Meta-analysis of unipolar and bipolar hemiarthroplasty for femoral neck fractures

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Research Article

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Abstract

Background

Femoral neck fracture is a common fracture in the elderly. Improper treatment seriously impacts the patient and could potentially shorten their lifespan. Hemi-arthroplasty is a common treatment for femoral neck fractures, but the selection of unipolar prosthesis or bipolar prosthesis is still a controversial issue. Therefore, we conducted this comprehensive meta-analysis to compare the outcomes of unipolar and bipolar prostheses.

Methods

We searched the PubMed, EMbase, The Cochrane Library, and Web of Science databases for randomized controlled trials and cohort studies comparing unipolar hemiarthroplasty and bipolar hemiarthroplasty. The revised Jadad scale or Newcastle-Ottawa Scale was used to assess the quality of the included studies. After data extraction, continuous data were expressed as standardized mean differences and binary data were expressed as odds ratio. The postoperative infection, mortality, acetabular erosion rate, dislocation rate, and Harris hip score were compared and analyzed with Stata software.

Results

Nineteen studies that compared unipolar and bipolar replacement were included in the meta-analysis. We found no significant differences in the postoperative infection, mortality, dislocation rate, or Harris hip score between unipolar and bipolar replacement. The rate of acetabular erosion in the unipolar group was slightly higher than that in the bipolar group.

Conclusions

Existing studies have revealed that bipolar hemiarthroplasty is superior to unipolar hemiarthroplasty for femoral neck fractures in terms of acetabular erosion.

Background

Due to an aging population, femoral neck fractures have become a major medical and health care issue worldwide [1]. These types of fractures have a high morbidity and are commonly responsible for debility in the elderly. Moreover, femoral neck fractures are also an important risk for death in the elderly population. Although increasing documents on hip fractures have emerged, the optimal treatment remains uncertain [2].

A successful therapeutic regimen has a major impact on a patient's outcome. Long-term bed rest is required for non-surgical treatments, which can cause a variety of complications. Surgical treatments for femoral neck fractures mainly include internal fixation and joint replacement. Internal fixation is mostly used in young adults with good bone quality. However, a higher incidence of postoperative complications, associated with long-term dysfunction, is unavoidable in elderly patients undergoing internal fixation treatment. Thus, hip replacement, including total hip replacement and hemiarthroplasty, is the preferred treatment for femoral neck fractures in the elderly [3]. Hemiarthroplasty is the most common treatment for traumatic femoral neck fractures with dislocation in the elderly [4]. This method can eliminate osteonecrosis as a complication of femoral fractures and enables elderly patients to resume weight-bearing activities immediately, which helps avoid complications due to prolonged inactivity [5].

Hemiarthroplasty includes unipolar replacement and bipolar replacement. A unipolar prosthesis is characterized by its lower cost, but it can easily cause acetabular wear, which increases the risk of acetabular erosion. In contrast, a bipolar prosthesis is designed to move on the internal bearing and articulate with the joint on the prosthetic acetabulum interface. Therefore, the

use of a bipolar prosthesis can reduce acetabular wear and thereby reduce the rate of acetabular erosion and pain [5]. However, there is no consensus on whether the use of bipolar prostheses, with their higher cost, can bring about better functional outcomes and quality of life compared to unipolar prostheses. Similarly, a dispute on the decision to use unipolar or bipolar prostheses for hemiarthroplasty still exists.

This meta-analysis included randomized controlled trials (RCTs) and cohort studies published in the past 10 years, and comprehensively compared unipolar and bipolar prostheses for hemiarthroplasty from the multiple aspects of mortality, postoperative infection, and acetabular erosion to determine which of these treatment protocols provides the optimal outcomes. It is expected that this study can provide reliable evidence-based medicine support for the clinical treatment of femoral neck fractures.

Methods

This meta-analysis was designed and performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines[6], with no need for ethical approval and written informed consent from patients because all analyses in this study were based on the results of existing studies.

Search strategy

We searched the PubMed, EMbase, The Cochrane Library, and Web of Science databases using the search terms “hemiarthroplasty” and “femoral neck fractures” for literature published from January 1, 2010 to July 2, 2020 comparing unipolar and bipolar prostheses for hemiarthroplasty. In addition, the reference lists of the literature meeting the inclusion and exclusion criteria were also manually searched.

Inclusion criteria and exclusion criteria

Inclusion criteria included: (1) RCTs and cohort studies in the past 10 years; (2) patients over 55 years old with femoral neck fractures; (3) unipolar and bipolar prostheses for hemiarthroplasty; (4) documentation of at least one of the following outcomes: Harris hip score (HHS), mortality, postoperative infection, or acetabular erosion; and (5) includes authentic and credible literature data available as, or that could be converted into, binary variables or continuous variables to represent various indicators. Exclusion criteria included: (1) animal research; (2) non-English literature; (3) research that could not be extracted or converted into valid data; (4) non-controlled trials; and (5) conference abstracts without full text.

Study selection

All included studies were independently assessed by two researchers(Xiaoming Dong and Wei Li) in the order of duplication, reading title, abstract, and full text to determine whether the literature was to be included in the meta-analysis. A cross-check was then conducted. Disagreement was resolved by discussion with the third researcher(Wenrui Qu) until an agreement was reached.

Potential effect modifiers and reasons for heterogeneity

Potential effect modifiers were identified as demographic and characteristic differences in subjects, such as patient age, between studies, as well as differences in study design, including the follow-up time.

Study quality assessment

Two researchers(Xiaoming Dong and Wei Li) independently assessed the quality of the included RCTs using the modified Jadad scale; scores below 4 indicated low quality. Included cohort studies were assessed using the Newcastle-Ottawa Scale, with scores below 5 indicating low quality. Disagreement was resolved by discussion with the third researcher(Wenrui Qu).

Data extraction strategy

The two researchers(Xiaoming Dong and Wenrui Qu) independently extracted data from the included studies, followed by cross-checking. Divergent opinions were resolved by discussion with the third researcher(Meng Xu). If necessary, we contacted the original author via email to obtain the necessary data.

The following data were extracted from the included studies: the name of the main authors, year of publication, type of study, number of patients, mean age, sex ratio, and follow-up time. Outcomes included the HHS score, mortality, postoperative infection rate, and acetabular erosion rate.

If the included studies had incomplete or unclear data, attempts were made to contact the corresponding authors for original findings, but we did not receive a response from any of the requests. In some cases, the standard deviation (SD) was not given; again, we attempted to contact the corresponding authors but received no response. Then, we used range or median for estimation or used the method described in the Cochrane Intervention Manual Systematic Evaluation Manual to convert and estimate from the confidence interval (CI).

Study outcomes

Acetabular erosion rate: The acetabular erosion rate is a primary outcome for evaluating postoperative adverse events. Acetabular erosion is evaluated by imaging findings. In this study, the acetabular erosion rate of patients in the unipolar and bipolar groups was compared within 1 year postoperatively.

Postoperative infection rate: Postoperative infections are a common postoperative complication. Various treatment options impact operation time and blood loss differently, which may result in different rates of postoperative infections. This study compared the postoperative infection rate between the unipolar and bipolar groups at 6 months, 12 months, and > 12 months postoperatively.

Mortality: Death is the most serious complication of any disease. Elderly patients with femoral neck fractures often die from a surgical trauma. In this study, we compared the mortality rate of unipolar and bipolar groups at 6 months, 1 year, and 2 years postoperatively.

Dislocation rate: Dislocation is a common adverse event after prosthesis replacement and is the main reason for reoperation. In this study, we compared the dislocation rate of unipolar and bipolar groups at the last follow-up visit.

HHS: The HHS score is a widely-used method to evaluate hip function and is also an important indicator for assessing the outcomes of hip replacement. This study compared the HHS scores of unipolar and bipolar groups at the last follow-up visit.

Data synthesis and presentation

Stata software (STATA 15.1 (Stata Corp LP, College Station, TX)) was used to conduct a meta-analysis of the included studies, in which the binary variable data were expressed as the odds ratio (OR), and continuous variable data were expressed as standardized mean differences (SMD). Each effect size was given as a point estimate and its 95% CI. Heterogeneity for each study was assessed using a chi-square test (significance level was set at $P = 0.1$), and the I^2 statistic (significance level was set at $I^2 = 50\%$). If there was no heterogeneity between the studies, a fixed effects model was selected for statistical analysis. On the contrary,when we needed to determine the origins of heterogeneity, a random effects model was selected for meta-analysis. If required, a sensitivity analysis and subgroup analysis were performed to find the sources of heterogeneity. If at least 10 articles met the inclusion criteria, we planned to use a funnel plot to assess publication bias.

Results

Search results

We initially included 2559 articles from the database search and 1 from the manual search (Fig. 1). After the removal of duplicated documents (n = 1088), 1472 articles were included. After reading the title and abstract, 39 articles were included for

full-text reading, among which, the articles by by Hedbeck [11] in 2011 and Inngul et al. [12] in 2013 focused on the same experimental study, with the measurement of the indicators at different time nodes. Therefore, these two articles were included for final analysis. A total of 19 eligible articles [5, 7–24] involving 3149 patients were finally included in this meta-analysis. The basic information and quality of the included studies are shown in Table 1.

Table 1
Main characteristics of all eligible studies included in the analysis.

Author,Year	**Research Type**	**Numbers (Unipolar / Bipolar)**	**Mean Age (Unipolar / Bipolar)**	**Male(numbers) (Unipolar / Bipolar)**	**Follow up(months) (Unipolar / Bipolar)**	**Jadad/NOS**
Abdelkhalek,M.[2011]	RCT	25/25	63.5	16	52.8	1[□]
Ayhan,E[2014]	CS	81/63	77.679/78.873	35/17	32.52/18.52	6[§]
Bauer,S.[2010]	CS	206/97	85/78	42/21	6	5[§]
Enocson,A.[2011]	CS	427/403	86.1/81.8	126/95	-	7[§]
Figved,W.[2018]	RCT	14/14	81/80	3/3	24	6[□]
Hedbeck,C[2011]	RCT	60/60	87.4/85.5	11/18	12	6[□]
Inngul,C.[2013]	RCT	60/60	87.4/85.5	11/18	48	6[□]
Jain,V.[2016]	RCT	1918	67/69	-	6	4[□]
Jeffcote,B.[2010]	RCT	27/24	81.4/80.1	6/6	24	6[□]
Kanto,K.[2014]	RCT	88/87	-	-	60	7[□]
Lin,C.C.[2012]	CS	62/58	88.73/86.83	25/20	60	6[§]
Mishra,A.K.[2013]	CS	20/20	72.2/65	8/9	12	3[§]
Prasad,V.N.K.[2015]	CS	15/15	72.2/65.3	6/5	12	4[§]
Sabnis,B.M.[2011]	CS	433/274	-	86/62	4	3[§]
Shah,S.W.A.[2019]	CS	30/30	-	21/21	6	4[§]
Somashekar[2013]	CS	20/21	75.6/67.3	11/3	12	4[§]
Stoffel,K.K.[2013]	RCT	128/133	-	-	12	7[□]
Zacharia,B.[2018]	CS	29/19	69.07/68.21	-	8	4[§]
Krishna,KatragaddaSai[2015]	CS	52/52	69.1/70.4	-	12	4[§]
RCT: randomized controlled trials,CS:ohort studies ,□:Cohort Study NOS Score,§:RCT study modified Jadad score						

Figure 1. Flowchart of selection of studies.

Table 1. Main characteristics of all eligible studies included in the analysis.

RCT: randomized controlled trials,CS:ohort studies ,□:Cohort Study NOS Score,§:RCT study modified Jadad score

Outcome results

Acetabular erosion rate

A total of 6 studies reported the acetabular erosion rate [5, 13, 18, 19, 22, 24]; among the 503 cases, 256 cases belonged in the unipolar group and 247 cases in the bipolar group. Considering that $I^2 = 0\%$, the fixed effects model was used. The rate of acetabular erosion in the unipolar group was significantly higher than that in the bipolar group [OR = 5.211, 95% CI (1.935–14.035); P = 0.001]. Therefore, bipolar hemiarthroplasty was superior to unipolar hemiarthroplasty in terms of the acetabular erosion rate (Fig. 2).

Figure 2. Forest plot for Acetabular erosion rate

Postoperative infection rate

A total of 9 studies reported the postoperative infection rate [5, 12, 14, 15, 17, 19, 21–23], including 824 cases, of which 413 cases were in the unipolar group and 411 cases in the bipolar group. Two of the nine studies reported the infection rate at 6 months postoperatively, five studies reported the infection rate at 12 months postoperatively, and two studies reported the infection rate more than 12 months postoperatively. We performed a subgroup analysis of the postoperative infection rate at different postoperative times. Considering the value of $I^2 = 0\%$, the fixed effects model was used; there was no significant difference in the postoperative infection rate between the two groups at different postoperative times [OR = 1.056, 95% CI (0.626–1.782); $P = 0.838 > 0.05$].(Fig. 3)

Figure 3. Forest plot for Postoperative infection rate

Mortality

A total of 10 studies reported the mortality rate [8, 10, 11, 15–17, 22–24], including 1687 cases, of which 990 cases were in the unipolar group and 697 cases in the bipolar group. We analyzed the mortality in the following postoperative periods: less than 6 months, 12 months, and more than 24 months(Fig. 4). Considering $I^2 > 50\%$, the random effects model was used; there was no statistical difference in the mortality between the two groups [OR = 1.244, 95% CI (0.831–1.864); $P = 0.289 > 0.1$]. The studies by Sabnis, BM and Brenkel, IJ [20] were removed for the sensitivity analysis, and we found the value of $I^2 = 24.5\%$. The conclusion remained unchanged.

Figure 4. Forest plot for Mortality

Dislocation rate

A total of 8 studies reported the dislocation rate [5, 10, 12, 14, 16, 17, 22, 23], including 1688 cases, comprising 856 cases in the unipolar group and 832 cases in the bipolar group. We performed the statistical analysis of the dislocation rate at the last follow-up visit. The value of $I^2 = 0\%$ indicated no heterogeneity, and the fixed effects model was used. Results from the forest plots revealed no significant difference in the dislocation rate between the two groups [OR = 1.416, 95% CI (0.813–2.465); $P = 0.219 > 0.1$] (Fig. 5).

Figure 5. Forest plot for Dislocation rate

HHS score

A total of 10 studies reported the HHS score [7, 8, 13, 14, 18, 19, 21–24], among which the study by Shah et al. and Zacharia et al. described multi-categorical variables, and the remaining 8 studies described continuous variables. The eight studies with continuous variables included 723 cases (368 in the unipolar group and 355 in the bipolar group), which were analyzed for the

HHS score at the last follow-up(Fig. 6). The value of $I^2 > 50\%$ indicated a heterogeneity, and the random effects model was used. Sensitivity analysis and subgroup analysis were conducted to determine the source of heterogeneity, but neither indicated the source of the heterogeneity. There was no significant difference in the HHS score at the last follow-up between the two groups [SMD = -0.035, 95% CI (-0.330–0.260), P = 0.816].

Figure 6. Forest plot for HHS

Discussion

This study pooled the data from RCTs and cohort studies related to unipolar and bipolar hemiarthroplasty in the past 10 years. We found that compared with unipolar hemiarthroplasty, bipolar hemiarthroplasty resulted in a lower acetabular wear rate, but there were no significant differences in the postoperative infection rate, mortality, dislocation rate, and HHS score between the two groups.

Femoral neck fracture is a common injury in middle-aged and elderly patients in plastic surgery, with a high incidence of mortality. Patients with femoral neck fracture present with hip pain and an inability to stand and walk. Moreover, these fractures may induce avascular necrosis of the femoral head, causing serious functional disorder and even disability in severe cases [25–27]. Internal fixation is a common treatment for femoral neck fracture, as it is characterized by its shorter operation time and decreased intraoperative blood loss [28, 29]. However, this treatment is often related to a higher incidence of non-healing and vascular necrosis. To avoid these adverse events, hip replacement is an attractive alternative [30]. Although hip replacement has been shown to have a high revision rate, it is the most feasible treatment for elderly patients with femoral neck fractures [5]. Compared with total hip replacement, hemiarthroplasty has the advantages of being a simple operation, with a shorter operation time, less blood loss, and a lower initial cost. Hemiarthroplasty is mostly used in clinical practice. Patients undergoing hemiarthroplasty can resume weight-bearing activities immediately after surgery. However, there is still considerable controversy regarding the choice of prosthesis for hemiarthroplasty. Unipolar hemiarthroplasty has a lower cost and no risk of polyethylene wear debris, but it is prone to acetabular wear. Bipolar prosthesis can reduce acetabular wear, thereby reducing the incidence of acetabular erosion, but it may cause infection due to polyethylene debris and has a higher cost. This lack of consensus on the selection of unipolar or bipolar prosthesis precipitated this study. It is necessary to update the literature using the latest publications and to compare the postoperative infection rate, mortality, acetabular erosion rate, dislocation rate, and HHS score between the unipolar and bipolar prosthesis, followed by statistical analysis, to determine the optimal treatment method.

Acetabular erosion is an important cause of revision. In order to compare the acetabular erosion rate of the unipolar and bipolar groups, a statistical analysis of the 1-year indicators described in five studies was conducted. This analysis found that the rate of acetabular erosion in the unipolar group was significantly higher than that in the bipolar group. These results are consistent with the findings of Inngul et al. and Mishra et al. [5, 13, 18, 19, 22, 24], which is also the cause of introducing bipolar prosthesis into the treatment of femoral neck fractures. This treatment can be used as a solution for acetabular erosion. Theoretically, the use of bipolar prosthesis decreases acetabular wear and reduces the dislocation rate of the dual support system. The additional weight-bearing joint will undertake some friction transferred from the weight-bearing joint, thereby reducing the incidence of prosthetic arthritis due to the wear of metal on the cartilage [30], and also reducing the risk of reoperation [31]. Less acetabular wear can lead to better hip function and reduced pain.

To evaluate the postoperative infection rate, we compared the infection rates of the unipolar group and the bipolar group at 6 months, 1 year, and more than 1 year after surgery. There was no statistically significant difference between the unipolar and bipolar groups in terms of the postoperative infection rate, as confirmed by Hedbeck et al. [12]. Therefore, polyethylene debris cannot induce a high infection rate. Generally, it has a certain relationship between the patient’s physique and the nature of the disease, and no differences were found between unipolar and bipolar hemiarthroplasty.

Mortality is the most serious complication. Elderly patients with femoral neck fracture often die from surgical trauma. In this study, we compared the mortality of patients at 6 months, 1 year, and 2 years between the unipolar and bipolar groups, and the

findings indicated heterogeneity. A sensitivity analysis was conducted to determine the source of heterogeneity. We removed the studies by Sabnis et al. and Brenkel et al. in the meta-analysis, and the heterogeneity was significantly reduced, possibly because the small sample size caused a deviation in the experimental results. There was no statistically significant difference in the mortality between the unipolar and bipolar groups, which is consistent with the findings of many studies [8, 10, 11, 15–17, 22–24].

Traditionally, acetabular erosion is considered to be a potential risk factor for dislocation and functional decline. However, in this study, even though we found that the acetabular erosion rate was higher in the unipolar group than in the bipolar group, and the dislocation rate and HHS score showed no statistical difference between the groups, which was inconsistent with the previous associative theory. This may be related to the length of follow-up. Perhaps, the difference in dislocation and HHS scores between the two groups had not yet been shown in the relatively shorter follow-up period. Further investigation on relevant RCTs with long follow-ups is required.

Based on the current research, we found that the postoperative infection rate, mortality, dislocation rate, and HHS score were not statistically different between the unipolar and bipolar groups, while the acetabular erosion rate was higher in the unipolar group than in the unipolar group, indicating a higher acetabular erosion rate related to unipolar hemiarthroplasty compared with that in than bipolar hemiarthroplasty. Although acetabular erosion is an important cause of clinical pain and dislocation, there was no significant difference in the HHS score and dislocation rate between the two groups in this study. Mild physical pain induced by acetabular erosion, in this study, had not yet triggered the functional decline and dislocation in a relatively short follow-up period. Therefore, we can consider predicting patient's lifespan to determine the prosthesis in patients with femoral head fractures. If the life expectancy is short, a unipolar prosthesis is preferred. Despite a higher rate of acetabular erosion, unipolar prosthesis has no impact on dislocation and hip function, and greatly reduces the treatment cost. If the life expectancy is long, a bipolar prosthesis can be considered, which can effectively reduce acetabular erosion, thereby avoiding the risk of dislocation and functional decline [32].

Strengths

This study formulated strict inclusion and exclusion criteria and obtained abundant primary documents by including both cohort studies and RCTs. Furthermore, we only extracted and analyzed relevant literature published in the past 10 years, with no impact of the large gap between medical conditions and prosthetic treatment methods and choices in the early stage.

Limitations

There are limitations in this study, however, which should be acknowledged. In the studies that described the HHS score, no source of heterogeneity was found. In addition, no long-term follow-ups were described in the available literature included in the meta-analysis; therefore, it is impossible to evaluate the difference in HHS scores and dislocation rates between unipolar and bipolar groups during long-term follow-ups.

Conclusion

This study indicated that bipolar hemiarthroplasty for femoral head fractures has advantages over unipolar hemiarthroplasty in terms of acetabular erosion, with no significant differences in any of the other analyzed indicators. Therefore, barring other considerations, bipolar hemiarthroplasty is superior to unipolar hemiarthroplasty.

Abbreviations

randomized controlled trials (RCTs)

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

Harris hip score (HHS)

standard deviation (SD)

confidence interval (CI)

odds ratio (OR)

standardized mean differences (SMD)

Declarations

Ethics Approval and consent to participate

As the study was a meta-analysis based on the existing population-based studies, we did not apply for the approval of institutional review board.

Consent for publication

Not applicable.

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Authors' contributions

All authors participated in the literature search, assessment of bias, and data analysis.
XD and WL participated in the design of this study, both developed and performed the statistical analysis.WQ collected important background information, critically reviewed the study proposal, and drafted the manuscript. MX participated in the design and development of the study, as well as helped to draft the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

he datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests

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Figures

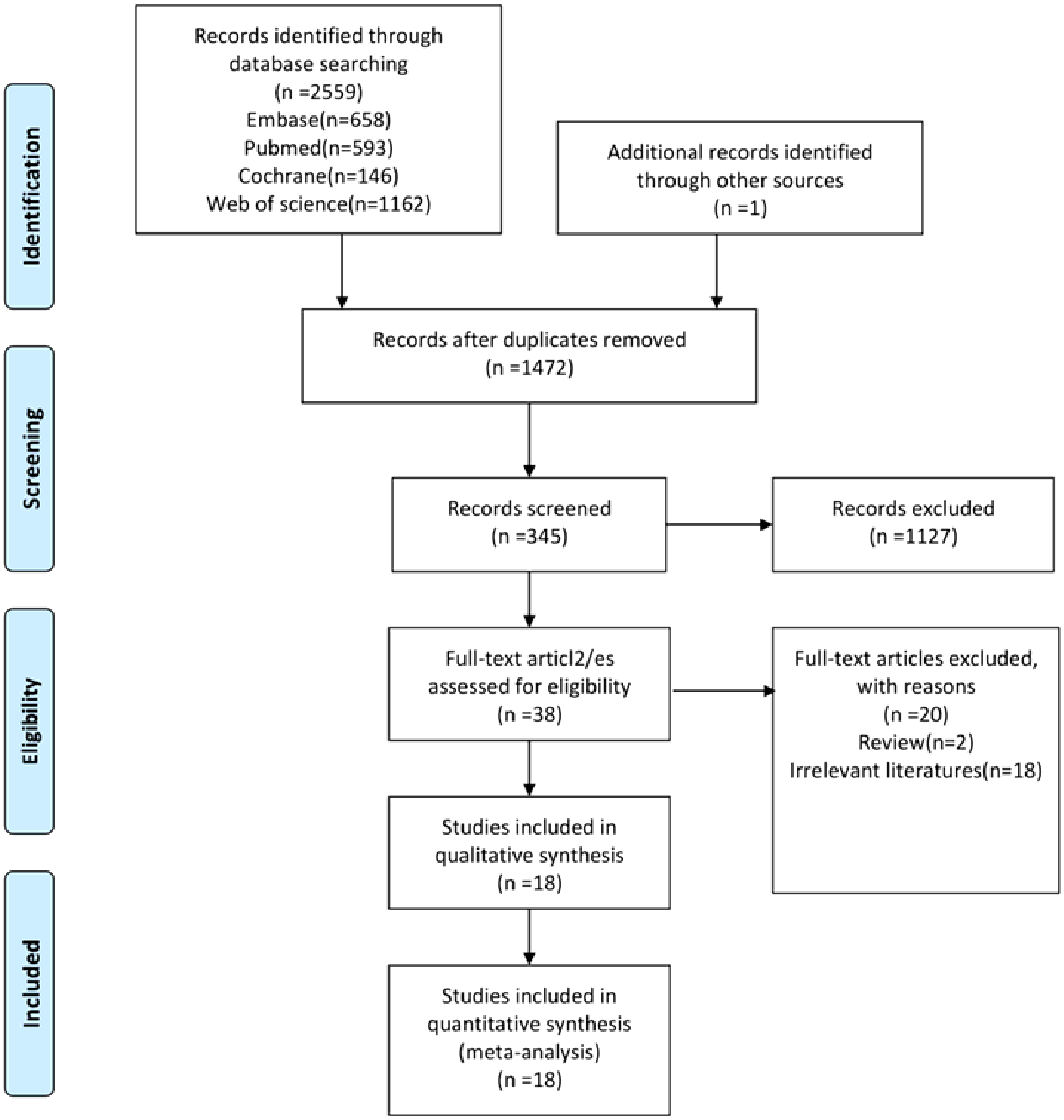

Figure 1

Flowchart of selection of studies.

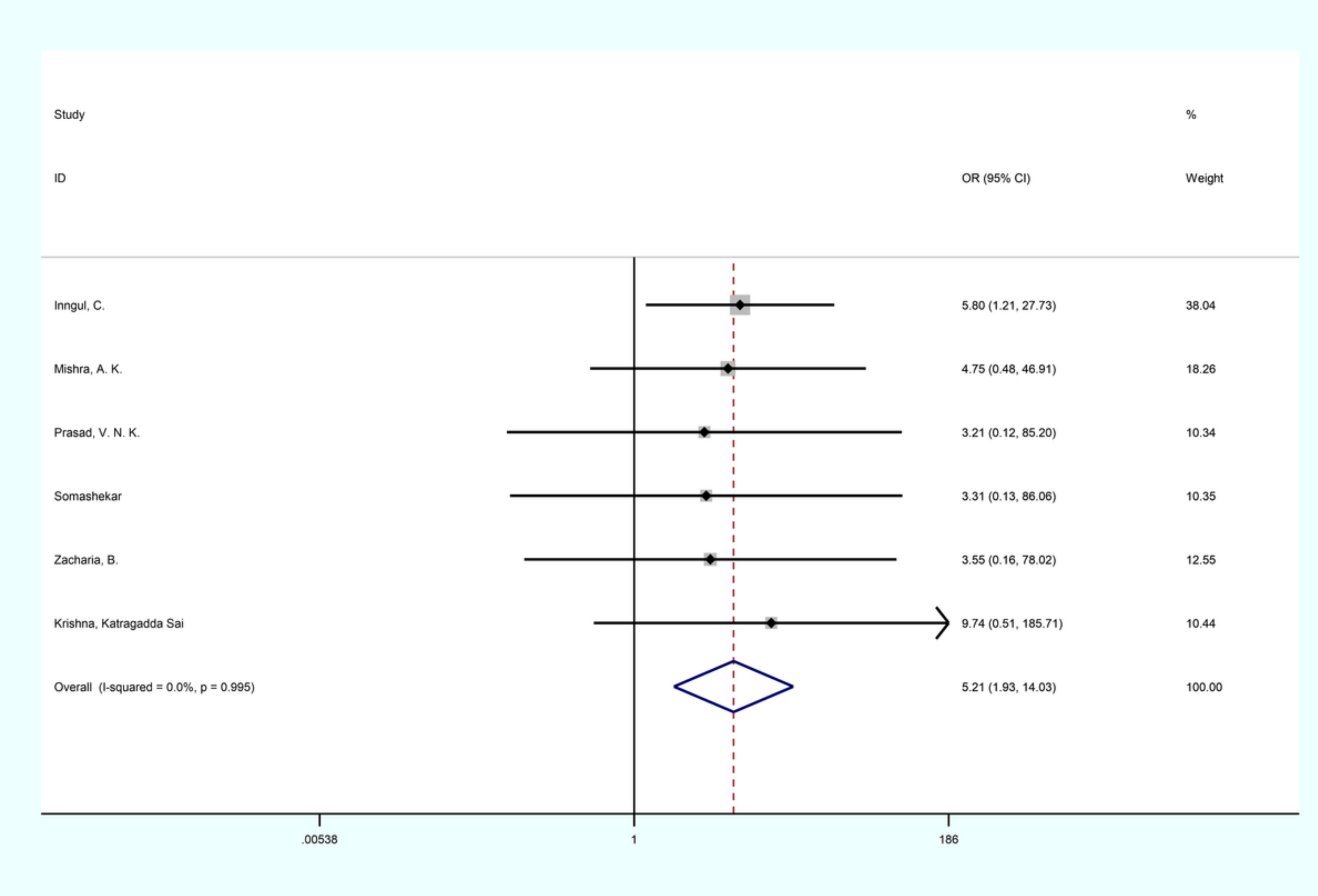

Figure 2

Forest plot for Acetabular erosion rate

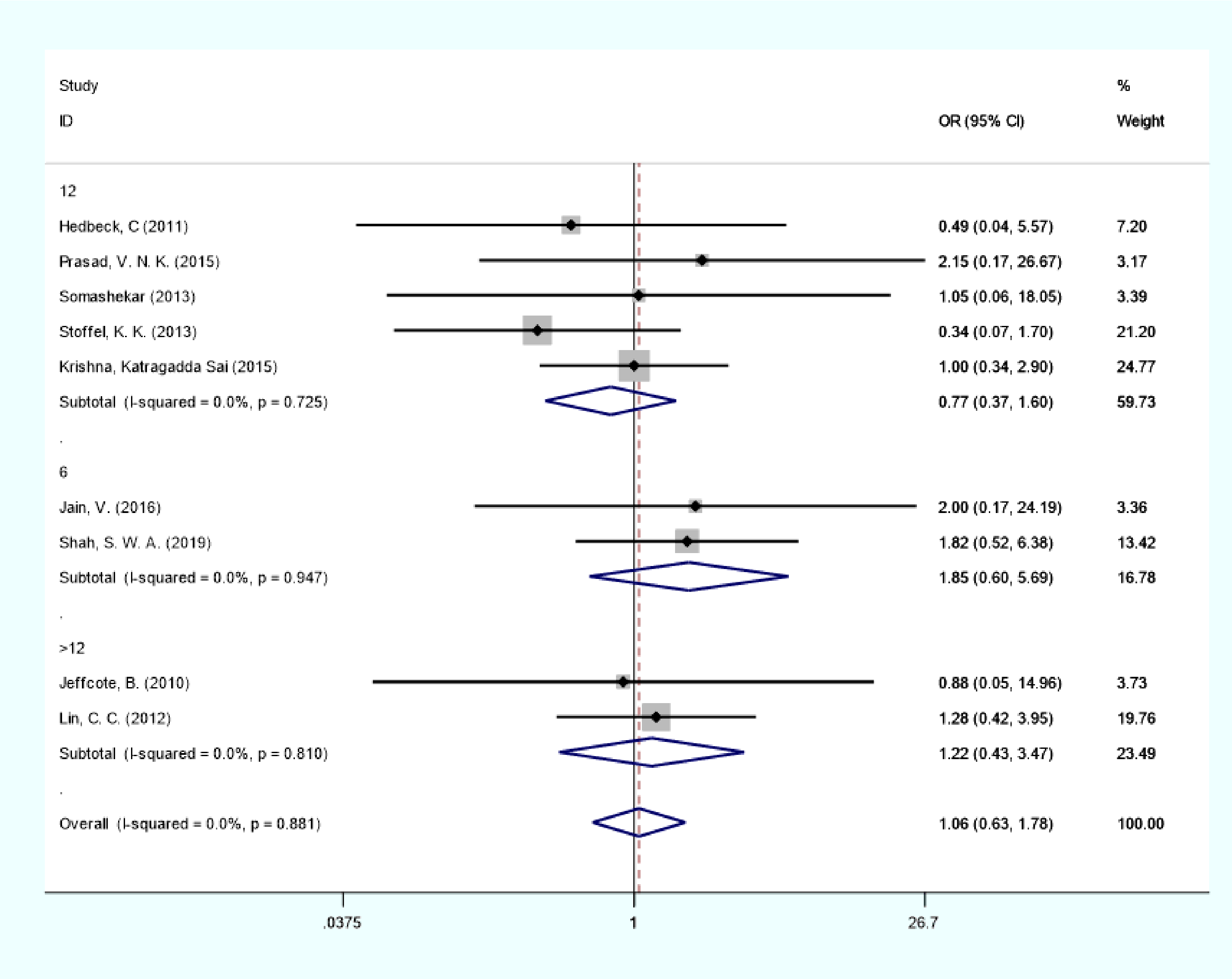

Figure 3

Forest plot for Postoperative infection rate

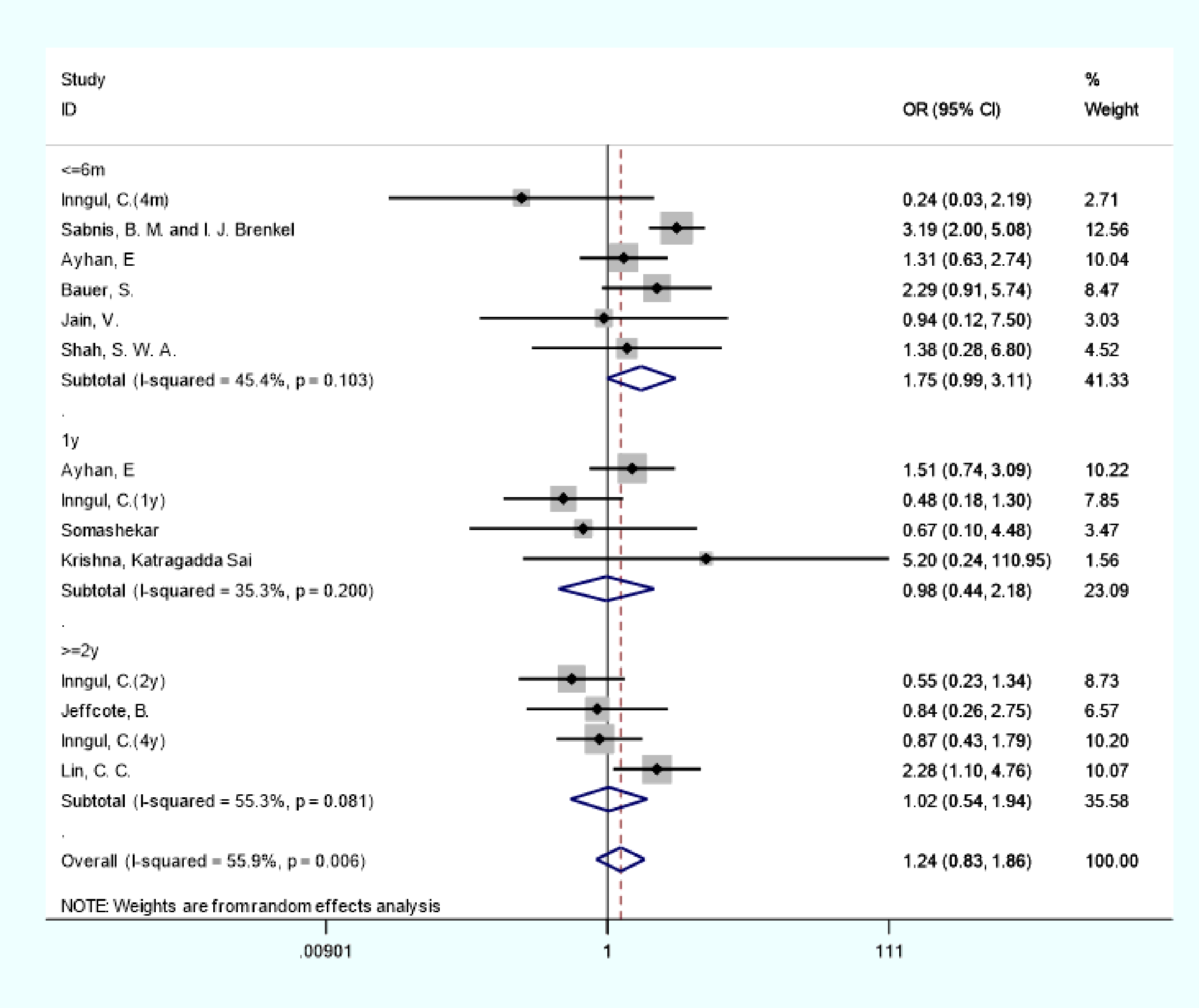

Figure 4

Forest plot for Mortality

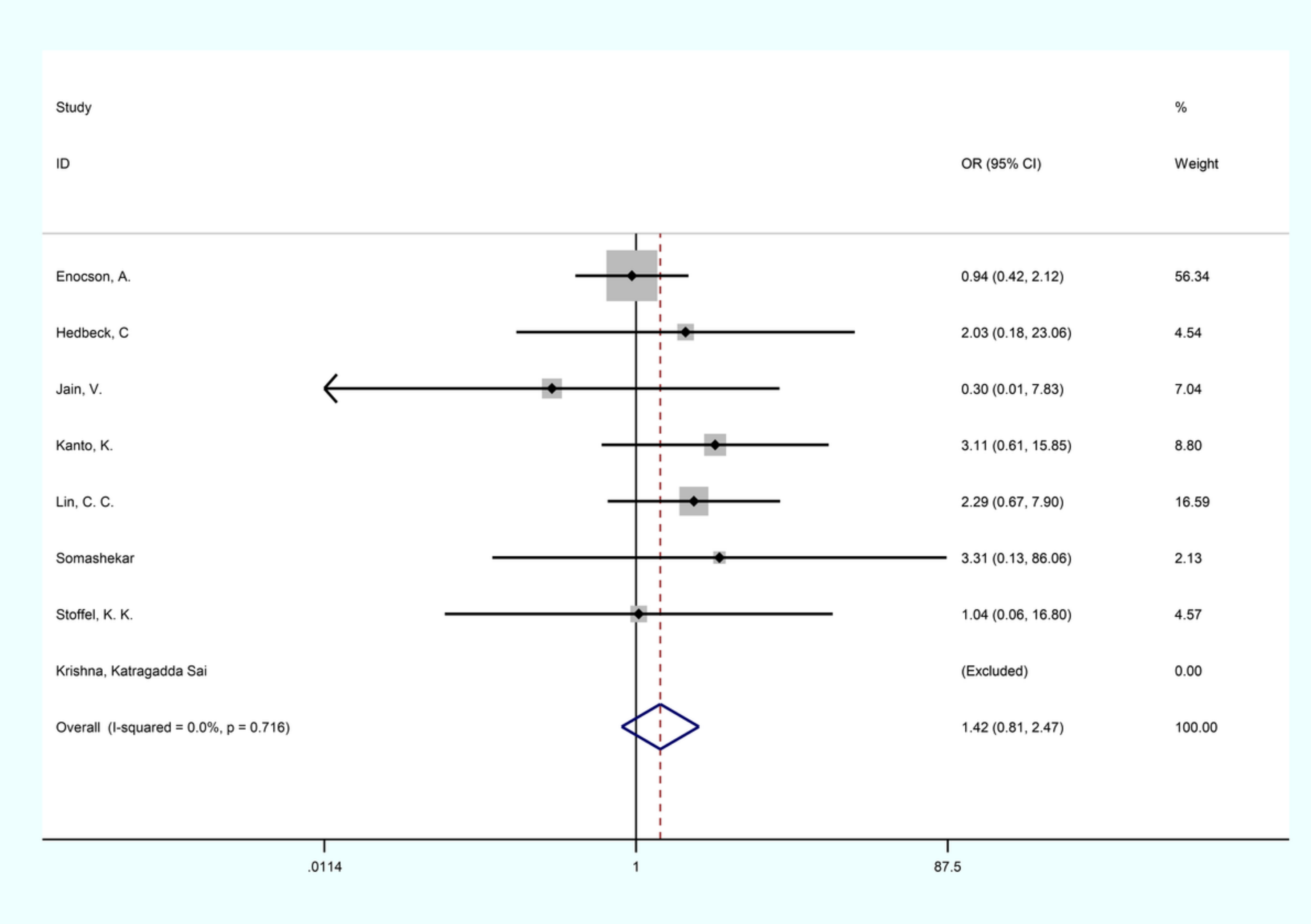

Figure 5

Forest plot for Dislocation rate

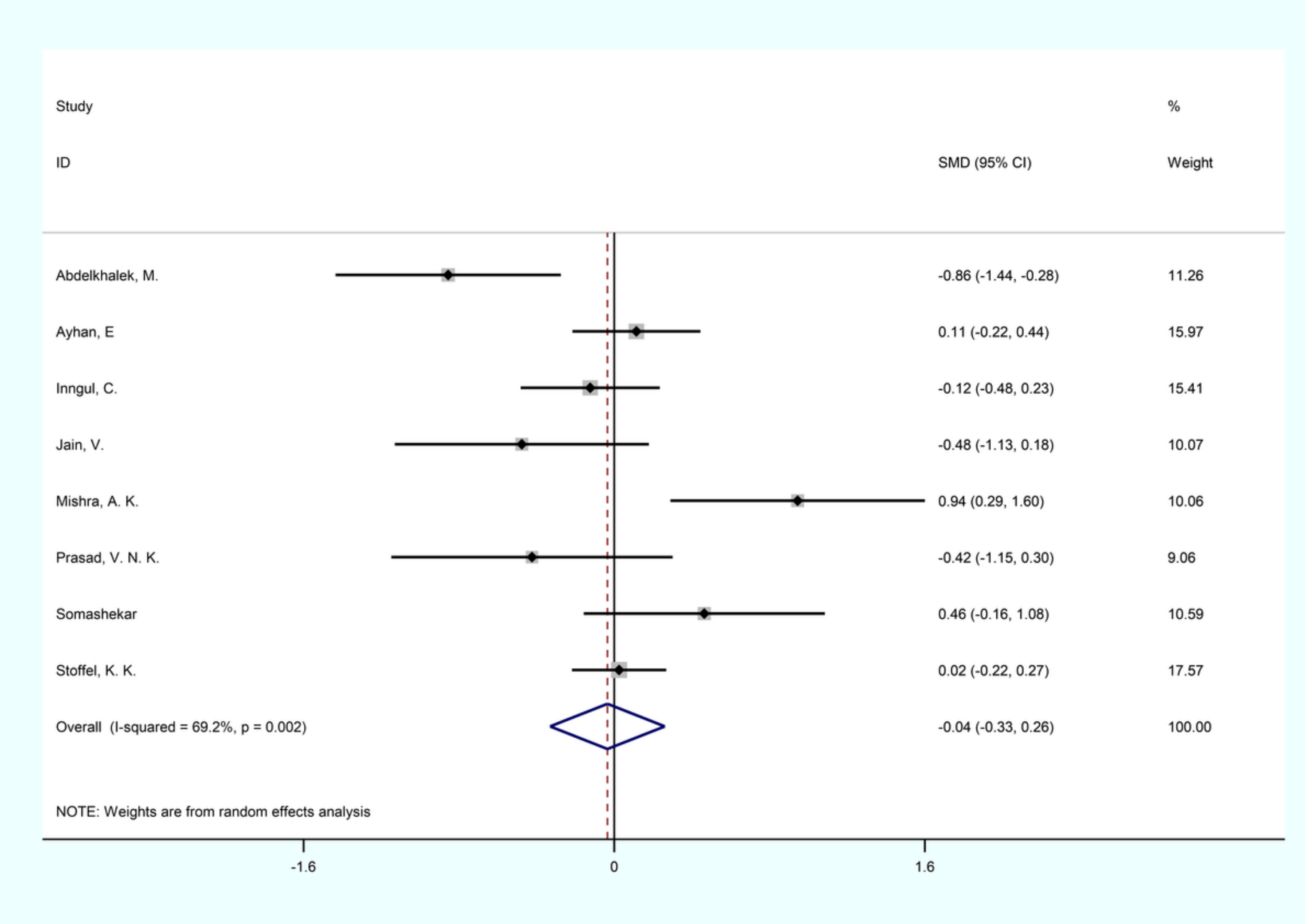

Figure 6

Forest plot for HHS

Supplementary Files

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

- PRISMAChecklist.doc