Dynamic hip screws versus cephalocondylic intramedullary nails for unstable extracapsular hip fractures in 2021: A systematic review and meta-analysis of randomised trials

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Abstract

Background

Extracapsular hip fractures comprise approximately half of all hip fractures and the incidence of hip fractures is exponentially increasing. Extramedullary fixation using a dynamic hip screw (DHS) has been the gold standard method of operative treatment for extracapsular fractures, however, in recent years, intramedullary nails (IMN) have become a popular alternative. Intramedullary versus extramedullary fixation is continuously discussed and debated in literature therefore, the purpose of this systematic review and meta-analysis is to directly compare the peri-operative and post-operative outcomes for DHS versus IMN to provide an up-to-date analysis as to which method of fixation is superior.

Methods

The MEDLINE/Pubmed, Embase and Web of Science Database were searched for eligible studies, from 2008 to August 2021, that compared peri- and post-operational outcomes for patients undergoing IMN or DHS operations for fixation of unstable extracapsular hip fractures (PROSPERO registration ID:CRD42021228335). Primary outcomes included mortality rate and re-operation rate. Secondary outcomes included operation time, blood loss, transfusion requirement, complication, and failure of fixation rate. The risk of bias and quality of evidence were assessed using the Cochrane RoB 2.0 tool and GRADE analysis tool, respectively.

Results

Of the 6776 records identified, 22 studies involving 3151 patients, were included in the final review. Our meta-analysis showed no significant different between mortality rates (10 studies, OR 0.98; 95% CI 0.80 to 1.22, p = 0.88), and similarly, no significant difference for re-operation rates (10 studies, OR 1.03; 95% CI 0.64 to 1.64, p = 0.91). There was also no significant difference found between complication or failure of fixation rates (17 studies, OR 1.29; 95% CI 0.79 to 2.12, p = 0.31) and (14 studies, OR 1.32; 95% CI 0.74 to 2.38, p = 0.35). Mean blood loss was not included in the meta-analysis but was demonstrated to be significantly greater in those undergoing DHS in 12 out of 13 studies.

Conclusion

Overall, based on the outcomes assessed, this review has demonstrated no significant difference in the peri- or post-operative outcomes for DHS vs IMN. Future studies should investigate DHS vs IMN for different types of unstable fractures as well as investigating different types and generations of fixation devices.

Introduction

Hip fractures, also known as proximal femoral fractures, are fractures that occur in the upper region of the femur. They are one of the most common injuries affecting elderly people and are associated with significant morbidity and mortality. The incidence of hip fractures increases with age and are commonly fragility fractures resulting from osteoporosis, a condition that causes the bones to become weak and brittle and susceptible to breaking.

Due to a growing ageing population, the incidence of hip fractures is exponentially increasing and majorly impacting healthcare systems and patients. In 2019, 76,000 patients presented to a hospital in the UK with a hip fracture, an increase from the approximate 65,000 patients that presented in 2017 [1]. Fortunately, there has been a decrease in 30-day mortality rate following hip fractures from 6.9% in 2017 to 6.1% in 2018, yet there is still a significant mortality risk [2]. Nevertheless, hip fractures account for 1.8 million hospital bed days per year and cost the NHS £1.1 billion in hospital costs annually, excluding the costs of social care [3]. Similar trends are seen globally as ageing populations are affecting many countries, notably in the US where annual hip arthroplasties are expected to increase by 174% by 2030 [4]. By 2050, it is estimated that the annual worldwide incidence of hip fractures will be 6 million [5–6].

Extracapsular hip fractures comprise approximately half of all hip fractures and are usually the result of low-energy mechanisms in elderly patients [7]. Extracapsular fractures are fractures that traverse the femur within the area of bone bounded by the intertrochanteric line proximally up to five centimeters below the distal part of the lesser trochanter [8]. These types of hip fractures are currently treated exclusively via surgical intervention, given that previous non-operative treatments historically had a significant association with complications resulting in prolonged bed-rest and immobilisation, as well as high mortality rates [7]. Fortunately, most of the bone in this area is cancellous and highly vascularised in comparison to intracapsular hip fractures, resulting in a robust healing environment suitable for surgical intervention [4].

The type of fractures can be further classified depending on their relationship to the greater and lesser trochanters. The most recent classification method is the AO/OTA classification. It is a widely recognised classification system for classifying long-bone fractures. Extracapsular hip fractures are classified by AO as Type 31-A and subdivided into groups A1, A2 and A3. Types A1 and A2 are pertrochanteric, with the main fracture line running obliquely from proximal-lateral to distal-medial. Type A1 is a stable trochanteric fracture and type A2 is an unstable trochanteric fracture. Type A3 is an unstable transtrochanteric fracture, which includes those fracture lines at the level of the lesser trochanter and reverse oblique patterns [9].

For the past 40 years, the dynamic (sliding) hip screw (DHS) has been the gold standard method of operative treatment for extracapsular hip fractures [10]. DHS consists of a lag screw passed into the femoral head which is then attached to a plate, to be secured on the side of the femur. They are given the term ‘dynamic’ because they allow the femoral head component to move along one plane [11]. In the last 20 years, intramedullary nails (IMN) have become a popular method of fixation as an alternative to DHS, especially for those with unstable fracture patterns. Cephalocondylic IMN are inserted through the greater trochanter or piriform fossa of the femur and are secured by a screw that is passed up the femoral head into the neck [12]. They may be biomechanically advantageous for unstable fractures by providing better load sharing [10].

Intramedullary versus extramedullary fixation is still frequently and controversially discussed and debated in the literature. Older studies (1991–1999) demonstrated that DHS appeared to be a superior implant to IMN due to lower complication rates and risk of femoral fracture, however, newer studies (2000–2005), utilising newer generations of IMN, demonstrated that IMN did not in fact increase the risk of periprosthetic femoral fracture [13]. The current NICE guidelines recommend DHS as the surgical treatment for A1 and A2 fractures, as per the AO/OTA classification, and IMN for A3 fractures whereas the American Academy of Orthopaedic Surgeons (AAOS) guidelines recommend either DHS or IMN for stable fractures and IMN for unstable fractures [14–15]. These guidelines however are still not supported by clinical studies as many recent meta-analyses have demonstrated no notable difference or advantage to choosing DHS in comparison to IMN [16–18].

The purpose of this systematic review is to review more recent randomised controlled trials comparing IMN and DHS in adult patients for the stabilisation of extracapsular hip fractures from 2008 to 2021 to provide a more focussed analysis of the outcomes using the newer generations of IMN’s and DHS’s. This review will assess and evaluate the recent evidence for treating adult patients with extracapsular hip fractures using either IMN or DHS to assess which procedure results in better peri- and post-operative outcomes for the patient.

Methods

The article search and selection for this review was carried out based on the standard methodology recommended by the Cochrane Methods group for the systematic review of interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) group.

Search strategy

The MEDLINE/Pubmed, Embase and Web of Science Database were searched for eligible studies. The search was limited to studies from 2008 to August 2021. Details of the search strategy have been provided (Appendix A). Two reviewers (S.G. and S.R) performed the search and evaluated titles, abstracts then full-text articles to decide eligible studies to include. The reference lists of the articles included were also searched for further eligible studies. The Cochrane Risk of Bias 2.0 Tool was used to guide the assessment of the studies identified from the literature search [19]. For all eligible articles, S.G and S.R performed data extraction including demographics of participants, study characteristics, and procedure and outcomes. Any disagreement was resolved via discussion and any dispute was settled by a consensus involving all authors. The data gathered was inputted into pre-defined categories in a spreadsheet.

Eligible studies

Only randomised/quasi-randomised studies comparing peri-operational and post-operational outcomes for patients undergoing operations with cephalocondylic IMN in comparison to DHS for fixation of extracapsular trochanteric hip fractures were included for this review. Duplicate studies, case reports, editorials, letters, and conference proceedings were excluded (Table 1).

Eligible participants

This systematic review included male or female skeletally mature patients with extracapsular (intertrochanteric or subtrochanteric) hip fracture undergoing treatment with either cephalocondyllic IMN or DHS for fixation in the primary setting, therefore excluding those who were undergoing revision surgery.

Eligible interventions and comparators

The eligible intervention included fixation by cephalocondyllic IMN, of any material and type for fixation of extracapsular hip fractures. The comparator was the use of DHS for fixation of extracapsular fractures of any type and material and using any technique.

Outcome measures

The primary outcome measures were patient mortality and reoperation rates at final follow-up, measured in percentages. The secondary outcomes were failure of fixation rate, complication rate, surgical outcomes (mean operating time, blood loss and transfusion requirement).

Assessment of risk of bias

All randomised control trials included in this study were assessed for risk of bias via the Cochrane Risk of Bias 2.0 tool [19] and the quality of our effect estimate was analysed using the GRADE ranking system [20].

Data analysis

All quantitative data for patient mortality and the re-operation rate at final follow-up that were available has been included and presented in a table demonstrating primary outcomes. All quantitative data for secondary outcomes including operating time, blood loss, transfusion requirement, complication rate and failure of fixation has been measured as either mean or true values and presented in a table. A quantitative meta-analysis has also been carried out to compare mortality, re-operation, complication, and failure of fixation rates between the intervention and comparator using the Review Manager (RevMan) software. Mean difference and odds ratios were calculates and the confidence intervals were provided. Studies that had incomplete data or incomparable outcomes were excluded from the meta-analysis. A full discussion of possible explanations and conclusions from the meta-analysis and tabulated data have been explored in the discussion and conclusion sections.

Results

Following a systematic search, 6776 studies were identified using defined criteria. After the removal of duplicates, 5040 studies remained. The number of full-text articles assessed for eligibility was 37 and 22 studies were included in the final review. In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a flow diagram demonstrating the study selection procedure has been included (Fig. 1). The PRISMA checklist has been included as “Appendix B”.

Study characteristics

The baseline characteristics for this study are shown in Table 2. Studies comparing fixation of extracapsular (intertrochanteric and subtrochanteric) hip fractures using DHS and IMN were assessed in this systematic review. The patients were allocated to each intervention using various randomisation techniques, in ten studies randomisation was carried out using sealed envelopes that were computer-generated or generated by a medical statistician [21–30], in three studies randomisation was carried out by the operating surgeon [31–33] and in another three studies randomisation was carried out using number generators [34–36], the other studies did not specify their randomisation technique [37–42]. Only one study utilised a single surgeon for the operations in the study [35]. The patient recruitment period ranged from 2006 to 2019, and all studies were published after 2008. A total of 3151 patients, with a mean age of 74.5 (range 58–84) were included, the median number of male and female participants was 25 and 65 respectively. Out of these 3151 patients, 1595 underwent treatment with DHS and 1556 underwent treatment with IMN. The types of IMN used included all of but not limited to gamma nail, intramedullary hip screw and proximal femoral nail. Patients included had either 31-A1, 31-A2 or 31-A3 fractures, as classified by the AO/OTA classification. The median follow-up duration was 12 months (range 6–18 months).

Primary outcomes

The individual results for the primary outcomes are shown in Table 3. The primary outcomes were mortality rate at final follow-up as well as the reoperation rate for fixation failure at final follow-up. Eleven studies recorded final-follow up mortality [21–25, 33–35, 37, 40–41] and 13 reported re-operation rate for failure fixation at final follow-up [21–25, 28, 31, 33, 35, 37–38, 40, 42]. Of those studies that reported final-follow up mortality, none reported any statistically significant difference between patients that had DHS versus those that had IMN. Of those studies that reported the reoperation rate for fixation failure at final follow-up, only one study [33] reported a significant difference ($p < 0.05$) between DHS and IMN with 2 out of 25 patients requiring a further operation for fixation failure in those that underwent DHS versus 0 out of 25 patients that underwent IMN.

Ten studies [21–25, 33–35, 37, 41] were eligible for meta-analysis of mortality rates at final follow-up (Fig. 2). No significant difference was found between mortality rates for those undergoing DHS in comparison to IMN operations (mean difference 0.98; 95% CI 0.80 to 1.22, $p = 0.88$). On analysis of re-operation rate, 10 studies [21–25, 31, 33, 37–38, 42] were eligible for meta-analysis, and similarly, no significant difference was shown between DHS and IMN (mean difference 1.03; 95% CI 0.64 to 1.64, $p = 0.91$) (Fig. 3).

Secondary outcomes

The individual results for secondary outcomes are shown in Table 4.

Operation time

The length of operation was recorded in 17 studies [22–25, 27, 29–33, 35, 37–40, 41–42]. In 10 studies, there was a significant difference in length of operation between DHS and IMN, in each of these studies the DHS operation was significantly longer than IMN [25, 30–33, 35, 38, 41–42]. One study recorded the greatest difference in operating time between DHS and IMN with an average operation time of 93.0 minutes for DHS, in comparison to 52.0 minutes for IMN ($p < 0.05$) [38]. Only two studies demonstrated a longer average operating time for IMN in comparison to DHS [22, 37]. The study by Little et al. [37], demonstrated an average operating time of 40.3 minutes for DHS and 54.0 minutes for IMN ($p < 0.001$) and the study by Xu et al. [22], demonstrated an average operating time of 56.5 for DHS and 68.5 for IMN ($p < 0.0001$).

Blood loss and transfusion requirement

The mean blood loss during the operation was recorded in milliliters for 13 studies [22–23, 27, 29–33, 35, 37–40]. Each study demonstrated that for all DHS operations the mean blood loss was greater than for that of IMN operations. A statistically significant difference was observed in 12 out of the 13 studies. The mean blood loss ranged from 122.2ml to 472.9ml [22, 32] for DHS and 84.7ml to 220.4 for IMN [22, 30]. Only 5 studies reported mean transfusion requirement in milliliters [23–24, 39–40, 42]. No statistically significant differences were observed for the mean transfusion requirement between DHS or IMN in any of the studies.

Complication rate

Complication rates were reported in 17 studies [22–31, 33, 35, 37–40, 42]. Only one study demonstrated a significant difference in complication rates between DHS and IMN [23] where 21 of the 343 patients that underwent DHS operations developed complications in comparison to 62 out of 341 patients that underwent IMN operations that developed complications ($p < 0.001$). No other study showed a significant difference in complication rates between DHS and IMN. Three studies reported a complication rate of 0% for IMN [28, 30–31] whereas the lowest reported complication rate for DHS was 1.5% [25]. The highest reported complication rates were 62.7% for DHS and 64.6% for IMN, both of which were reported in the same study [35]. Seventeen studies [22–28, 29–31, 33, 35, 37–40, 42] were included in the meta-analysis of complication rates between DHS and IMN, this revealed no significant difference (mean difference 1.29; 95% CI 0.79 to 2.12, $p = 0.31$) (Fig. 4).

Failure of fixation rate

Fourteen studies [22–31, 33, 36–37, 41] reported a failure of fixation rate of which only one study [33] reported a significant difference, where 2 out of 25 DHS patients had a failure of fixation and 1 out of 25 IMN patients had a failure of fixation ($p < 0.05$). Twelve of these studies [22–27, 29–30, 33, 36–37, 41] were eligible for meta-analysis which revealed a non-significant difference in failure of fixation rates between DHS and IMN (mean difference 1.32; 95% CI 0.74 to 2.38, p = 0.35) (Fig. 5).

Quality assessment

The studies involved in this review were all assessed using the Cochrane Risk of Bias 2.0 Tool and deemed to have some level of bias (Table 5). A GRADE analysis was done for the studies included in the meta-analysis. Failure of fixation revealed a very low overall GRADE rating whereas, re-operation for failure of fixation and complication rate revealed a low rating and mortality rate, a moderate rating (Table 6).

Discussion

Summary of findings

This systematic review and meta-analysis has been conducted to provide an up-to-date review to determine which procedure, DHS or IMN, results in better peri-operative and post-operative outcomes. In summary, on meta-analysis of the results there was no statistically significant difference in mortality or reoperation rates for either type of operation at final follow-up, there was also no significant difference in complication rate for either procedure. However, the majority of studies found that the DHS procedures led to significantly higher blood loss and longer operation time than IMN procedures. In the meta-analysis it was shown that there was no statistically significant difference in complication rate.

Previous systematic reviews

At the time of writing, this review is the largest systematic review with a meta-analysis that compares mortality and re-operation rates, as well as further adverse outcomes between DHS and IMN procedures. In 2017, a review investigating nail versus plate fixation was published by Parker et al. [43] which primarily looked at complications relating to fracture health. Although this review concluded that there was no difference in complication rates for either DHS or IMN procedures, this review only included type A3 fractures and only involved a total of 9 studies. A more recent review published by Lewis et al. [44] in 2022 compared intramedullary versus extramedullary fixation for extracapsular fractures. Contrary to our review, their primary outcomes were predominantly function-related including: performance of activities of daily living, functional status and health-related quality of life. Although this review involved 76 studies, the review reported that over half of the studies were conducted prior to 2010 and stated that the authors “could not easily judge whether care pathways in these older studies were comparable to current standard of care”. Moreover, a similar 2022 review also assessed post-operative outcomes including complication rate, nonunion, infection or mortality rates between DHS and IMN for AO/OTA subtypes: A1, A2 and A3. The authors investigated each subtype separately and reported difficulty in obtaining data for each one and therefore could not complete a meta-analysis [18]. Our review therefore adds to the existing literature by providing an up-to-date review that directly compares DHS and IMN procedures for all of A1, A2 and A3 extracapsular fractures collectively and specifically addresses peri-operative as well as post-operative outcomes.

Primary outcomes

In this review, the studies included reported various peri- and post-operative outcomes. Nine studies reported both primary outcomes [21–25, 33, 35, 40, 43]. Our review found no difference in mortality rate at final follow-up between DHS and IMN procedures. This is in keeping with previous reviews by Wessels et al [18] and Zhang et al [45], that also found no difference in mortality rate when comparing DHS to IMN. It has been suggested both procedures could result in a mortality rate of up to 10% in the first year post-procedure, however this could be attributed to the predominantly elderly age group being treated and their existing medical comorbidities [36]. Our review also demonstrated no significant difference in reoperation rate for fixation failure for either procedure. Alternatively, one study that investigated 17,341 patients demonstrated a lower reoperation rate for IMN at 1 and 3 years in comparison to DHS for unstable femoral fractures [46]. However, this study investigated reoperations for various other reasons such as implant-related infection, peri-implant fracture, mechanical complications and pain, as opposed to failure of fixation only.

Secondary outcomes

In this review, no single study reported all secondary outcomes and the number of secondary outcomes reported by each study ranged from 0–5, meaning that there was marked heterogeneity in the number of secondary outcomes reported. This meant that not all secondary outcomes were eligible for meta-analysis. It was not possible to carry out a meta-analysis for operation time, blood loss or transfusion time. Of the secondary outcomes that underwent meta-analysis, no significant difference was found in complication rate or failure of fixation rate.

The meta-analysis of the 17 studies that reported complication rate, revealed that there was no significant difference in complication rates between either procedure. In keeping with the literature, one study followed approximately 5700 patients over 7 years following DHS or IMN procedures and noted that within 30 days after surgery, the complication rates was exactly 16% for both groups (p = 0.98) [47]. Similarly, a further meta-analysis showed no significant differences in implant-related post-operative complications such as femoral shaft fracture, non-union, breakage of implant and migration of screw between DHS or IMN [48]. Our review showed no difference in failure of fixation for either procedure. Although failed fixations are rarely reported, a previous study has provided data suggesting that for some unstable fracture patterns including high comminuted fractures or reverse oblique fractures, DHS may be more likley to fail [49]. Further comparison for specific unstable fracture types would be required before this can be confirmed, as well as investigating complication and failure of fixation over longer follow-up periods.

The results from the evaluation of papers demonstrated that for all DHS operations, blood loss was greater than that of IMN operations with a statistically significant difference in the 12 out of 13 studies that reported this outcome. This is in keeping with a meta-analysis by Hao et al, that used 24-active comparator studies, involving 3097 participants, and identified that more blood loss was observed for DHS use than for fixation using nails [50]. Another previous meta-analysis recommends the use of IMN for the treatment of unstable intertrochanteric fractures based on the fact that it results in a reduced blood loss [51]. Operation time was also significantly longer for DHS operations in 10 studies, which is in keeping with the literature [52]. There is speculation to suggest that DHS operations could result in more blood loss and higher infection rate given that they have a longer operative time [53]. Only five studies reported mean transfusion requirement in millilitres, the rest reporting the transfusion requirement per patient and therefore, along with blood loss, mean transfusion requirement was also not eligible for meta-analysis.

Even though DHS and IMN procedures provide similar post-operative outcomes such as mortality, complication, and failure of fixation rate, there has been some suggestion from these results that the DHS procedure results in a proportionally greater blood loss and longer operating time in comparison to IMN. This is suggesting that IMN could arguably be a safer treatment option from the peri-operative aspect, however, DHS remains the gold standard operation in the UK. A previous study in the US demonstrated that along with fixation failure rate, implant cost were the most important factors in determining implant choice for unstable intertrochanteric fractures [54], another study conducted in India reported that the cost of an IMN is 7–8 times the cost of DHS and therefore heavily influencing the decision for method of treatment [55]. Based on this data, in order to justify the increased use of IMN in the UK, an assessment of cost would also need to be identified and analysed.

Strengths and limitations

The strengths of this review include a prospective registration of the study protocol as well as an up-to-date literature search. This review also includes a meta-analysis to compare the primary and some of the secondary outcomes. However, the limitations of this study should be considered. Firstly, there is significant marked heterogeneity in the number of outcomes reported by each study, meaning that meta-analysis could not be conducted for each outcome. Secondly, there have been previous studies [43–44] that have suggested that variations of IMN could have different success rates in comparison to DHS, however this was not investigated further in our review. Following that, this review did not investigate the different surgical techniques for DHS and IMN to assess whether that had any impact on the results. Furthermore, this review also included older studies, from 2008–2010 [21–22, 37–40], which could've perhaps utilised older techniques and older models of nails and screws, therefore affecting the peri and post-operative outcomes. Finally, when assessing the risk of bias using the Cochrane Risk of Bias tool, seven studies were deemed to have an overall risk of bias of 'high risk' and the remaining studies were classified with 'some concerns'.

Conclusion

Overall, based on the studies that were included and outcomes that were assessed, this systematic review has demonstrated that, there is no significant difference in the peri- or post-operative outcomes for surgeries utilising DHS vs those that utilise IMN. It is currently not possible to come to a definitive conclusion as to which procedure is superior. Further studies should investigate DHS vs IMN for different types of unstable fractures, as well as investigating utilising different types and generations of fixation devices. Future studies should also address and analyse cost as a potential barrier or reason as to why DHS remains the current gold standard in the UK.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable.

Availability of data and material: The datasets supporting the conclusions of this review are included within the review and its additional files.

Competing interests: All authors declare that they have no competing interests.

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Authors' contributions: SR and SG performed the search and evaluated titles, abstracts, and then full-text articles to decide eligible studies to include. For all eligible articles SR and SG performed data extraction including demographics of participants, study characteristics, and procedures and outcomes. Disagreement was resolved via discussion and where no agreement was reached, a third independent party acted as an arbiter (APr). SR, SG and HB coordinated and equally contributed to writing the manuscript. MAF and APa oversaw, reviewed, and edited the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
● Randomised / quasi-randomised studies ● Skeletally mature patients ● Extracapsular proximal femur fracture ● Intramedullary cephalocondylic nails versus dynamic hip screws ● English language articles only ● Human studies ● Patient outcomes data clearly discussed (mortality, function, complications, reoperation) ● Trials published from 2008 to August 2021 (inclusive)	● Duplicate studies excluded ● Case reports, editorials, comments, letters, guidelines, protocols, abstracts, review papers, demographic studies, unpublished studies ● Anatomical/cadaveric/biomechanical studies ● Trials assessing only pathological or subtrochanteric fractures ● Trials assessing more than 2 methods of fixation

Table 2: Patient characteristics

Study	**Sample size (number)**		**Average age (years)**		**Participants**		**Fractures Included**
	DHS	**IMN**	**DHS**	**IMN**	**Male**	**Female**	
Little et al., 2008	98	92	84.2	82.6	28	157	31-A1/A2/A3
Zou et al., 2009	63	58	65.0	65.0	28	93	31-A1/A2/A3
Verettas et al., 2009	60	60	81.0	79.2	35	85	31-A2
Barton et al., 2009	110	100	83.3	83.1	44	166	31-A2
Huang et al., 2010	48	48	77.0	75.0	25	71	31-A1/A2
Xu et al., 2009	55	51	77.9	78.5	31	75	31-A2
Kumar et al., 2012	25	25	62.3	62.3	20	30	31-A1/A2/A3
Matre et al., 2013	343	341	84.1	84.1	171	513	31-A1/A2/A3
Nargesh et al., 2013	48	48	67.0	68.0	26	70	-
Bhakat et al., 2013	30	30	67.8	67.8	26	34	31-A2/A3
Guerra et al., 2014	19	12	77.9	80.2	6	25	31-A1/A2
Aktselis et al., 2014	40	40	-	-	24	56	31-A2
Chechik et al., 2014	31	29	83.1	83.1	14	46	31-A1/A2
Sharma et al., 2015	15	15	-	-	15	15	31-A2/A3
Zehir et al., 2015	102	96	76.9	77.2	76	122	31-A2
Reindl et al., 2015	92	112	80.0	82.0	88	116	31-A2
Neritan et al., 2016	41	22	77.3	77.3	15	48	31-A1/A2/A3
Parker et al., 2017	200	200	83.2	82.0	107	293	31-A1/A2/A3
Bajpai et al., 2019	60	60	67.4	66.9	60	60	-
Eceviz et al., 2020	27	29	80.8	80.8	26	30	-
Adeel et al., 2020	34	34	60.9	59.3	47	21	31-A2/A3
Saleem et al., 2020	54	54	60.2	58.5	68	40	-

Table 3: Primary outcomes (mortality rate, re-operation rate due to failure of fixation)

Study	Final follow-up (months)	Final-follow up mortality			Re-operation rate for fixation failure		
		DHS	IMN	p-value	DHS	IMN	p-value
Little et al., 2008	12	17/98 (17.3%)	16/92 (17.4%)	p>0.05	2/98 (2.0%)	0/92 (0%)	p>0.05
Zou et al., 2009	12	-	-	-	3/63 (4/8%)	0/58 (0%)	-
Verettas et al., 2009	-	-	-	-	-	-	-
Barton et al., 2009	12	24/110 (21.8%)	32/100 (32.0%)	p<0.26	2/110 (1.8%)	3/100 (3%)	p<0.67
Huang et al., 2010	9	0/48 (0%)	0/48 (0%)	-	0/48 (0%)	0/48 (0%)	p>0.05
Xu et al., 2009	12	3/55 (5.5%)	2/51 (3.9%)	p>0.05	1/55 (1.8%)	2/51 (3.9%)	p>0.05
Kumar et al., 2012	12	1/25 (4.0%)	1/25 (4.0%)	p>0.05	2/25 (8.0%)	0/25 (0%)	p<0.05
Matre et al., 2013	12	87/343 (25.4%)	84/341 (24.6%)	p=0.83	27/343 (7.9%)	28/341 (8.2%)	p=0.87
Nargesh et al., 2013	12	-	-	-	-	-	-
Bhakat et al., 2013	6	-	-	-	2/30 (6.7%)	1/30 (3.3%)	-
Guerra et al., 2014	12	8/19 (42.1%)	2/12 (16.7%)	p>0.05	-	-	-
Aktselis et al., 2014	12	5/40 (12.5%)	4/40 (10.0%)	-	-	-	-
Chechik et al., 2014	12	1/31 (3.2%)	1/29 (3.4%)	-	1/31 (3.2%)	1/29 (2.4%)	p>0.05
Sharma et al., 2015	6	-	-	-	1/15 (6.7%)	0/15 (0%)	-
Zehir et al., 2015	-	26/102 (25.5%)	23/96 (24.0%)	-	0/102 (0%)	0/96 (0%)	p>0.05
Reindl et al., 2015	12	-	-	-	-	-	-
Neritan et al., 2016	12	-	-	-	-	-	-
Parker et al., 2017	12	59/200 (14.5%)	60/200 (30.0%)	-	0/200 (0%)	3/200 (1.5%)	p=0.3
Bajpai et al., 2019	18	-	-	-	-	-	-
Eceviz et al., 2020	12	-	-	-	0/27 (0%)	0/29 (0%)	-
Adeel et al., 2020	12	-	-	-	-	-	-
Saleem et al., 2020	6	-	-	-	-	-	-

Table 4: Secondary outcomes (operation time, blood loss and transfusion requirement, complication rate, failure of fixation rate)

Study	Operation Time (mins)			Mean blood loss (ml)			Mean transfusion requirement (ml)			Complication rate			Failure of fixation	
	DHS	IMN	p-value	DHS	IMN	p-value	DHS	IMN	p-value	DHS	IMN	p-value	DHS	IMN
Little et al., 2008	40.3	54.0	p<0.001	160.0	78.0	p<0.001	-	-	-	19/98 (19.4%)	11/92 (12.0%)	p>0.05	2/98 (2.0%)	4/92 (4.3%)
Zou et al., 2009	93.0	52.0	p<0.05	410.0	156.0	p<0.05	-	-	-	4/63 (6.3%)	1/58 (1.7%)	p>0.05	-	-
Verettas et al., 2009	45.0	52.0	p=0.336	200.0	150.0	p=0.237	1000	1000	p=0.847	10/60 (16.7%)	11/60 (18.3%)	-	-	-
Barton et al., 2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Huang et al., 2010	52.4	50.5	-	225.0	202.5	-	200	200	-	3/48 (6.3%)	5/48 (10.4%)	-	-	-
Xu et al., 2009	56.5	68.5	p<0.0001	472.9	220.4	p<0.0001	-	-	-	20/55 (36.4%)	13/51 (25.5%)	p>0.05	1/55 (1.8%)	2/51 (3.9%)
Kumar et al., 2012	87.0	55.0	p>0.05	250.0	100.0	p<0.05	-	-	-	1/25 (4.0%)	1/25 (4.0%)	p>0.05	2/25 (8.0%)	1/25 (4.0%)
Matre et al., 2013	55.6	54.7	p<0.69	263.0	180.0	p<0.001	171	143	p=0.02	21/343 (6.1%)	62/341 (18.2%)	p<0.001	2/343 (0.6%)	4/341 (1.2%)
Nargesh et al., 2013	65.0	42.0	-	162.0	95.0	p<0.05	-	-	-	6/48 (12.5%)	1/48 (2.1%)	-	1/48 (2.1%)	0/48 (0%)
Bhakat et al., 2013	69.0	48.7	p<0.0001	213.0	116.0	p<0.0001	-	-	-	2/30 (6.7%)	0/30 (0%)	-	0/30 (0%)	0/30 (0%)
Guerra et al., 2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aktselis et al., 2014	75.5	45.7	p<0.001	-	-	-	-	-	-	-	-	-	3/40 (7.5%)	0/40 (0%)
Chechik et al., 2014	64.0	54.5	-	-	-	-	645	360	p=0.08	9/31 (29.0%)	5/29 (17.2%)	-	6/31 (19.4%)	5/29 (17.2%)
Sharma et al., 2015	59.7	44.5	p<0.05	-	-	-	435	200	p>0.05	5/15 (33.3%)	1/15 (6.7%)	-	-	-
Zehir et al., 2015	56.9	44.4	p<0.001	303.1	139.7	p<0.001	-	-	-	64/102 (62.7%)	62/96 (64.6%)	p>0.05	-	-
Reindl et al., 2015	-	-	-	-	-	-	-	-	-	-	-	-	2/92 (2.2%)	1/112 (0.9%)
Neritan et al., 2016	72.3	49.3	p<0.001	122.2	85.4	p<0.001	-	-	-	-	-	-	-	-
Parker et al., 2017	42.1	38.3	p<0.001	-	-	-	-	-	-	3/200 (1.5%)	2/200 (1.0%)	p>0.05	2/200 (1.0%)	2/200 (1.0%)
Bajpai et al., 2019	-	-	-	-	-	-	-	-	-	18/60 (30.0%)	26/60 (43.3%)	-	2/60 (3.3%)	0/60 (0%)
Eceviz et al., 2020	-	-	-	-	-	-	-	-	-	1/27 (3.7%)	0/29 (0%)	-	0/27 (0%)	0/29 (0%)
Adeel et al., 2020	58.7	35.4	p<0.05	273.8	149.8	p<0.05	-	-	-	2/34 (5.9%)	1/34 (2.9%)	p>0.05	6/34 (17.6%)	3/34 (8.8%)

Saleem et al., 2020	78.3	70.2	p<0.013	290.9	84.7	p<0.0000001	-	-	-	7/54 (1.9%)	0/54 (0%)	p<0.06	3/54 (5.6%)	0/54 (0%)

Table 5: Risk of bias for randomised comparative studies using the Cochrane RoB 2.0 tool

Study ID (Author, country and year of publication)	Bias from randomisation	Bias from effect of assignment to intervention	Bias from effect of adhering to intervention	Bias due to missing outcome data	Bias in measurement of outcome	Bias in selection of reported result	Overall risk of bais
Little et al., 2008	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk	Some concerns
Zou et al., 2009	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk	Some concerns
Verettas et al., 2009	Some concerns	Low risk	Low risk	High risk	Some concerns	High risk	High risk
Barton et al., 2009	Low risk	Low risk	Low risk	Some concerns	Low risk	Some concerns	Some concerns
Huang et al., 2010	Some concerns	Low risk	Low risk	Some concerns	Low risk	Some concerns	Some concerns
Xu et al., 2009	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Kumar et al., 2012	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some concerns
Matre et al., 2013	Low risk	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Nargesh et al., 2013	Low risk	Low risk	Low risk	High risk	Some concerns	High risk	High risk
Bhakat et al., 2013	Low risk	Low risk	Low risk	Some concerns	Low risk	Some concerns	Some concerns
Guerra et al., 2014	Low risk	Low risk	Low risk	High risk	Some concerns	High risk	High risk
Aktselis et al., 2014	High risk	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	High risk
Chechik et al., 2014	Low risk	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Sharma et al., 2015	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Zehir et al., 2015	Low risk	Low risk	Low risk	Some concerns	Some concerns	Low risk	Some concerns
Reindl et al., 2015	Low risk	Low risk	Low risk	High risk	Some concerns	Some concerns	High risk
Neritan et al., 2016	Some concerns	Low risk	Low risk	Some concerns	High risk	High risk	High risk
Parker et al., 2017	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some conerns
Bajpai et al., 2019	Low risk	Low risk	Low risk	Some concerns	Some concerns	High risk	High risk
Eceviz et al., 2020	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some concerns
Adeel et al., 2020	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some concerns
Saleem et al., 2020	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Some concerns

Table 6: Quality of evidence of each outcome using the GRADE analysis

Outcomes		No. of studies	Risk of bias	Imprecision	Inconsistency	Indirectness	Publication bias	Overall GRADE rating
Primary	Mortality rate	10	High	High	High	Moderate	Low	Moderate
	Re-operation for failure of fixation	10	High	Low	Moderate	Low	Low	Low
Secondary	Complication rate	17	High	Moderate	Low	Low	Low	Low
	Failure of fixation rate	12	High	Low	Low	Low	Low	Very Low

Figures

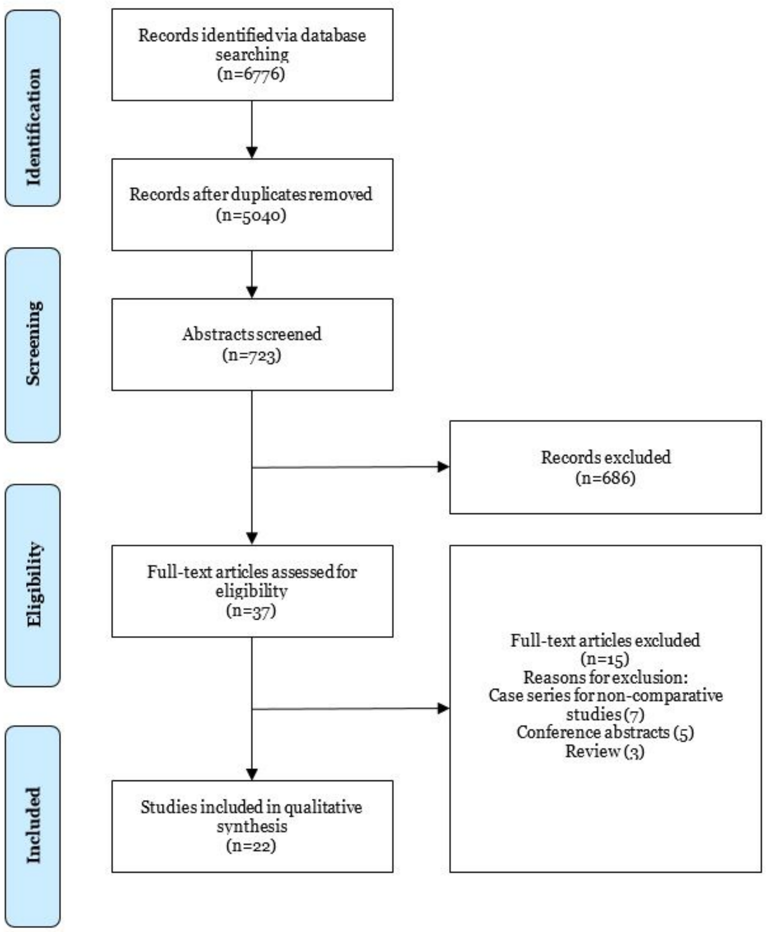


Figure 1

PRISMA flowchart of studies identified, screened, and included.

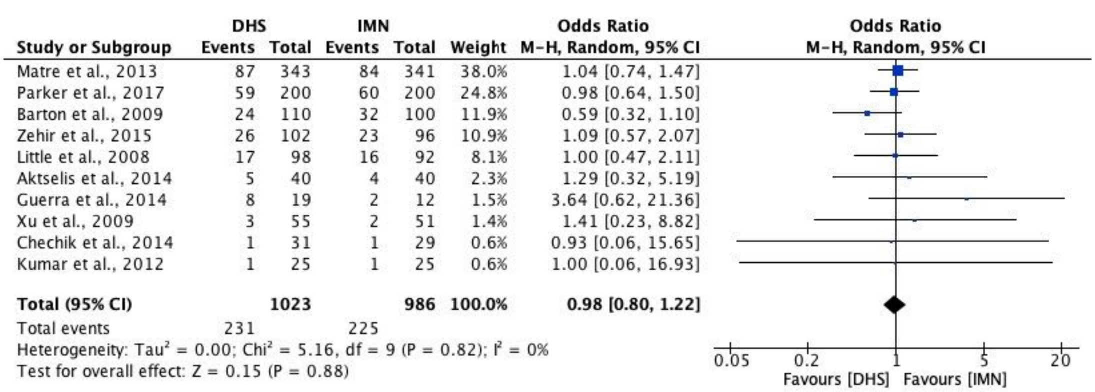
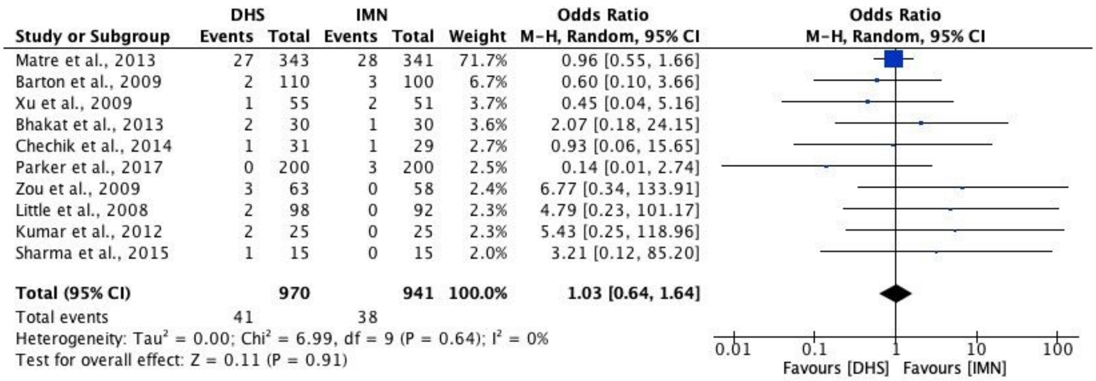


Figure 2

Meta-analysis of mortality rates between DHS and IMN

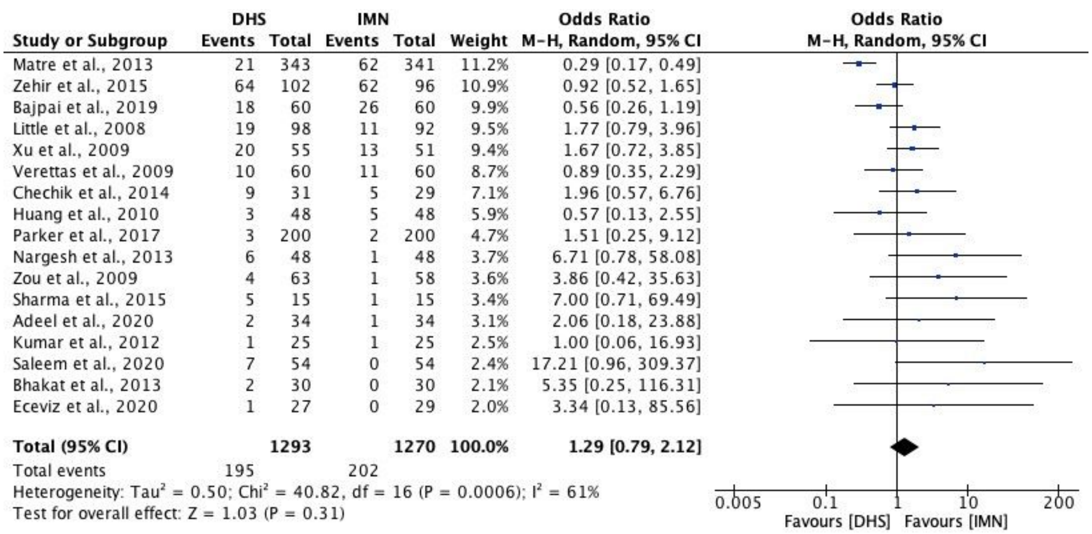


Study or Subgroup	DHS Events	DHS Total	IMN Events	IMN Total	Weight	Odds Ratio M-H, Random, 95% CI
Matre et al., 2013	27	343	28	341	71.7%	0.96 [0.55, 1.66]
Barton et al., 2009	2	110	3	100	6.7%	0.60 [0.10, 3.66]
Xu et al., 2009	1	55	2	51	3.7%	0.45 [0.04, 5.16]
Bhakat et al., 2013	2	30	1	30	3.6%	2.07 [0.18, 24.15]
Chechik et al., 2014	1	31	1	29	2.7%	0.93 [0.06, 15.65]
Parker et al., 2017	0	200	3	200	2.5%	0.14 [0.01, 2.74]
Zou et al., 2009	3	63	0	58	2.4%	6.77 [0.34, 133.91]
Little et al., 2008	2	98	0	92	2.3%	4.79 [0.23, 101.17]
Kumar et al., 2012	2	25	0	25	2.3%	5.43 [0.25, 118.96]
Sharma et al., 2015	1	15	0	15	2.0%	3.21 [0.12, 85.20]
Total (95% CI)		**970**		**941**	**100.0%**	**1.03 [0.64, 1.64]**
Total events	41		38			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 6.99$, df = 9 (P = 0.64); $I^2 = 0\%$
Test for overall effect: Z = 0.11 (P = 0.91)

Figure 3

Meta-analysis of re-operation rates between DHS and IMN

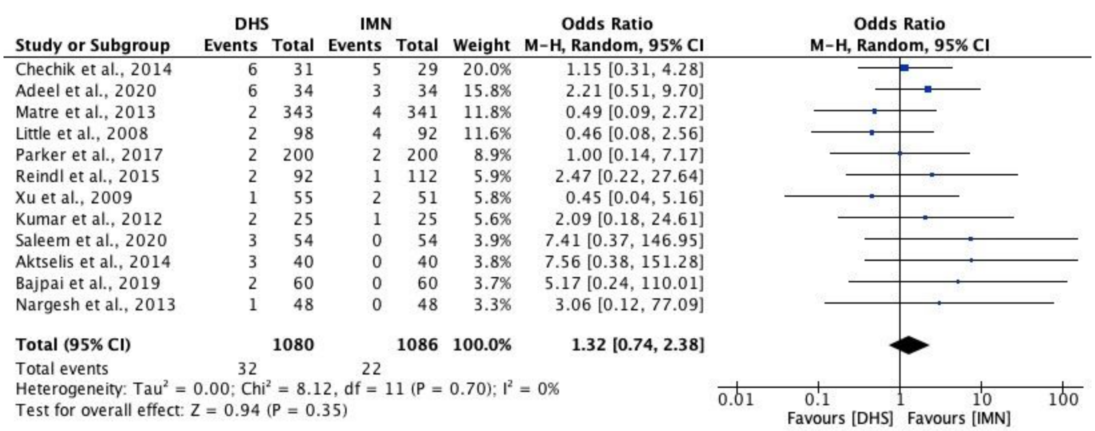


Study or Subgroup	DHS Events	DHS Total	IMN Events	IMN Total	Weight	Odds Ratio M-H, Random, 95% CI
Matre et al., 2013	21	343	62	341	11.2%	0.29 [0.17, 0.49]
Zehir et al., 2015	64	102	62	96	10.9%	0.92 [0.52, 1.65]
Bajpai et al., 2019	18	60	26	60	9.9%	0.56 [0.26, 1.19]
Little et al., 2008	19	98	11	92	9.5%	1.77 [0.79, 3.96]
Xu et al., 2009	20	55	13	51	9.4%	1.67 [0.72, 3.85]
Verettas et al., 2009	10	60	11	60	8.7%	0.89 [0.35, 2.29]
Chechik et al., 2014	9	31	5	29	7.1%	1.96 [0.57, 6.76]
Huang et al., 2010	3	48	5	48	5.9%	0.57 [0.13, 2.55]
Parker et al., 2017	3	200	2	200	4.7%	1.51 [0.25, 9.12]
Nargesh et al., 2013	6	48	1	48	3.7%	6.71 [0.78, 58.08]
Zou et al., 2009	4	63	1	58	3.6%	3.86 [0.42, 35.63]
Sharma et al., 2015	5	15	1	15	3.4%	7.00 [0.71, 69.49]
Adeel et al., 2020	2	34	1	34	3.1%	2.06 [0.18, 23.88]
Kumar et al., 2012	1	25	1	25	2.5%	1.00 [0.06, 16.93]
Saleem et al., 2020	7	54	0	54	2.4%	17.21 [0.96, 309.37]
Bhakat et al., 2013	2	30	0	30	2.1%	5.35 [0.25, 116.31]
Eceviz et al., 2020	1	27	0	29	2.0%	3.34 [0.13, 85.56]
Total (95% CI)		**1293**		**1270**	**100.0%**	**1.29 [0.79, 2.12]**
Total events	195		202			

Heterogeneity: $Tau^2 = 0.50$; $Chi^2 = 40.82$, df = 16 (P = 0.0006); $I^2 = 61\%$
Test for overall effect: Z = 1.03 (P = 0.31)

Figure 4

Meta-analysis of complication rates between DHS and IMN



Study or Subgroup	DHS Events	DHS Total	IMN Events	IMN Total	Weight	Odds Ratio M-H, Random, 95% CI
Chechik et al., 2014	6	31	5	29	20.0%	1.15 [0.31, 4.28]
Adeel et al., 2020	6	34	3	34	15.8%	2.21 [0.51, 9.70]
Matre et al., 2013	2	343	4	341	11.8%	0.49 [0.09, 2.72]
Little et al., 2008	2	98	4	92	11.6%	0.46 [0.08, 2.56]
Parker et al., 2017	2	200	2	200	8.9%	1.00 [0.14, 7.17]
Reindl et al., 2015	2	92	1	112	5.9%	2.47 [0.22, 27.64]
Xu et al., 2009	1	55	2	51	5.8%	0.45 [0.04, 5.16]
Kumar et al., 2012	2	25	1	25	5.6%	2.09 [0.18, 24.61]
Saleem et al., 2020	3	54	0	54	3.9%	7.41 [0.37, 146.95]
Aktselis et al., 2014	3	40	0	40	3.8%	7.56 [0.38, 151.28]
Bajpai et al., 2019	2	60	0	60	3.7%	5.17 [0.24, 110.01]
Nargesh et al., 2013	1	48	0	48	3.3%	3.06 [0.12, 77.09]
Total (95% CI)		**1080**		**1086**	**100.0%**	**1.32 [0.74, 2.38]**
Total events	32		22			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 8.12$, df = 11 (P = 0.70); $I^2 = 0\%$
Test for overall effect: Z = 0.94 (P = 0.35)

Figure 5

Meta-analysis of failure of fixation rates between DHS and IMN

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AppendixA.docx
- AppendixBPRISMAChecklist.docx