** 13 (No SD or range reported) **Stiffness** 2 (No SD or range reported) **Attain pre-fracture mobility status** 8/16 (50%) **Subsidence any** 1/31 (3.2%) **Subsidence 6mm+** 0/31 (0%) **Cortical strut ingrowth** 14/14 (100%)	The results of this series suggest that this technique (Revision long stem, cemented) can provide acceptable results and offers the advantages of reduced cost and early weight bearing. Authors add that in the elderly patient with limited life expectancy, cemented revision +/- allograft can enable safe and pain free, full weight bearing.	No specific conclusions to add.

Da Assunção 2015 (6)	**Study design** Retro-spective case series n=37 (38 PFFs) **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=31/38(84%) B2 **Sampling** Consecutive **Recruitment 2008-2011** **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** NS **Index stem** NS **Mechanism injury** NS **Fracture diagnosis method** Pre-operative radiographs (two consultant review) **Setting** Single-centre Tertiary hospital Oxford, United Kingdom **Inclusion criteria** Patients with Vancouver B2 or B3 PFF undergoing revision arthroplasty with uncemented, modular, tapered, conical fluted long stem (Restoration, Cone conical, Stryker) **Exclusion criteria** NS	**Exposure A Revision +/- W/C/C (n=38)** Revision long stem, uncemented, modular, tapered, conical fluted + autograft at fracture site, Extensile posterior approach +/- ETO when necessary +/- Acetabular revision n=22/38 (58%) +/- cerclage n=30/38 (79%) Restoration cone conical, Stryker **Allocation of exposure** Surgeon preference **Surgeon experiential level** Consultant – experienced arthroplasty surgeons (3) **Weight bearing status** Individualised Weight bear as tolerated n=14/38 (37%) Partial weight bearing for 6 weeks n=12/38 (32%) **Venous thromboembolism prophylaxis** Low molecular weight heparin 4 weeks **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 17:30 **ASA** 1-2: 10/37 (27%), 3-5: 27/37 (73%) **Mean age in years:** 77.7 (SD 12#, 47-96)	-Surgical time -Transfusion -Subsidence -Union -Length of stay -Mortality -PFF post-operatively -Infection DSSI/SSSI -Dislocation -Re-operation -DVT -Multi-organ failure -Leg length discrepancy -Thigh pain -Buttock pain/Abductor weakness -Pressure Ulcer -OHS **Time-frame of outcomes assessment:** Pooled mean 35 months (SD 15.5#, 4-66)	Mann–Whitney U and chi-squared test or Fisher's Exact test were adopted. Uni-variate and multi-variate linear re-gressions were used to examine the effect of ASA on OHS control-ling for age and gender.	**Surgical time mins (mean)** 175 (SD 41.3#, 95-260) **Transfusion – PRBC transfusion units (mean)** 3 (SD 2.5#, 0-10) Note: Patients with an ASA ≥ 3 had a significantly higher rate of transfusion than those with ASA ≤ 2 (Fisher's exact test, p = 0.009) but there was no difference between ASA groups in the incidence of complications (Fisher's exact test, p = 0.4) **Subsidence** Mean 1.1 mm (SD 3.5#, 0-14) **Subsidence (>5mm)** 1/38 (2.6%) **Union** 38/38 (100%) **Length of stay days (mean)** 22 (SD 14.3#, 3-60) **Mortality at up to 44 months** 12/37 (32%) **PFF post-operatively** 1/37 (2.7%) **Infection DSSI** 1/38 (2.6%) **Dislocation** 4/38 (10.5%) **Re-operation** 3/38 (7.9%) **DVT** 1/37 (2.7%) **Multi-organ failure** 1/37 (2.7%) **Leg length discrepancy (amount NS)** 1/38 (2.6%) **Thigh pain** 1/38 (2.6%) **Buttock pain/Abductor weakness** 1/38 (2.6%) **Pressure Ulcer** 1/37 (2.7%) **Oxford Hip Score (mean) of surviving 24 patients at mean 26 months** 35 (SD 8.5#, 14-48) Of 27 patients initially graded as ASA ≥ 3, 19	The results of this study suggest that a modular, titanium, conical, fluted tapered stem provides a flexible method of reconstruction for PFF. In our study, the effect of comorbidity on subsequent function was more relevant than age or gender, which is prognostically valuable. It also suggests that the anaesthetic and peri-operative management of these patients is crucial. Study limitations: non-randomised case series. Sample size doesn't allow sophisticated analysis of predictors of outcome. Strengths: Consecutive	Robust study, one of few that conducted regression analysis for ASA

						survived with a mean OHS of 31 (15 to 48) which was significantly lower than the mean OHS of 43 (36 to 48) found in patients assessed as ASA grade ≤ 2 (independent samples t-test, p < 0.001).	selection, reasonable follow-up, clinically relevant outcome measures	
Eingartner 2006 (7)	**Study design** Retro-spective case series n=21 **Data source** Unclear	**Participants** Mixed cohort of patients with PFF, n=8/21 (38%) B2 **Sampling** Unclear **Recruitment** 1992-2001 **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented Index stem** NS **Mechanism injury** NS **Fracture diagnosis method** Pre-operative radiographs **Setting** Unclear – Hospital(s) in Germany **Inclusion criteria** Patients with Vancouver B2 or B3 PFF undergoing revision with uncemented distal locking long stem implant **Exclusion criteria** Nil specified, however, states contra-indications: Unsuitability for extensive surgical procedure, peri-prosthetic infection, long stem TKR in distal femur	**Exposure A Revision +/- W/C/C (n=8)** (Revision distal locking long stem (20/21) OR distal press fit (1/21), uncemented, lateral transmuscular approach to femoral shaft + ETO, BiContact, Aesculap, +/- Acetabular revision n=11/21 +/- cancellous bone graft n=8/21 Note: Distal stem fixation removed once radiological evidence proximal femur remodelling **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** Bed rest 1 week then mob 20kg partial weight bear 12 weeks, From week 12 gradual increase 10kg/week with XR checks. Removal distal locking bolts 12-24 months at earliest. **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** 10 days antibiotics (route NS) Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 8:13 **Mean age in years:** 71.2 (SD 10.8#, 43-86)	-Union **Time-frame of outcomes assessment:** See outcome	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Union** 8/8 (100%) (at mean 5.6 months (SD 2#, 3-11)	A summary of the results shows that safe osseous consolidation of periprosthetic fractures is achievable using a transfemoral stem replacement procedure with interlocking of the prosthesis, even if bone defects are present.	Good operative technique paper.
Fink 2014 (8)	**Study design** Retro-spective case series n=23 **Data source**	**Participants** Mixed cohort of patients with PFF, n=15/23 (65%) B2 **Sampling** Unclear **Recruitment** NS **Indication index** NS **Index implant details** NS **Primary:Revision** NS	**Exposure A Revision +/- W/C/C (n=15)** (Revision long stem with distally curved modular stem with cerclage or cables for ETO site (dorsal and ventral), modified trans-femoral approach with extension to posterolateral approach hip, Revitan	-Union -Peri-prosthetic femoral fracture intra-operatively	Utilised descrip-tive statistics for remain-ing outcomes	**Union** 15/15 (100%) at mean 3.6 months (SD 1.3, No range given) **Peri-prosthetic femoral fracture intra-operatively** 0/15 (0%)	A standardized surgical technique for treatment of Vancouver B2 … PPFs with a modified transfemoral	Good operative technique paper. Excellent outcome reported for

	Unclear	**Cemented:Uncemented** **Index stem** NS **Mechanism injury** NS **Fracture diagnosis method** Pre-operative radiographs **Setting** Unclear – Hospital(s) in Germany **Inclusion criteria** Patients with Vancouver B2 or B3 PFF undergoing revision with uncemented revision curved long stem with cerclage **Exclusion criteria** Nil specified, however, states contra-indications: Periprosthetic joint infection, interprosthetic femoral shaft fractures needing total femoral replacement, Vancouver B1/C fractures	curved modular prosthesis, Zimmer, cables Zimmer **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** In general, Partial weight bearing 10kg for 6 weeks. Hip flexion limited top 70 deg. Gradual increase in weight bearing based on Xrays up to full WB after 3 months. If non-compliant with partial weight bearing in elderly convert to WBAT. **Venous thromboembolism prophylaxis** VTE prophylaxis until more than 30kg partial weight bearing achieved **Surgical antibiotic prophylaxis** Single pre-operative cefuroxime 250mg OR if surgical time >2 hours, 24 hours IV antibiotics (3 doses) Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 8:15 **Mean age in years:** 70.7 (SD 12.2, 42-88)	-Beals and Towers' Criteria **Time-frame of outcomes assessment:** Pooled mean 86.4 months (SD 31.2, minimum 60 months)	for exposure group	**Beals and Towers' criteria proportion of Excellent outcome** 15/15 (100%) note: no explicit time-frame given	approach and modular, tapered, fluted, uncemented revision stem (titanium) yields reliable and satisfactory results with respect to healing.	all B2s undergoing Exposure A
Garcia-Rey 2013 (9)	**Study design** Retro-spective case series n=35 **Data source** Local medical records	**Participants** Mixed cohort of patients with PFF, n=20/35 (57%) B2 **Sampling** Unclear **Recruitment** 1992-2006 **Indication index** OA 26/40 (65%) NOF # 8/40 (20%) Post traumatic OA 3/40 (7.5%) RA: 2/40 (5%) DDH: 1/40 (2.5%) **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** 28:22 **Index stem** Charnley:18, Muller: 5, Other cemented: 5, RM Isoelastic:1, PCA (stryker): 2, Harris-Galante:6, Mittelmeir:2, Omniflex (stryker):4, Alloclassic (Zimmer):3, Other cementless: 4 **Mechanism injury** NS **Fracture diagnosis method**	**Exposure A Revision +/- W/C/C (n=20)** (Revision uncemented long stem distal press fit, with cerclage fixation, postero-lateral approach, Solution system, Depuy. **Sex M:F** 12:11 **Mean age in years:** 79.2 (SD 6#, 56-80) **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** Bed rest with abduction triagular pillow 3-5 days then; Partial weight bearing with 2 crutches for younger patients without neurological deficits and minor defects (B2s) **Venous thromboembolism prophylaxis** Subcutaneous heparin until patient's fully mobile	-Subsidence -Union Osseointegration/ingrowth fixation stem -Dislocation **Time-frame of outcomes assessment:** Pooled mean 99.6 months (SD 42#, 36-204)	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Subsidence (10mm or greater)** 12/23 (52%) **Union at mean 5 months (SD 1.3, 3-8)** 20/20 (100%) **Osseointegration/ingrowth fixation stem** 20/20 (100%) **Dislocation** 0/20 (0%)	In conclusion, an extensive porous-coated stem without allograft can be used to treat difficult Vancouver B2 and B3 periprosthetic femoral fractures. Although the incidence of stem subsidence is not low, all fractures healed without compromising	High incidence of subsidence. Published numbers for Sex B2 and Cemented/un cemented cohort and subsidence include some cases which were lost to follow-up.

		Pre-operative radiographs (two experienced assessors) **Setting** Single-centre Tertiary hospital Madrid, Spain **Inclusion criteria** Patients with Vancouver B2 or B3 PFF undergoing revision with extensively porous coated stem (Solution System, Depuy) **Exclusion criteria** Nil specified, however, states contra-indications: Consideration to pre-morbid medical condition Femoral canal <18mm **Lost to follow-up** 5 patients excluded due to death from causes unrelated to the operation prior to 3 year minimum follow-up	**Surgical antibiotic prophylaxis** 1g IV cephazolin 6 hourly for 48 hours total Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Time from index to fracture in years mean:** 7.7 (SD 4.8, Range 1-20)				subsequent function … at a mean of 8 years.	
Grammatop olous 2011 (10)	**Study design** Retro-spective case series n=21 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=14/21 (67%) B2 **Sampling** Unclear **Recruitment** 2006-2009 **Indication index** OA 17/21 (81%) NOF # 1/21 (4.7%) Post traumatic OA 2/21 (9.5%) RA 1/21 (4.8%) **Index implant details** 20:1 **Primary:Revision** 20:1 **Cemented:Uncemented** 20:1 **Mechanism injury** Traumatic **Fracture diagnosis method** Pre-operative radiographs (two authors) Illustrates identification of a spiral fracture pattern in patients with CCPT stems - needs to identify instability as to appropriately allocate as B2 NOT accidently B1 and thus appropriate revision in case of B2. **Setting** Single-centre Tertiary hospital Oxford, United Kindom **Inclusion criteria** Patients with PFF around collarless polished tapered stem undergoing revision	**Exposure A Revision +/- W/C/C (n=14)** (Revision long stem with impaction bone grafting n=5/14 OR cerclage wires n=9/14, Lateral approach, Oxford tri-modular stem (Corin) OR BiMetric impaction Allograft stem (Biomet) OR Long stem CPT (Zimmer OR Restoration Cone Conical (Stryker) **M:F** 4:10 **Mean age in years:** 75.7 (SD not reported, Range 28-89) **Index stem** CPT: 4/14 Exeter: 10/14 **Allocation of exposure** Surgeon preference **Surgeon experiential level** Consultant (5 surgeons) **Weight bearing status** 6 weeks Partial weight bearing then full weight bear as tolerated **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided, pooled data published is as follows:	-PFF post-operatively -Dislocation -Re-operation **Time-frame of outcomes assessment:** Pooled mean 25 months (SD 9.1, 15-48)	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**PFF post-operatively** 1/14 (7.1%) **Dislocation** 1/14 (7.1%) **Re-operation** 1/14 (7.1%)	In conclusion, we describe a common fracture pattern around Collarless, polished, tapered stems, the extent of which can be underestimated preoperatively using standard radiographs. This fracture pattern requires extensive reconstruction surgery invariably with revision of the existing hip replacement with possible supplemental	Internal audit of CPT PFF. No conclusions from reviewers.

		Exclusion criteria NS	**Time from index to fracture in years (mean):** 5.8 (SD 3.8, Range 0.03-9.8)				fixation and allograft. Nil specific to B2 management	
Haidar 2005 (11)	**Study design** Retro-spective case series n=27 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=6/27 (22%) B2 **Sampling** Consecutive **Recruitment** 1994-2000 **Fracture diagnosis method** Not clear, implies radiographs **Setting** Single-centre Tertiary hospital Dorset, United Kindom **Inclusion criteria** Patients with a Vancouver B1 OR B2 OR B3 PFF undergoing ORIF with dynamnic compression plate **Exclusion criteria NS** **Lost to follow-up** n=4 (2 deaths within 2 months post op and 2 lost to follow-up)	**Exposure A ORIF with plate (n=6)** ORIF with lateral dynamic compression plate +/- cerclage n=4/6 +/- iliac crest bone graft n=1/6, lateral approach to femur, implant NS, company NS **M:F** 3:3 **Mean age in years:** 76 (SD not reported, Range 51-92) **Index implant details** THA:HA 5 (2 primary cemented THA and 3 revision):1 (AM) **Primary:Revision** 3:3 **Cemented:Uncemented** 5:1 **Index stem** NS **Mechanism injury** All minor trauma **Allocation of exposure** Surgeon preference – state deviated from protocol of revision for B2 sue to existing long stem n=3 and advanced age deemed not appropriate for revision n=2 **Surgeon experiential level** NS **Weight bearing status** Early non-weight bearing, but if couldn't tolerate, progression to toe touch weight bearing was permitted **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	-Infection DSSI -Re-operation -DVT -Leg length discrepancy -Union **Time-frame of outcomes assessment:** Mean 41 months (No SD reported, 32-48)	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Infection DSSI** 1/6 (16.7%) **Re-operation** 2/6 (33.3%) **DVT** 1/6 (16.7%) **Leg length discrepancy (2cm or more)** 1/6 (16.7%) **Union** 5/6 (83.3%) at mean 4.1 months (3-5 months)	We also recommend this fixation (DCP with bicortical proximal and distal fixation) when revision surgery is contra-indicated). Acknowledges plating isn't an optimal biomechanical fixation for adult femoral fractures but seems adequate for low demand patients (global comment not specific to B2s). Need good quality bone, sufficient length plate.	High complication rate with ORIF 4/6 complication rate including 2 re-operations, one significant LLD (2cm short) and a DVT.

Holder 2014 (12)	**Study design** Retro-spective case series n=45 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=21/45 (47%) B2 **Sampling** Consecutive **Recruitment** 2004-2009 **Indication index** OA 31/45 (69%) NOF # 13/45 (29%) RA 1/45 (2.2%) **Index implant details** NS **Primary:Revision** 43:2 **Cemented:Uncemented** 13:32 (incl 2 uncemented revisions) **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographic assessment **Setting** Single-centre, Tertiary hospital Ottowa, Canada **Inclusion criteria** Patients sustaining a PFF post-operatively managed surgically **Exclusion criteria** Pathalogical fractures Intra-operative PFFs (n=7) **Loss to follow-up** n= 3 died <3 months4 n=8 lost to follow-up	**Exposure A Revision mixed methods/unspecified (n=21)** Revision and ORIF no technique specified, no implants specified, no company specified. Note n=1 ORIF (NS) **Allocation of exposure** Surgeon preference guidance from Vancouver algorithm **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 15:30 **Mean age in years:** 78 (SD 12.8#, 46-97)	-Union **Time-frame of outcomes assessment:** Pooled range of observation for union outcome 2-64 months.	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** 20/20 (100%)	Authors conclude it is vital to distinguish B2 from B1 fractures	Small study. Poorly disclosed intervention methods/tech nique. No conclusions.
Holley 2007 (13A,B,C,D)	**Study design** Retro-spective case series n=66 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=20/66 (30%) B2 **Sampling** Unclear **Recruitment** 1984-2001 **Indication index** OA: 57/99 (58%) RA/JRA: 22/99 (22%) Post traumatic OA 13/99 (13%) AVN: 5/99 (5%) Other: 2/99 (2%) **Index implant details** THA:HA 90 (53 primary, 37 revision):9 **Stem** NS **Fracture diagnosis method** Radiographs **Setting** Single-centre, Tertiary Hospital, San Diego, USA **Inclusion criteria** Patients sustaining a PFF following a THA managed within their unit	**Exposure A Revision +/- W/C/C (n=8)** (Revision, cemented (4), uncemented (4), length stem NS, implant NS, company NS **M:F** 4:4 **Mean age in years:** 64.1 (Range 38-86, No SD reported) **Index implant details** **Primary:Revision** 4:4 **Cemented:Uncemented** 8:0 **Mechanism injury** Low energy trauma 6/8 (75%) Spontaneous 2/8 (25%) **Time-frame of outcomes assessment:** Mean 34 months (Range 12-100, No SD reported) **Exposure B Revision mixed methods/unspecified (n=3)** (Revision stem (length NS), cemented (Bhattacharyya, Chang et al.), uncemented (1) + ORIF plate +	-Union -Re-operation -Unstable implant **Time-frame of outcomes assessment:** See previous column	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 5/8 (63%) B: 2/3 (67%) C: 6/7 (85%) D: 1/2 (50%) **Re-operation** A: 3/8 (38%) B: 1/3 (33%) C: Unclear D: 1/2 (50%) **Unstable implant** A: 1/8 (12.5%) B: 0/3 (0%) C: 1/7 (14%) D:1/2 (50%) **Infection (NS)** A: 1/8 (12.5%) **Haematoma** C: 1/7 (14%)	No specific B2 conclusions	Relatively low union rates except for Revision with strut allograft, high re-operation rates although utility limited by small sample size.

		Exclusion criteria <12 months follow-up n=33 including n=25 deaths and n=8 uncontactable	strut allograft, approach NS, implant NS, company NS **M:F** 1:2 **Mean age in years:** 62.3 (Range 37-78, No SD reported) **Index implant details** **Primary:Revision** 0:3 **Cemented:Uncemented** 2:1 **Mechanism injury** Low energy trauma 2/3 (67%) Spontaneous 1/3 (33%) **Time-frame of outcomes assessment:** Mean 68 months (Range 26-139, No SD reported) **Exposure C Revision + cortical strut allograft (n=7)** (Revision + strut allograft, cemented (5), uncemented (Bhattacharyya, Chang et al.), length stem NS, approach NS, implant NS, company NS **M:F** 3:4 **Mean age in years:** 62.9 (Range 42-82, No SD reported) **Index implant details** **Primary:Revision** 3:4 **Cemented:Uncemented** 6:1 **Mechanism injury** Low energy trauma 4/7 (57%) Spontaneous 3/7 (43%) **Time-frame of outcomes assessment:** Mean 65.9 months (Range 24-111, No SD reported) **Exposure D ORIF with plate (n=2)** (ORIF plate, approach NS, implant NS, company NS **M:F** 0:2 **Mean age in years:** 73.5 (Range 71-76, No SD reported) **Index implant details** **Primary:Revision** 1:1 **Cemented:Uncemented** 0:2 **Mechanism injury** Low energy trauma 2/2 (100%) **Time-frame of outcomes assessment:** Mean 69.5 months (Range 57-82, No SD reported) **Allocation of exposure** Surgeon preference			**Dislocation** C: 2/7 (29%) **PE** C: 1/7 (14%) **Post op PFF** D: 1/2		

			Surgeon experiential level NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS					
Inngul 2015 (14A/B)	**Study design** Retro-spective case series n=63 **Data source** Local records and Swedish joint registry	**Participants** Mixed cohort of patients with PFF, n=25/63 (40%) B2 **Sampling** Consecutive **Recruitment** 1998-2010 (index) outcome data collected up to 2012 **Indication index** NOF # (primary or due to failed internal fixation with non-union or AVN) 63/63 (100%). Unit policy 80 years or older hemiarthroplasty vs <80 years and lucid usually THA. **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** All cemented **Stem** All Exeter polished taper stem **Mechanism injury** NS **Fracture diagnosis method** Radiographs (revision hip surgeons, both investigators) **Setting**Single-centre Karolinska Insitute, Sweden **Inclusion criteria** Patients sustaining a post-operative PFF following a THA or HA managed operatively by Revision or ORIF **Exclusion criteria** Pathalogical fractures**,** Intra-operative fractures, Vancouver A fractures	**Exposure A Revision +/- W/C/C (n=16)** Revision longer stem with distal fixation, uncemented (distal fixation stem) or cemented Note: a maximum of 2/16 were treated with supplementary ORIF plate (unclear in publication) **Indication index** NOF # 16/16 (100%) **Exposure B ORIF mixed methods/unspecified (n=9)** Either ORIF single lateral plate or screw fixation and cerclage wires (study states approximately 50% each) **Indication index** NOF # 9/9 (100%) **Allocation of exposure** NS **Surgeon experiential level** NS **Weight bearing status** Weight bear as tolerated from day 1 post-operatively **Venous thromboembolism prophylaxis** Low molecular weight heparin, type NS, dose NS, duration NS **Surgical antibiotic prophylaxis** 3 doses IV cloxacillin Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 29:34 **Mean age in years:** 83 (SD 8.5#, 63-97) **Time from index to fracture in years (mean):** 0.93 (SD 2.2#, Range 0.016-9)	-Re-operation **Time-frame of outcomes assessment:** Unclear, observation from time of HA/THA to end 2012 or death	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Re-operation** A: 1/16 (6.3%) B: 2/9 (22%)	The re-operation rate due to fracture-related complications was highest among patients with B2 fractures. Limitations – Joint registry data may not identify all PFF managed by ORIF (authors elude to suspicion of under reporting) Authors recognize lack of patient control group for comparison.	The purpose of this study is to report on the cumulative incidence and the outcome of surgically-treated postoperative PPFs in patients with femoral neck fractures treated with a THA or HA using an Exeter stem. Incidence of re-operation following ORIF was higher than those undergoing revision. Note: for the association under study there was no attempt to account for presence of confounding factors (e.g. older/frail are patients more likely to

								receive ORIF and are more likely to die)
Ko 2003 (16)	**Study design** Retro-spective case series n=12 **Data source** Local records	**Participants** Cohort of patients with Vancouver B2 PFF n=12 **Sampling** Unclear **Recruitment** 1996-2000 **Indication index** NS **Index implant details** THA:HA 6:6 (incl 4 AM) **Primary:Revision** 9:2 **Cemented:Uncemented** 8:4 **Stem** NS **Mechanism injury** Minor trauma: 5/12 (42%) Spontaneous: 7/12 (58%) **Fracture diagnosis method** Radiographs pre-op **Setting** Single-centre, Chai Wan, Hong Kong **Inclusion criteria** Patients with a Vancouver B2 PFF following a hip arthroplasty managed with a Wagner revision stem **Exclusion criteria** Management by other method/implant n=18, Under 65 years of age, < 3 years follow-up, Death n=2 (1 patient day 26 post op MRSA DSSI and 1 patient 1 year post op due to sigmoid carcinoma)	**Exposure A Revision +/- W/C/C (n=12)** Revision conical long stem distal press fit, uncemented, ETO +/- bone graft, Transfemoral approach, Wagner revision stem, Sulzer orthopaedics Note: Acetabulum revised in 5/6 cases of THA. All HA converted to THA. Bone graft to proximal femur 6/8 cemented) **M:F** 1:11 **Mean age in years:** 74.5 (Range 67-83, No SD reported) **Time from index to fracture in years mean:** 6.8 (Range 1-10, No SD reported) **Allocation of exposure** NS – implies need for 10cm intact diaphyseal bone distal to fracture **Surgeon experiential level** NS **Weight bearing status** Sit in orthopaedic chair, start partial weight bearing (no weight specified) exercise D2-3 post op. Abduction pillow 5 days. Discharged when managing partial weight bearing with crutches. XRs weekly post op until signs of healing at which point upgraded to full weight bearing **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	-Subsidence -Union Osseointegration -Malrotation -Heterotopic ossification -Mortality -PFF post op -Dislocation -DVT -Leg length discrepancy -Thigh pain -Repeat revision femoral component -Harris hip score post op -Beals and Towers' Criteria **Time-frame of outcomes assessment:** Mean 56 months (Range 36-64, No SD reported) **Minimum 3 years**	Utilised descrip-tive statistics for remain-ing outcomes for exposure group	**Subsidence any** A: 2/12 (17%) **Subsidence 6mm or more** A: 0/12 (0%) **Union** A: 12/12 (100%) at mean 14.5 weeks (Range 12-16, No SD reported) **Osseointegration** A: 12/12 (100%) **Malrotation** A: 0/12 (0%) **Heterotopic ossification** A: 0/12 (0%) **Mortality** A: 2/14 (14%) **PFF post op** A: 1/12 (8.3%) **Dislocation** A: 0/12 (0%) **DVT** A: 1/12 (8.3%) **Leg length discrepancy (>2cm)** A: 1/12 (8.3%) **Thigh pain** A: 0/12 (0%) **Repeat revision femoral component** A: 0/12 (0%) **Harris hip score post op mean (n=12)** A: 80 (SD 3#, Range 74-86) **Beals and Towers' Criteria proportion of Excellent score** A: 7/12 (58%) **Beals and Towers' Criteria proportion of Good score** A: 3/12 (25%) **Beals and Towers' Criteria proportion of Poor score** A: 2/12 (17%)	Authors conclude the Wagner revision stem is a satisfactory prosthesis in treatment of PFF Vancouver B2 PFFs in geriatric patients due to its ability to directly transmit forces into femoral shaft distal to fracture and provide optimal environment for bone healing.	Exclusion of 2 deaths arbitrary.

Konan 2011 (17)	**Study design** Retro-spective case series n=17 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=9/17 (53%) B2 **Sampling** Unclear **Recruitment** 2000-2008 **Indication index** NS **Index implant details** THA:HA 9:0 **Primary:Revision** 9:0 **Cemented:Uncemented** Unclear **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs. Aspiration, WCC, ESR, CRP **Setting** Multi-centre, Two tertiary hospitals, University college London and Nottingham University, United Kingdom **Inclusion criteria** Patients with an infected Vancouver B2 or B3 PFF following a hip arthroplasty managed with revision arthroplasty **Exclusion criteria** NS	**Exposure A Revision +/- W/C/C (n=9)** Revision long stem with distal fixation (non-HA coated) +/- cables, uncemented, approach NS, Cannulock (n=7), Orthodesign, or Kent (n=2), Biomet, **M:F** NS **Mean age in years:** 82.1 (Range 70-90, No SD reported) **Allocation of exposure** Not explicit. **Surgeon experiential level** NS **Weight bearing status** Weight bear as tolerated with crutches **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** Empirical antibiotics (Teicoplanin). Directed therapy tailored to microscopy, culture and sensitivity results continued until normalised or static to normal inflammatory markers	-Union -Harris hip score post op -Attain pre-fracture mobility status **Time-frame of outcomes assessment:** Mean 52 months (Range 39-84, No SD reported)	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 9/9 (100%) **Harris hip score post op mean** A: 84.2 (Range 78-89, No SD reported) **Attain pre-fracture mobility status** A: 9/9 (100%)	Authors conclude that non HA coated revision distally locked spacer allows for treatment of infection and stabilization of fracture to allow mobilisation AND ultimately easier to remove at subsequent definitive revision, preserves bone stock (no bony ingrowth).	Nil additional conclusions
Korbel 2013 (18A/B)	**Study design** Retro-spective case series n=47 (40 patients) **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=24/47 (51%) B2 **Sampling** Unclear **Recruitment** 2004-2010 **Indication index** NS **Index implant details** THA:HA NS **Primary:Revision** NS **Cemented:Uncemented** 14:10 **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs and intra-operative stability assessment **Setting** Single-centre, University hospital, Prague, Croatia **Inclusion criteria** Patients sustaining a post-operative PFF managed surgically within their unit	**Exposure A Revision +/- W/C/C (n=18)** Revision stem (usually modular non-cemented stem), anterolateral approach, implant NS, company NS. **Exposure B ORIF with plate (n=6)** ORIF locking compression plate (LCP), approach NS **Allocation of exposure** Surgeon preference. Broadly standard was to revise B2 PFFs, however, was deviated from early in series by way of ORIF **Surgeon experiential level** NS **Weight bearing status** Mobilised from day 1 to 6 post-operatively (no weight bearing allowance specified) **Venous thromboembolism prophylaxis** Low molecular weight heparin based on weight (no drug specified) **Surgical antibiotic prophylaxis**	-Infection DSSI -Dislocation -Neurovascular injury (femoral nerve palsy) -Femoral stem breakage -Plate breakage **Time-frame of outcomes assessment:** Pooled mean 27 months (SD 8.3#, 12-45)	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Infection DSSI** A: 1/18 (5.6%) B: 0/6 (0%) **Dislocation** A: 2/18 (11%) B: 0/6 (0%) **Neurovascular injury (femoral nerve palsy)** A: 2/18 (11%) (resolved at 3 months post op) B: 0/6 (0%) **Femoral stem breakage** A: 1/18 (5.6%) B: Not applicable **Plate breakage** A: Not applicable B: 3/6 (50%)	No specific Vancouver B2 PFF conclusions made. Comments anatomical reduction imperative when performing cemented revision in elderly patients to avoid extrusion which may lead to non-union.	High incidence of plate breakage in ORIF exposure group.

		Exclusion criteria Peri-prosthetic acetabular fractures**,** intra-operative fractures**,** Non-operatively managed PFFs	2 grams IV antibiotics 30 minutes pre-operatively, 1 gram every 2 hours intra-operatively, 1 gram eight hourly for two doses post-operatively Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 18:22 **Mean age in years:** 72 (SD 8.5#, Range 54-88) **Time from index to fracture in years (mean):** 7.3 (No SD or Range reported)					
Levine 2008 (19)	**Study design** Retro-spective case series n=17 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=12/17 (70.5%) B2 **Sampling** Unclear **Recruitment** 1997-2004 **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** 11:6 **Stem** NS **Mechanism injury** Minor trauma: 15/17 (88%) High energy: 2/17 (12%) **Fracture diagnosis method** Radiographs **Setting** Single-centre Tertiary hospital, Illinois, USA **Inclusion criteria** Patients with a Vancouver B2 or B3 PFF undergoing Revision arthroplasty including extended trochanteric osteotomy **Exclusion criteria** Minimum 2 year follow-up **Loss to follow-up** n=3 (Death at 9 months not related to surgery (n=1) and no reason (n=2))	**<u>Exposure A</u> Revision mixed methods/unspecified (n=12)** Revision stem (length unclear), cemented/uncemented (unclear) + cables +/- acetabular revision +/- poly exchange +/- conversion to THA (if HA index) +/- cortical struts where necessary (unclear proportion), posterior approach, mixed implant usage. **Allocation of exposure** Surgeon preference **Surgeon experiential level** NS **Weight bearing status** 0-6 weeks: Toe touch weight bear 6 weeks, 6-12 weeks: Full weight bearing with protection of walking aid depending on healing 12+ weeks: Wean off of walking aids. Active hip abduction restricted 6 weeks. Resisted active hip abduction restricted 12 weeks **Venous thromboembolism prophylaxis** Warfarin, no duration specified **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 5:12 **Mean age in years:** 77.8 (SD 8#, Range 55-87)	-Union -Union ETO **Time-frame of outcomes assessment:** Not explicit. Minimum 2 years.	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 12/12 (100%) **Union ETO** A: 12/12 (100%) at mean 13.1 weeks (No SD or range reported)	High rates of osteotomy and fracture union can be obtained when performing an ETO during revision for a PFF. Limitations of this study include the retrospective nature of data collection, relatively short-term length of follow-up, and the small patient population.	No specific conclusions to add.

Lunebourg 2015 (21A/B)	**Study design** Retro-spective case series n=43 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=23/43 (53%) B2 **Sampling** Unclear **Recruitment** 2002-2007 **Indication index** NS **Index implant details** NS **Primary:Revision** 43:0 **Cemented:Uncemented** 32:11 **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs and intra-operative assessment **Setting** Unclear **Inclusion criteria** Patients with a Vancouver B1, B2 OR B3 PFF following THA or HA managed with curved non-locking plate with eccentric holes with or without revision **Exclusion criteria** <1 year follow-up (death within a year (n=10), lost to follow-up (n=10)), ORIF by alternative method (n=1), Sepsis episode prior to PFF	**Exposure A ORIF with plate (n=16)** ORIF curved non-locking plate with eccentric holes +/- temporizing cerclage, posterolateral approach, 12, 15 or 18 hole plate, Aesculap **Exposure B Revision + ORIF plate (n=7)** Revision long stem, cemented and ORIF curved non-locking plate with eccentric holes, Arcad longue, Symbios, plate as above **Allocation of exposure** Unit preference – Generally, Revision for loose implants, however, ORIF if index femur cementless OR in very old patients **Surgeon experiential level** Consultant (senior) **Weight bearing status** Wheel chair mobility for day 1-2 post op. Then Weight bear as tolerated with two canes for 6 weeks with EXCEPTION Bed to wheelchair transfers only FOR non-compliant patients or those with very fragile bone **Venous thromboembolism prophylaxis** Prophylactic low molecular weight heparin 6/52 **Surgical antibiotic prophylaxis** NS Note: Although no specific B2 demographic data provided, pooled data published is as follows: **Sex M:F** 21:22 ASA 2:8/43, **Mean age in years:** 79 (SD 13, 41-98) **Time from index to fracture in years (mean):** 4.3 (SD 5.3, 0.08-26)	-Surgical time -Union -Malunion -Aseptic loosening femur **Time-frame of outcomes assessment:** Pooled mean observation 42 months (SD 20, 16-90)	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Surgical time (Incision to dressing wound) mean (Wasko and Kaminski)** A: 122 (SD 26, 80-165) B: 209 (SD 41, 165-278) **Union (timing NS)** A: 16/16 (100%) (worst case by 4 months) B: 7/7 (100%) (worst case by 4 months) **Malunion** A: 0/16 (0%) B: 0/7 (0%) **Aseptic loosening femur** A: Not reported B: 0/7 (0%)	(Not specific to B2) Use of a curved non-locking plate with eccentric holes results min a high fracture union rate, satisfactory clinical outcomes and minimal complications. The current study has several limitations. The retrospective nature of the study led to a high number of patients being lost to follow-up.	Surgical time was longer on average for Revision ORIF compared with ORIF alone. Although not specific to B2 PFFs, reviewers do not agree with conclusion of 'minimal complications' given that global mortality for study was 25/53 (47%)

Marx 2012 (22)	**Study design** Retro-spective case series n=29 **Data source** Local records	**Participants** Mixed cohort of patients with intra-operatively and post-operatively sustained PFF, n=8/29 (28%) post-operative B2 **Sampling** Unclear **Recruitment** 2002-2003 **Indication index** Not reported **Index implant details** NS **Primary:Revision** 11:4 **Cemented:Uncemented** 3:12 **Stem** Not reported **Mechanism injury** NS **Fracture diagnosis method** Radiographs (pre and post-operatively) and intra-operative notes **Setting** Single-centre, Clinic of joint replacement, Germany **Inclusion criteria** Patients with an intra-operative or post-operative Vancouver B2 PFF managed with a Wagner revision stem **Exclusion criteria** Trans-femoral approach for revision femoral stem Vancouver B1 and C PFFs **Lost to follow-up** Death prior to follow-up n=9/39 (23%)**,** Revision for aseptic loosening prior to follow-up n=1	**Exposure A Revision +/- W/C/C (n=8)** Revision long stem distal press fit, uncemented + cerclage +/- acetabular revision as indicated, trans-gluteal approach, Wagner 3rd Generation, Zimmer **Allocation of exposure** Unit protocol **Surgeon experiential level** NS **Weight bearing status** 0-6 weeks: Non-weight bear**.** Rehab program to strengthen thigh and hip. **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided, pooled data (incl intra-operative B2) published is as follows: **M:F** 3:12 **BMI** 26.9 (SD 2.7#, 22.6-33.5) **Mean age in years:** 67.9 (SD 10.5#, 40-82)	-Union **Time-frame of outcomes assessment:** Mean 74 months (No SD or range reported)	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 8/8 (100%)	100% fracture union was achieved for Vancouver Type B2 fractures treated with the uncemented Wagner revision stem (3rd generation)	100% union rate.
Moreta 2014 (23)	**Study design** Retro-spective case series n=59 (58 patients) **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=14/59 (24%) B2 **Sampling** Unclear **Recruitment** 1995-2011 **Indication index** Primary OA 6/14 (43%) NOF # 4/14 (29%) AVN 3/14 (21%) Inflammatory 1/14 (7%) **Index Implant details** THA:HA 12:2 **Primary:Revision** 13 (incl 2 AM HA):1 **Cemented:Uncemented** 1:13 **Stem** NS **Mechanism injury**	**Exposure A Revision mixed methods/unspecified (n=14)** Revision stem (length NS), uncemented, with cortical strut or impaction allografting n=4/14 (29%), approach NS, implant NS **M:F** 8:6 **ASA:** 2: 5 (36%), 3: 8 (58%), 4: 1/14 (7%) **Mean age in years:** 75.9 (SD 7.5, No range specified) **Allocation of exposure** Vancouver algorithm **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS	-Dislocation -Harris hip score (post-operatively) -Beals and Towers' Criteria -Attain pre-fracture mobility status **Time-frame of outcomes assessment:** Not explicit. Minimum10	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Dislocation** A: 2/14 (14.2%) **Harris hip score (post-operatively) mean (n=6/14)** A: 73 (SD 3.2, 70-85) **Beals and Towers' Criteria proportion of Excellent score** A: 3/14 (21%) **Beals and Towers' Criteria proportion of Good score** A: 6/14 (43%) **Beals and Towers' Criteria proportion of Poor score** A: 5/14 (36%) **Attain pre-fracture mobility status** A: 6/14 (43%)	No specific conclusions for B2 PFFs	Low incidence of attaining pre-fracture mobility status for B2 fractures managed with Revision

		Minor trauma: 12/14 (86%) High energy: 2/14 (14%) **Fracture diagnosis method** NS **Setting** Single-centre, Spain **Inclusion criteria** Patients sustaining a post-operative PFF following THA or HA treated at their institution **Exclusion criteria** Death within 10 months of follow-up (n=7) **Lost to follow-up** n=6 (no reason specified)	**Surgical antibiotic prophylaxis** NS	months observation				
Munro 2014 (26)	**Study design** Retro-spective case series n=55 (9 excluded) **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=30/46 (69%) B2 **Sampling** Unclear **Recruitment** 2000-2010 **Indication index** NS **Index implant details** THA:HA 54:1 **Primary:Revision** 47:8 **Cemented:Uncemented** 30:25 **Stem** NS **Mechanism injury** Minor trauma: 55/55 (100%) **Fracture diagnosis method** Radiographs pre-operatively **Setting** Single-centre, Tertiary hospital Canada **Inclusion criteria** Patient's suffering a PFF following THA or HA treated at their institution with Revision femoral arthroplasty with modular distal taper fluted titanium stems **Exclusion criteria** <2 years follow-up (n=9) including; Death <2 years (n=8) Moved overseas (n=1)	**Exposure A Revision +/- W/C/C (n=30)** Revision long stem modular distally curved, uncemented +/- wires/cables/heavy suture, posterior extensile approach, ZMR 3.5 deg, Zimmer OR Revitan 2 deg (preference for smaller patients) Note: a maximum of 4/30 (13%) were treated with supplementary trochanteric claw plate (unclear in publication) **Allocation of exposure** Unit preference for PFF where less than 4cm distal diaphyseal fit available, expanded to all PFF unless no diaphysis remained **Surgeon experiential level** NS **Weight bearing status** Globally – 0-6 weeks post op: Partial weight bear (50% body weight) if stem fixation secure. IF any doubt Toe touch weight bearing 0-6 weeks then partial weight bearing (50% body weight) **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided, pooled data (incl intra-operative B2) published is as follows: **Mean age in years:** 72 (SD 12.3#, 44-93)	-Aseptic loosening femur -Union -SF-12 mental -SF-12 physical -Oxford hip score post-operatively -Womac score (Global, pain, function, stiffness) -Satisfaction score (self reported – Overall, pain, function, recreation) -Subsidence **Time-frame of outcomes assessment:** Minimum 24 month observation Pooled mean observation	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Aseptic loosening femur** A: 1/30 (3.3%) **Union** A: 30/30 (100%) **SF-12 Mental score post-operatively mean** A: 53 (No SD or Range given) n=16/30 **SF-12 Physical score post-operatively (mean)** A: 41 (No SD or Range given) n=16/30 (53%) **Oxford hip score post-operatively (mean)** A: 74 (No SD or Range given) n=16/30 (53%) **Womac scores (mean) n=16/30 (53%)** (No SD or Range specified) **Global** A: 76 **Pain** A: 80 **Function** A: 75 **Stiffness** A: 70 **Satisfaction score (self reported 0-100)** n= 16/30 (53%) **Overall** A: 96 **Pain** A: 98	We believe the continued use of tapered fluted titanium stems in the treatment of Vancouver B2 and B3 fractures is justified, and further follow-up is needed to ensure that patients with asymptomatic subsidence do not become symptomatic. Limitations No control group. Limited responder rate.	Main limitations high risk of reporter/resp onder bias. Called patients via telephone if they didn't respond to questionnaire s on QoL and functional outcomes. Only 28/46 completed QoL and functional assessments.

				54 months (29.8#, 24-143)		**Function** A: 90 **Recreation** A: 86 **Subsidence** (amount NS – includes 1 symptomatic patient with >10mm necessitating revision) A: 6/30 (20%)		
Niikura 2014 (27A/B/C)	**Study design** Retro-spective case series n=18 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=6/18 (33%) B2 **Sampling** Consecutive **Recruitment** 2005-2012 **Index implant details** THA:HA 7 (4 uncemented, 2 cemented, 1 uncemented revision):11 (6 uncemented bipolar HA and 5 AM) **Primary:Revision** 7:11 **Cemented:Uncemented** 7:11 **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs (Trauma and hip surgeon) **Setting** Single-centre Tertiary hospital, Kobe, Japan **Inclusion criteria** Patient's with a PFF following THA or HA managed (operative or non-op) at their institution **Exclusion criteria** NS	**Exposure A Revision +/- W/C/C (n=2)** Revision longer length stem, uncemented OR same length stem, cemented + wires, approach NS, implant NS, company NS **M:F** 0:2 **Mean age in years:** 71 (Range 69-73, No SD reported) **Index implant details** THA:HA 1:0 (1 NS) **Primary:Revision** 1:0 (1 NS) **Cemented:Uncemented** 0:1 (1 NS) **Indication index** OA 1/2 (50%) NS 1/2 (50%) **Surgeon experiential level** Consultant (hip surgeon) **Exposure B ORIF with plate (n=3)** ORIF Locking compression plate (LCP), approach NS, LCP Synthes. **M:F** 0:3 **Mean age in years:** 82.7 (Range 80-86, No SD reported) **Index implant details** NS **Surgeon experiential level** Consultant (Trauma surgeon) **Exposure C Non-operative (n=1)** **M:F** NS **Age in years:** 91 **Index implant details** NS **Allocation of exposure** Vancouver algorithm +/- modification with surgeon judgement (patient physiology and experience). **Surgeon experiential level** Consultant (hip surgeon) **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS	-Surgical time -Blood loss -Transfusion requirement (Packed red blood cells) -Union -Malunion -Loss of reduction -Intra-operative mortality -Infection DSSI - Infection SSSI -Parker mobility score pre and operatively -Ambulatory status post-operatively -Attain pre-fracture mobility status -Attain pre-fracture social status **Time-frame of outcomes assessment:**	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Surgical time (Operation time) mean (Wasko and Kaminski)** A: 146 (SD 8.49, No Range specified) B: 152.7 (SD 71.7, No Range specified) **Blood loss (intra-operative) mean (mL)** A: 1502mL (SD NS, Range 535-2470) B: 390mL (SD 232, 150-615) **Transfusion requirement (Units packed red blood cells) mean** A: 7 (SD 7.07, No Range given) B: 3 (SD 1.15, 2-4) C: NS **Union** A: 2/2 (100%) B: 3/3 (100%) C: 1/1 (100%) **Malunion** A: 0/2 (0%) B: 0/3 (0%) C: NS **Loss of reduction (fracture)** A: 0/2 (0%) B: 0/3 (0%) C: N/A **Intra-operative mortality** A: 0/2 (0%) B: 0/3 (0%) C: N/A **Infection DSSI** A: 0/2 (0%) B: 0/3 (0%)	In summary, we suggest that decisions regarding the treatment method for peri-prosthetic femoral fractures should be based on the algorithmic approach of the Vancouver classification, in addition to the assessment of each patient's hip joint pathology, physical status and activity, especially for type B2 fractures with a loose stem. Cooperation of a trauma surgeon and a hip joint surgeon is desirable, if possible	Agree with authors.

			Surgical antibiotic prophylaxis NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided, pooled data (incl intra-operative B2) published is as follows: **Time from index to fracture in years (mean):** 11.5 (SD 12.3, Range NS)	Pooled follow-up mean 18.4 months (SD 14.2, range NS)		**Infection SSSI** A: 0/2 (0%) B: 0/3 (0%) **Parker mobility score post-operatively mean** A: 6 (SD 4.24, Range 3-9) B: 2 (SD 2.65, Range 0-5) C: 4 ***Note: Parker mobility score pre-operatively** A: 6 (SD 4.24, Range 3-9) B: 2 (SD 2.65, Range 0-5) C: 4 **Ambulatory status post-operatively** A: 1/2 (50%) with walker, 1/2 (50%) no aids B: 2/3 (66%) non-ambulatory, 1/3 (33%) with crutch C: 1/1 (100%) with cane **Attain pre-fracture mobility status** A: 2/2 (100%) B: 3/3 (100%) C: 1/1 (100%) **Attain pre-fracture social status** A: 2/2 (100%) B: 3/3 (100%) C: 1/1 (100%)		
Pogliacomi 2014 (29)	**Study design** Retro-spective case series n=45 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=36/45 (80%) B2 **Sampling** Unclear **Recruitment** 1999-2013 **Indication index** NS **Index implant details** THA:HA 45:0 **Primary:Revision** 45:0 **Cemented:Uncemented** 1:44 **Stem** NS **Mechanism injury** Minor or no trauma 10/45 (22%) 'Substantial' trauma 35/45 (78%) **Fracture diagnosis method**	**<u>Exposure A</u> Revision +/- W/C/C (n=36)** Revision distal press fit long stem, uncemented +/- Cables (n=14), approach NS, implant NS, company NS **Allocation of exposure** Not explicit, implies Vancouver algorithm **Surgeon experiential level** NS **Weight bearing status** NS **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided,	-Osseo-integration -Infection DSSI -Infection SSSI -Union **Time-frame of outcomes assessment:** Pooled (n=45) observation mean 55	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Osseointegration** A: 36/36 (100%) **Infection DSSI** A: 0/36 (0%) **Infection SSSI** A: 0/36 (0%) **Union** A: 36/36 (100%)	Where Revision is indicated for PFF, long stem uncemented with distal anchorage can be used to manage the majority of cases with satisfactory results. Algorithm required but	No additional conclusions.

		Radiographs (pre-operative) and intra-operative assessment **Setting** Single-centre Tertiary hospital, Parma, Italy **Inclusion criteria** Patients with post-operative PFF following primary THA undergoing surgical treatment at Ortho clinic University of Parma **Exclusion criteria** Death (n=19), inability to attend follow-up visit (n=6)	pooled data (incl intra-operative B2) published is as follows: **Sex** M:F 12:33 **Mean age in years:** 78.5 (SD 12.3#, 43-92) **Time from index to fracture in years (mean):** 6.8 (SD 7.25#, 1-30)	months (SD 36#, 12-156)			not always possible. Type, level fracture, PP bone quality, stability of index prosthesis, age, general condition patient should be considered.	
Rayan 2010 (30)	**Study design** Retro-spective case series n=26 **Data source** Local records	**Participants** Mixed cohort of patients with PFF, n=14/26 (54%) B2 **Sampling** Unclear **Recruitment** 1999-2005 **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** 22:4 **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs (pre-operatively by clinical fellow) and intra-operative assessment **Setting** Single-centre, University college London, United Kingdom **Inclusion criteria** Patients with Vancouver B2 OR B3 PFF after femoral arthroplasty managed with uncemented revision arthroplasty in the unit **Exclusion criteria** NS	**<u>Exposure A</u> Revision mixed methods/unspecified (n=14)** Revision long stem, uncemented with cables, +/- cortical strut allograft (unclear proportion) +/- acetabular revision (unclear proportion), posterior approach, Eschelon (250mm), Smith and Nephew **Allocation of exposure** Vancouver algorithm **Surgeon experiential level** Consultant (Senior surgeon) **Weight bearing status** 0-6 weeks: Touch weight bear, then 6-12 wees: Partial weight bear (no weight specified) **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided, pooled data (incl intra-operative B2) published is as follows: **Sex** M:F 16:10 **Mean age in years:** 68.4 (SD 7.76, 46-81) **Time from index to fracture in years (mean):** 5.9 (SD 2.45, 0.67-9)	-Union - Neurovascular injury -Subsidence -Malunion **Time-frame of outcomes assessment:** Minimum 2 years observation	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 14/14 (100%) **Neurovascular injury** A: 1/14 (7.1%) (sciatic nerve palsy which resolved completely, no time-frame) **Subsidence** A: 0/14 (0%) **Malunion** A: 0/14 (0%)	Cementless Revision stem favourable outcome with reliable return to pre-morbid state (don't know how they can convincingly say this premorbid state).	Supports successful management of B2s with Uncemented revision stem in Eschelon setting. Note: Operative surgeon also conducted HHS assessment Heterogeneit y of stems and short follow-up.

Sexton 2006 (31)	**Study design** Retro-spective case series n=145 (including 36/145 (25%) PPFs) **Data source** Local records	**Participants** Mixed cohort of patients including; n=25/145 (17%) B2 PFF **Sampling** Consecutive **Recruitment** 1987-2000 **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** NS **Stem** NS **Mechanism injury (for PFF)** Minor trauma: 33/36 (92%) Major trauma: 2/36 (5%) 'No obvious cause': 1/36 (3%) **Fracture diagnosis method** Radiographs pre-operatively **Setting** Multi-centre, Two tertiary hospitals, University College London, Maidstone district general hospital, Maidstone, United Kingdom **Inclusion criteria** Patients undergoing Revision hip surgery using Kent prosthesis at either institution for any indication. **Exclusion criteria** Nil	**Exposure A Revision +/- W/C/C (n=25)** Revision long stem with distal locking, uncemented non-HA coated, posterior approach, Kent hip revision, Biomet **Allocation of exposure** Vancouver algorithm **Surgeon experiential level** Consultant **Weight bearing status** 3 days: Partial weight bear (no weight specified) then progressing to Full weight bear **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS Note: Although no specific post-operatively sustained Vancouver B2 PFF demographic data provided, pooled data (incl intra-operative B2) published is as follows: **Sex** M:F 20:16 **Mean age in years:** 66 (No SD specified, Range 52-79) Note: 2/36 deaths during follow-up period	-PFF post-operatively -Attain pre-fracture mobility status -Non-union -Malunion **Time-frame of outcomes assessment:** Pooled PFF (n=36) Mean observation 38 months (SD 19.8#, 3-82 months	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**PFF post-operatively** A: 0/25 (0%) **Attain pre-fracture mobility status** A: 25/25 (by 18 months post op) **Non-union** A: 1/25 (4%) **Malunion** A: 0/25 (0%)	Implant important place in age 70 + salvage procedure when alternative methods failed.	For B2s treated with Kent Revision prosthesis for PFF 100% attain pre-op mobility re walking aid requirement by 18 months (*Functional level by 12 months - they don't define what this is). Most unite either 24/25 OR 23/24 (removing patient with screw breakage as you can't include in union assessment as didn't have a chance. 1 NON-UNION.
Sledge 2002 (32)	**Study design** Retro-spective case series n=7 **Data source** Local records	**Participants** Cohort of patients with Vancouver B2 PFF, n=7/7 (100%) **Sampling** Unclear **Recruitment** 1996-1998 **Indication index** NS **Index implant details** NS **Primary:Revision** 5 (3 cemented, 2 non-cemented): 2 (2 uncemented) **Cemented:Uncemented** 3:4 **Stem** NS **Mechanism injury** Minor trauma: 6/7 (86%) Major trauma: 1/7 (14%)	**Exposure A Revision + cortical strut allografts (n=7)** Revision long stem, uncemented + cerclage wires and cortical strut allografts (2 per patient) + 3-4 cables tightened with stem inside +/- acetabular revision if indicated, Kocher-Langenbeck incision, S-Rom stem (n=3), Johnson and Johnson, Restoration stem (n=4), Stryker **M:F** 5:2 **Mean age in years:** 63 (Range 54-71, No SD reported) **Allocation of exposure** Unit algorithm **Surgeon experiential level** NS	-Surgical time -Transfusion -Length of stay -Aseptic loosening femur -PFF post-operatively -Harris hip score post-operatively -Attain pre-fracture	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Surgical time mean (Wasko and Kaminski)** A: 215 (no SD or range specified) **Transfusion mean (Units Packed red blood cells)** A: 2 (no SD or range specified) **Length of stay (days)** A: 6 (no SD or range specified) **Aseptic loosening femur** A: 0/7 (0%) **PFF post-operatively** A: 0/7 (0%) **Harris hip score post-operatively (mean)**	Small case series to describe a surgeons approach to management of B2s. Good alternative to Revision long stem with ORIF Plate. Use strut instead. Interestingly didn't report	Nil to add.

		Fracture diagnosis method Radiographs pre-operatively **Setting** Single-centre Tertiary hospital, Massachusetts, USA **Inclusion criteria** Patient's suffering a Vancouver B2 PFF treated using local algorithm **Exclusion criteria** NS	**Weight bearing status** 0-3 months Partial weight bear with walker or crutches **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	mobility status -Subsidence -Cortical strut ingrowth **Time-frame of outcomes assessment:** Observation range 24-48 months (no mean given)		A: 83 (no SD or range specified) **Attain pre-fracture mobility status** A: 6/7 (86%) **Subsidence (any)** A: 2/7 (29%) **Cortical strut ingrowth** A: 7/7 (100%)	on radiographic or clinical union.	
Wu 2009 (35)	**Study design** Retro-spective case series n=13 **Data source** Unclear	**Participants** Mixed cohort of patients with PFF, n=5/13 (38%) B2 **Sampling** Unclear **Recruitment** NS **Indication index** NS **Index implant details** NS **Primary:Revision** NS **Cemented:Uncemented** NS **Stem** NS **Mechanism injury** NS **Fracture diagnosis method** Radiographs pre-operatively **Setting** Single-centre, Tertiary Hospital, Zhejiang, China **Inclusion criteria** Patients admitted to local hospital with Vancouver B2 or B3 PFF around THA **Exclusion criteria** NS	**Exposure A Revision + cortical strut allograft (n=5)** Revision extensively porous coated stem, uncemented + cortical strut allografts (1 or 2), mixed approach either posterolateral or trochanteric osteotomy (not clear proportion), Solution stem (Depuy) **M:F** 3:2 **Mean age in years:** 61.6 (Range 55-72, No SD reported) **Allocation of exposure** NS **Surgeon experiential level** NS **Weight bearing status** For 'most hips' 0-6 weeks: Partial (25%) weight bearing **Venous thromboembolism prophylaxis** NS **Surgical antibiotic prophylaxis** NS	-Union -Harris Hip score post-operatively -Satisfaction score pain VAS -Cortical strut ingrowth **Time-frame of outcomes assessment:** Pooled (n=13) mean observation 63.6 months (Range 45-89, no SD stated	Utilised descript-tive statistics for remain-ing outcomes for exposure group	**Union** A: 5/5 (100%) at mean 5.6 months (Range 3-9) **Harris Hip score post-operatively (mean)** A: 70 (SD 9.3, 62-82) **Satisfaction score pain VAS (0-100)** A: Mean 18.4 (SD 6.07, 11-25) **Cortical strut ingrowth** A: 5/5 (100%)	Revision with cortical strut is a rigid mechanical stability for fracture fixation and enhancing healing bone stock restoration.	Study supports uncemented long stem revision with cortical strut allografts for B2s All healed.

Appendix V: Critical appraisal scores

Table **- Critical appraisal scores for included cohort studies – Questions in appendix X. Y = Yes, N = No, N/A = Not applicable, U = Unclear

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Bhattacharyya, 2007	Y	Y	Y	U	Y	Y	Y	Y	N/A	Y	89%
Joestl, 2016	Y	Y	Y	N	Y	Y	Y	N/A	N/A	U	75%
Lindahl, 2006	Y	Y	Y	U	Y	Y	Y	Y	U	Y	80%
Mukka, 2016	Y	Y	Y	N	Y	Y	Y	N/A	N	Y	78%
Mukundan, 2010	Y	Y	Y	U	Y	Y	Y	U	N/A	Y	78%
Pavlou, 2011	Y	Y	Y	U	Y	Y	Y	N	U	Y	70%
Solomon, 2015	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	90%
Spina, 2014	Y	Y	Y	U	Y	Y	U	Y	U	Y	70%
Young, 2007	Y	Y	Y	N	Y	Y	Y	Y	U	Y	80%
Zuurmond, 2010	Y	Y	Y	N	Y	Y	Y	Y	U	Y	80%

Table x.x– Critical appraisal scores for included descriptive studies – Questions in appendix X. Y = Yes, N = No, N/A = Not applicable, U = Unknown

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Amenabar, 2015	Y	Y	N	Y	Y	Y	Y	U	Y	78%
Briant-Evans, 2009	Y	Y	N	N	Y	Y	Y	N	N/A	63%
Canbora, 2013	Y	Y	Y	Y	Y	Y	Y	N	Y	89%
Corten, 2012	Y	Y	U	Y	Y	N	Y	N	Y	67%
Da Assunção, 2015	Y	Y	Y	Y	Y	Y	Y	N	Y	89%
Eingartner, 2006	Y	Y	U	N	Y	N	Y	N	N/A	50%
Fink, 2014	Y	Y	U	Y	N	Y	Y	N	Y	56%
Garcia-Rey, 2013	Y	Y	Y	Y	Y	N	Y	N	Y	78%
Grammatopoulos, 2011	Y	Y	Y	Y	Y	Y	Y	N	N/A	88%
Haidar, 2005	Y	Y	Y	Y	Y	N	Y	N	Y	78%
Holder, 2014	Y	Y	Y	Y	Y	N	Y	Y	Y	89%
Holley, 2007	Y	Y	Y	Y	Y	N	Y	Y	Y	89%
Inngul, 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Ko, 2003	Y	Y	Y	Y	Y	N	Y	Y	Y	89%
Konan, 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Korbel, 2013	Y	Y	U	Y	Y	Y	Y	Y	Y	89%
Levine, 2008	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Lunebourg, 2015	Y	Y	Y	Y	Y	Y	Y	N	Y	89%
Marx, 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Moreta, 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Munro, 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Niikura, 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Pogliacomi, 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Rayan, 2010	Y	Y	U	Y	Y	Y	Y	Y	Y	89%
Sexton, 2006	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Sledge, 2002	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Wu, 2009	Y	Y	U	Y	Y	Y	Y	Y	Y	89%