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KNEE ARTHROPLASTY

Does unicompartmental knee arthroplasty have worse outcomes in spontaneous osteonecrosis of the knee than in medial compartment osteoarthritis? A systematic review and meta-analysis

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Abstract

Introduction The role of unicompartmental knee arthroplasty (UKA) in spontaneous osteonecrosis of the knee (SONK) remains controversial, even though SONK involves only one compartment of the knee joint. We aimed to compare the survival rate and clinical outcomes of UKA in SONK and medial compartment osteoarthritis (MOA) via a meta-analysis of previous studies.

Materials and methods MEDLINE, Embase, and Cochrane Library were searched up to January 2018 with keywords related to SONK and knee arthroplasty. Studies were selected with predetermined inclusion criteria: (1) medial UKA as the primary procedure, (2) reporting implant survival or clinical outcomes of osteonecrosis and osteoarthritis, and (3) follow-up period > 1 year. Quality assessment was performed using the risk of bias assessment tool for non-randomized studies. A random-effects model was used to estimate the pooled relative risk (RR) and standardized mean difference.

Results The incidence of UKA revision for any reason was significantly higher in SONK than in MOA group (pooled RR = 1.83, $p = 0.009$). However, the risk of revision due to aseptic loosening was not significantly different between the groups. Moreover, when stratified by the study quality, high-quality studies showed similar risk of overall revision in SONK and MOA ($p = 0.71$). Subgroup analysis revealed no significant difference in failure between SONK and MOA after cemented mobile and fixed bearing UKA. Results of uncemented UKA were reported only in one study, which showed higher failure of SONK compared to MOA. Clinical outcomes after UKA were similar between SONK and MOA ($p = 0.66$).

Conclusions Cemented UKA has similar survival and clinical outcomes in SONK and MOA. Prospective studies designed specifically to compare the UKA outcomes in SONK and MOA are necessary.

Keywords Knee · Osteoarthritis · Arthroplasty · Unicompartmental knee arthroplasty · Unicondylar knee arthroplasty · Spontaneous osteonecrosis of the knee

Introduction

Spontaneous osteonecrosis of the knee (SONK) is a relatively common pathology that occurs in 9.4% of patients older than 65 years [1]. SONK is considered a consequence of insufficiency fractures combined with necrosis of the

Chan Yoon and Moon Jong Chang contributed equally to this work.

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surrounding bone, which leads to subchondral collapse and arthritis [2, 3]. Because it usually affects only medial condyles, it is considered an indication for unicompartmental knee arthroplasty (UKA). However, some studies reported inferior outcomes of UKA compared to those of total knee arthroplasty (TKA) in SONK [4, 5].

In patients with SONK, the relatively small amount of bone cutting in UKA may result in osteonecrotic portion exposure. Worse outcomes of UKA than of TKA in patients with SONK might be a consequence of poor bone bed for fixation. Although UKA has shown good outcomes in medial compartment osteoarthritis [6], the role of UKA in SONK is still unclear. Some studies reported worse outcomes of UKA in SONK than in medial osteoarthritis (MOA) [7, 8]. However, the outcomes of UKA in SONK compared to MOA are controversial, because several studies reported similar survival rates and clinical outcomes of the two groups [9–13]. To the best of our knowledge, no systematic review or a meta-analysis has been performed on this issue yet. Therefore, the present study aimed to compare the survival rate and clinical outcomes of UKA between patients with SONK and those with MOA via a meta-analysis of previous studies. We hypothesized worse survival rate and clinical outcomes of UKA in SONK than in MOA.

Materials and methods

This meta-analysis was designed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [14]. We reviewed studies published in peer-reviewed journals to compare the outcomes of UKA between SONK and MOA. Our protocol was registered in PROSPERO, an international prospective register of systematic reviews (CRD42018086726).

Literature search

MEDLINE database, Embase database, and Cochrane Library were searched up to January 16, 2018 with keywords related to SONK and knee arthroplasty using the following search strategy (Supplement for more details):

(((“Arthroplasty, Replacement, Knee” [Mesh]) OR ((“Arthroplasty, Replacement, Knee” [TW] OR “Arthroplasties, Replacement, Knee” [TW] OR “Arthroplasty, Knee Replacement” [TW] OR “Knee Replacement Arthroplasties” [TW] OR “Knee Replacement Arthroplasty” [TW] OR “Replacement Arthroplasties, Knee” [TW] OR “Knee Arthroplasty, Total” [TW] OR “Arthroplasty, Total Knee” [TW] OR “Total Knee Arthroplasty” [TW] OR “Replacement, Total Knee” [TW] OR “Total Knee Replacement” [TW] OR “Knee Replacement, Total” [TW] OR “Knee Arthroplasty” [TW] OR “Arthroplasty, Knee” [TW] OR “Arthroplasties, Knee Replacement” [TW] OR “Replacement Arthroplasty, Knee” [TW] OR “Arthroplasty, Replacement, Partial Knee“[TW] OR “Unicompartmental Knee Arthroplasty” [TW] OR “Arthroplasty, Unicompartmental Knee” [TW] OR “Knee Arthroplasty, Unicompartmental” [TW] OR “Unicondylar Knee Arthroplasty” [TW] OR “Arthroplasty, Unicondylar Knee” [TW] OR “Knee Arthroplasty, Unicondylar” [TW] OR “Partial Knee Arthroplasty” [TW] OR “Arthroplasty, Partial Knee” [TW] OR “Knee Arthroplasty, Partial” [TW] OR “Unicondylar Knee Replacement” [TW] OR “Knee Replacement, Unicondylar” [TW] OR “Partial Knee Replacement” [TW] OR “Knee Replacement, Partial” [TW] OR “Unicompartmental Knee Replacement” [TW] OR “Knee Replacement, Unicompartmental” [TW])))) OR ((“UKA” [TW] OR “TKA” [TW] OR “TKRA” [TW])))) OR “unicompartmental knee replacement arthroplasty” [TW].

AND

((((“SONK” [TW]) OR “spontaneous osteonecrosis of the knee” [TW]) OR “Osteonecrosis” [Mesh]) OR ((“Osteonecrosis” [TW] OR “Osteonecroses” [TW] OR “Bone Necrosis” [TW] OR “Bone Necroses” [TW] OR “Necroses, Bone” [TW] OR “Necrosis, Bone” [TW] OR “Necrosis, Avascular, of Bone” [TW] OR “Avascular Necrosis of Bone” [TW] OR “Bone Avascular Necrosis” [TW] OR “Necrosis, Aseptic, of Bone” [TW] OR “Aseptic Necrosis of Bone” [TW] OR “Bone Aseptic Necrosis” [TW])))) OR “avascular necrosis” [TW].

No limitation was applied to the search; however, only published articles were used to ensure methodological oversight. Bibliographies of relevant articles were also reviewed to locate additional publications.

Study selection and data extraction

Study inclusion criteria were (1) medial UKA as the primary procedure studied, (2) reporting implant survival or clinical outcomes of osteonecrosis and osteoarthritis, and (3) a follow-up period > 1 year. Studies with the following attributes were excluded: (1) procedure other than medial UKA, (2) not reporting the number of knees with osteonecrosis and osteoarthritis separately, (3) not reporting implant survival or clinical outcomes of osteonecrosis and osteoarthritis independently, or (4) case reports, literature reviews, or expert opinion articles.

First, identified studies were screened based on titles, keywords, and abstracts to select studies reporting outcomes of medial UKA in subjects with osteonecrosis and osteoarthritis. If a decision could not be made based on the title, keywords and abstract, full articles were reviewed for selection into this analysis based on pre-determined selection criteria.

In case of studies with shared subjects, studies with longer follow-up were selected. Two authors (CY, MJC) independently screened all studies retrieved from the databases and disagreements between the authors were resolved by discussion. We requested unpublished data from the authors of studies that met the inclusion criteria, but reported data were insufficient for meta-analysis. Additionally, we requested additional data from the authors of studies that reported the survival data, but did not specify the number of revisions due to aseptic loosening of the implant or that reported the clinical outcome, but not in usable form for meta-analysis.

Data were independently extracted from the selected studies by two authors (CY, MJC) using a standardized data extraction form. General characteristics of the study, including study design, country where the study was conducted, total number of subjects, type of implant used, sex proportion, and mean age were extracted. Mean follow-up periods and body mass index (BMI) were also extracted if available. We extracted the number of implant revisions for any reason, and revisions due to aseptic loosening of the implant during follow-ups from osteonecrosis and osteoarthritis groups, independently. Any pre- and post-operative clinical scores were also extracted from the studies.

The quality of studies was evaluated by two authors (CY, MJC) using a risk of bias assessment tool for non-randomized studies (RoBANs) [15]. Selection of participants, confounding variables, measurement of exposure, blinding of outcome assessment, incomplete outcome data, selective outcome reporting were also assessed. Disagreements between evaluators were resolved by discussion or in consultation with a third author (CBC).

Statistical analysis

A random effects model was used to estimate a pooled relative risk (RR) of revision for any reason and revision due to aseptic loosening of the implant. Standardized mean difference was estimated to compare the range of motion and clinical outcome scores between SONK and MOA groups. A p value < 0.05 was considered significant for the test of overall effect. We assessed between-study heterogeneity using the Cochrane Q test with $p < 0.10$ considered significant. I^2 was also calculated to quantify the proportion of the total variation in effect estimates attributed to heterogeneity. The cause of heterogeneity was explored if heterogeneity was significant in Q statistic or I^2 exceeded 25%. Review Manager (RevMan) 5.3 was used for statistical analysis. Sensitivity analysis was performed to examine effect sizes when only studies with relatively low risk of bias in quality assessment were included. Subgroup meta-analysis was carried out by type of implant: cemented fixed bearing vs. cemented mobile bearing vs. uncemented UKA.

Results

Identification of relevant studies

Among a total of 759 articles identified after removal of duplicated articles, 62 articles were selected for the full-text review (Fig. 1). Among them, 50 studies were excluded, because they did not report implant survival or clinical outcomes of SONK and MOA independently. One study [16] was excluded due to shared study population with a more recent study [17] with the same group with longer follow-up period. Finally, 11 studies, including three matched case–control studies [7, 9, 18] and eight retrospective case reviews [8, 10–12, 17, 19–21] were included (Table 1).

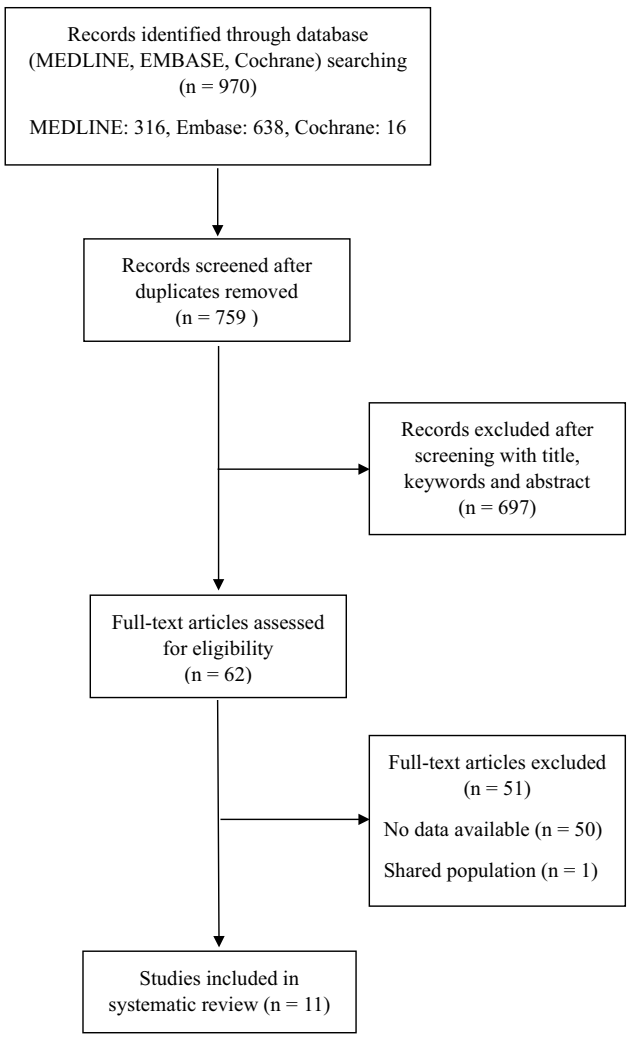

Fig. 1 Flow diagram for identification of relevant studies

Table 1 Characteristics of studies ($n=11$) included in the systematic review

Author	Year	Country	Study design	Study period	Implant used	Total (*N*)	Female (%)	Age, years (range)		Body mass index, kg/m^2 (range)		Mean follow-up, years (range)		Participants	
								ON	OA	ON	OA	ON	OA	ON	OA
Langdown et al.	2005	UK and Sweden	Matched case–control	NA	Oxford phase 3 (Biomet)	57	79.3	73 (43–88)	71 (46–85)	NA		5.0 (1–13)		SONK	MOA
Servien et al.	2008	France	Matched case–control	1988–2004	HLS Uni (Tornier)	68	72.1	75 ± 6	74 ± 8	25 ± 3.6	26 ± 3.1	5.1 ± 2.0 (2.0–11.5)	4.5 ± 2.4 (2.0–13.3)	SONK-F	MOA
Heller et al.	2009	Israel	Retrospective review	2003–2005	Oxford phase 3 (Biomet)	42	73.8	63 (45–80)		NA		2.7 (2–5)		SONK-F	MOA
Lustig et al.	2009	France	Retrospective review	1988–2004	HLS Uni (Tornier)	84	82.8[a]	72.2 ± 1.5 (25–90)[a]		25.3 ± 1.7 (16.7–34.3)[a]		5.2 (2.0–13.3)[a]		SONK	MOA
Zermatten et al.	2012	Switzerland	Retrospective review	1992–1999	Oxford phase 2 (Biomet)	48	77.1	69.2 (57–82)		NA		N.A. (1–11)		SONK-F	MOA
Ji et al.	2014	Korea	Retrospective review	2002–2010	Oxford (Biomet)	245	84.9	64.3 (50–76)		NA		2.8 (1–8)		SONK	MOA
Zhang et al.	2015	China	Matched case–control	2003–2012	Oxford phase 3 (Biomet)	58	58.6	63.8 ± 9.2	65.7 ± 11.1	25.4 ± 3.5	24.2 ± 3.7	3.7 ± 1.2	3.7 ± 1.2	SONK-F	MOA
Bruni et al. (1)	2016	Italy	Retrospective review	2000–2007	Preservation Uni (Dupey)	273	63.4	67.9 ± 8.6 (53–84)		28.2 ± 3.4 (25–35)		10.2 ± 1.5 (5.0–12.5)		ON	MOA
Bruni et al. (2)	2016	Italy	Retrospective review	2006–2009	MaioR Biojoint (Finceramica)	76	52.6	62 ± 8.2 (56–65)		27.4 ± 3.9 (19–30)		6.0 ± 0.4 (4.7–7.0)		ON	MOA
Ma et al.	2017	China	Retrospective review	2007–2013	Oxford phase 3 (Biomet)	258	68.6	71.6 (60–85)		25.0 ± 2.0	25.2 ± 1.9	5.0 (2–9)		SONK-F	MOA
Xue et al.	2017	China	Retrospective review	2005–2014	Oxford phase 3 (Biomet)	708	53.5	67.8 ± 10.2		30.5 ± 1.4		6.2 (2.7–12.0)		SONK	MOA

ON osteonecrosis, *OA* osteoarthritis, *NA* not available, *SONK* spontaneous osteonecrosis of the knee, *SONK-F* spontaneous osteonecrosis of the knee at femur

[a]In medial and lateral UKA

Characteristics of studies

A total of 1917 subjects have participated in 11 observational studies [7–12, 17–21] included in the current review (Table 1). Mean age varied from 62 to 75 years. The percentage of female subjects ranged from 52.6 to 84.9%. Mean follow-up duration varied from 32 to 122 months. All studies used cemented UKA, except for one study that demonstrated high risk of implant loosening in uncemented resurfacing type UKA [8]. Among studies using cemented UKA, mobile bearing implants were used in seven studies [9–11, 18–21], whereas fixed bearing all polyethylene tibial implants were used in three studies [7, 12, 17].

Among 11 studies included in the current review, the number of revisions for any reason was reported in nine studies [7–10, 17–21] (Table 2). We contacted the authors of two selected studies [11, 12] that did not report the number of revision in the article. However, additional data could not be used in the meta-analysis; Lustig et al. [12] demonstrated comparison of clinical outcomes without any implant survival data and Xue et al. [11] provided only the 5-year cumulative survival rate of UKA in SONK and MOA (98.7% and 98.8%, respectively, $p > 0.05$). The number of revisions due to aseptic loosening was available in seven studies [7, 9, 10, 18–21]. The reasons for revision other than aseptic loosening of the implant were osteoarthritic change in other compartment, deep infection, bearing dislocation that could not be managed with thicker bearing, and unexplained pain. In addition, we contacted the authors of the two other studies [8, 17] for the number of revision surgeries due to aseptic loosening; however, additional data were not provided.

Clinical outcomes of SONK and MOA were compared in seven studies [7, 9–12, 18, 21] (Table 3). Among them, three studies [9, 11, 21] used Oxford knee score (OKS), three studies [7, 10, 12] used international knee society (IKS) knee and function score, and one study [18] used hospital for special surgery (HSS) score [22]. Two studies [11, 12] reported only p values of the comparison of clinical outcome, while Heller et al. [10] provided only mean outcome score without standard deviation.

Risk of bias assessment

Methodological quality of studies included in final analyses was assessed on the basis of six predetermined quality assessment items of RoBANs (Fig. 2). Blinding of outcome assessment was not reported in all studies. A high risk of attrition bias was detected in three studies due to follow-up loss [10, 12, 19]. Only four studies were assessed to be at low risk of selection bias [7, 9, 18, 21].

Outcomes

Of 260 knees with osteonecrosis in nine studies included in the meta-analysis, 30 knees (11.5%) required revision of implant, whereas 48 (5.5%) of 865 knees with osteoarthritis needed revision. The risk of revision for any reason after UKA was significantly higher in SONK than in MOA with a pooled RR of 1.83 [95% confidence interval (CI) 1.16–2.90] (Fig. 3a). The heterogeneity among included studies was low ($\chi^2 = 5.17$, $p = 0.64$, $I^2 = 0\%$). When revision due to aseptic loosening was defined as the end point ($\chi^2 = 2.14$, $p = 0.34$, $I^2 = 7\%$), pooled RR was 2.36 (95% CI 0.41–13.54) (Fig. 3b).

When sensitivity analysis was performed using four studies [7, 9, 18, 21] with low risk of selection, attrition, and reporting bias ($\chi^2 = 0.41$, $p = 0.81$, $I^2 = 0\%$), the pooled RR for revision for any reason was 1.30 (95% CI 0.32–5.27). In subgroup analysis by implant type (Fig. 4), mobile and

Table 2 Survival outcome of studies ($n = 11$) included in the systematic review

#	Authors, year	Osteonecrosis			Medial osteoarthritis		
		Revision for any reason	Revision due to aseptic loosening	Total N	Revision for any reason	Revision due to aseptic loosening	Total N
1	Langdown, 2005	0	0	29	0	0	28
2	Servien, 2008	2	0	33	2	0	35
3	Heller, 2009	0	0	9	7	3	33
4	Lustig, 2009[a]	NA	NA	31	NA	NA	53
5	Zermatten, 2012	4	1	10	6	0	38
6	Ji, 2014	0	0	6	10	5	239
7	Zhang, 2015	1	0	29	1	0	29
8	Bruni (1), 2016	10	NA	89	15	NA	184
9	Bruni (2), 2016	13	NA	32	6	NA	44
10	Ma, 2017	0	0	23	1	0	235
11	Xue, 2017[b]	NA	NA	41	NA	NA	667

[a]No survival data was provided

[b]Only 5-year cumulative survival rate was provided

Table 3 Clinical outcome of studies ($n=7$) included in the systematic review

Author, year	Postoperative clinical outcomes	Osteonecrosis	Medial osteoarthritis	*p* value
Langdown, 2005	OKS	38 ± 6.2	40 ± 6.2	0.3
Servien, 2008	IKS knee score	93 ± 7	91 ± 9	≥ 0.05
	IKS function	84 ± 22	85 ± 16	≥ 0.05
	Range of motion	133 ± 12	135 ± 8	≥ 0.05
Heller, 2009	IKS knee score	87.6	83.8	NA
	IKS function	75	84.3	NA
	Range of motion	126	121	NA
	WOMAC	34.3	28.2	NA
Lustig, 2009	IKS knee score	NA	NA	≥ 0.05
	IKS function	NA	NA	≥ 0.05
	Forgotten knee	80%	55%	0.04
Zhang, 2015	HSS score	93.45 ± 4.73	91.59 ± 5.05	0.153
	VAS score	1.97 ± 1.02	2.17 ± 0.89	0.413
	Range of motion	127.35 ± 7.30	126.59 ± 6.39	0.675
Ma, 2017	OKS[a]	40.35 ± 4.38	41.25 ± 3.76	0.282
Xue, 2017	OKS	NA	NA	≥ 0.05
	KSS	NA	NA	≥ 0.05
	Range of motion	NA	NA	≥ 0.05

OKS Oxford Knee Score, *IKS* International Knee Society, *HSS* hospital for special surgery, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, *KSS* Knee Society Score, *NA* not available

[a]Old version OKS was provided from the article in which it was converted to new version OKS [7]

fixed-bearing cemented UKA showed similar survival, whereas one study demonstrating the results of uncemented UKA showed higher risk of revision in osteonecrosis compared to osteoarthritis (RR = 1.83, 95% CI 1.27–6.99). The pooled RR for revision for any reason of cemented UKA was 1.51 (95% CI 0.88–2.59) with low heterogeneity ($\chi^2 = 3.49$, $p = 0.75$, $I^2 = 0\%$).

Most studies included in the review demonstrated similar clinical outcomes of UKA in SONK and MOA (Table 3). Meta-analysis showed no significant difference in postoperative range of motion between the two groups (Fig. 5a). Moreover, despite the worse preoperative clinical score of SONK compared to MOA reported by Zhang et al. [18], meta-analysis revealed no significant mean difference in postoperative clinical scores ($p = 0.66$) between SONK and MOA (Fig. 5b).

Discussion

Although UKA has been reported to show high forgotten joint score [23], fast return to sports [24], and good survival outcomes [25, 26], concerns still exist regarding higher long-term revision rate compared to TKA [27, 28]. Caution is needed when performing UKA in patients with SONK due to poor bone quality of SONK lesion that may affect the implant fixation. Despite the good results of UKA that have been reported in patients with SONK [29–31], worse clinical and survival outcome of UKA compared to TKA in patients with SONK has been suggested [5]. Therefore, further evaluation is needed to determine whether SONK should be considered as an indication for UKA.

In the present study, we compared the survival and clinical outcomes of UKA in SONK and in MOA using the results of previous observational studies. Our meta-analysis found a significantly higher overall revision rate of UKA in SONK than in MOA. However, the risk of revision due to aseptic loosening was not significantly different between the two procedures. Moreover, when stratified by quality of the study, high-quality studies showed a similar risk of overall revision in SONK and MOA. Subgroup analysis revealed that worse survival of SONK is mainly due to a study reporting high failure after uncemented UKA in patients with SONK. Fixed bearing all polyethylene tibial implants showed similar survival outcomes with mobile bearing metal-backed tibial implants. It is consistent with a recent study by Scott et al. [32] that reported high long-term survival of UKA using all polyethylene tibial components. Clinical outcomes after UKA were similar between SONK and MOA.

Our results are in close agreement with unicompartmental indication score (UIS) which gives same points to osteoarthritis and osteonecrosis [33]. Similar revision

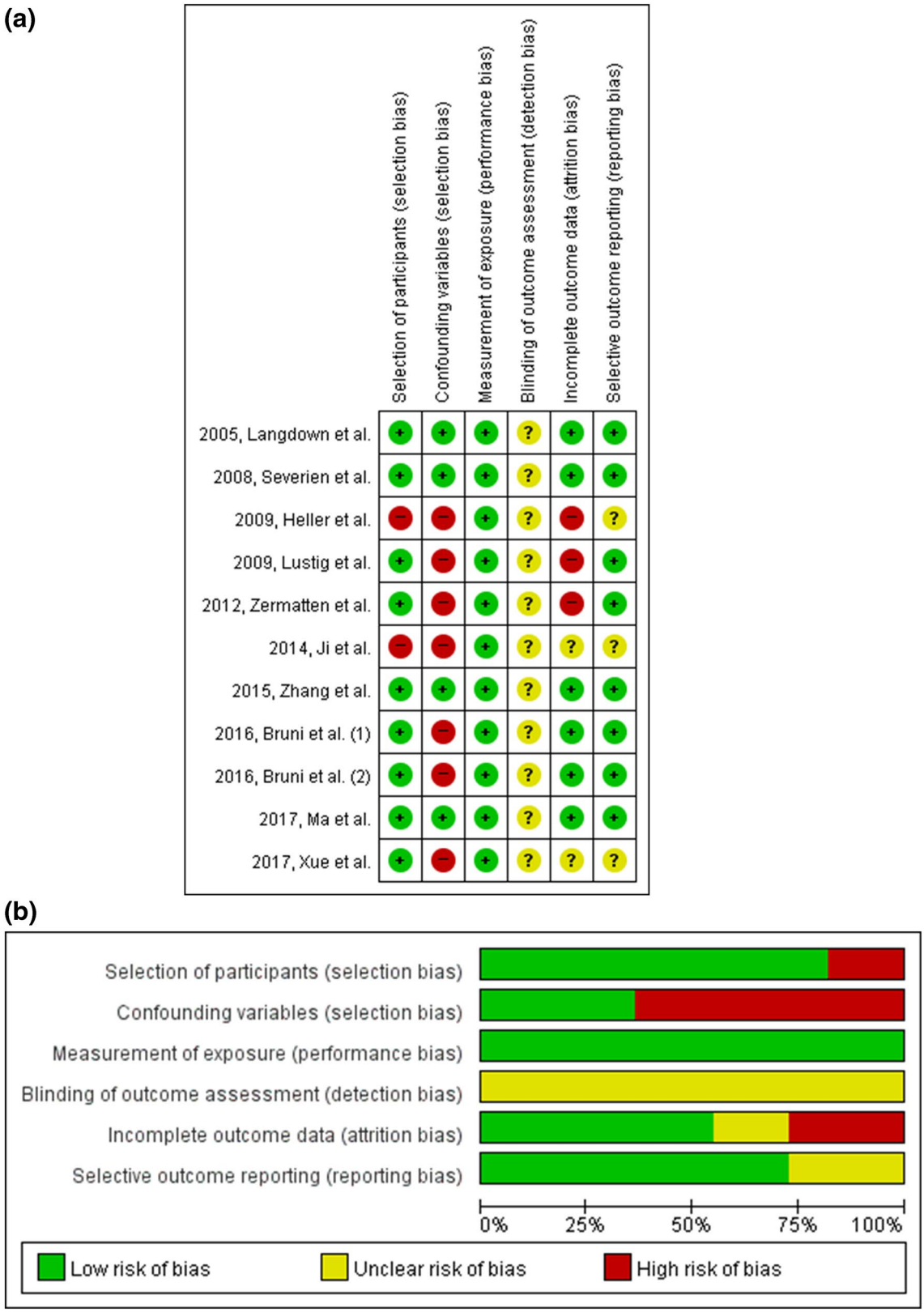

Fig. 2 Risk of bias assessment using risk of bias assessment tool for non-randomized studies (RoBANS). **a** Review of the author's judgment about each risk of bias item for each included studies; **b** review of the author's judgment about each risk of bias item presented as percentages in all included studies

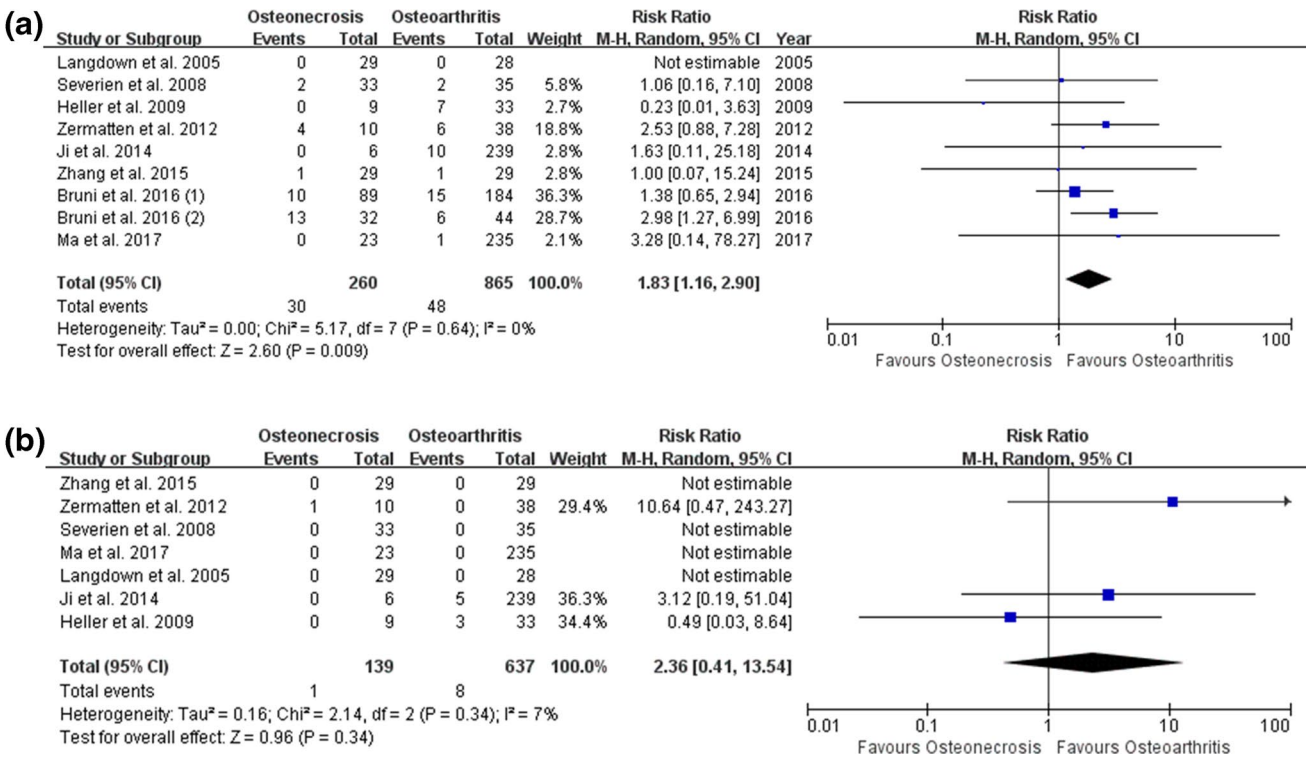

Fig. 3 Meta-analysis of the results of unicompartmental knee arthroplasty in spontaneous osteonecrosis of the knee and in medial osteoarthritis. **a** Revision for any reason; **b** revision due to aseptic loosening

rate of SONK and MOA in cemented UKA can partly be explained with pathologic property of SONK. A few pathologic studies reported that there is no necrotic bone in the so-called "SONK" lesion [3, 34]. Along with these findings, the presence of insufficiency fracture in SONK lesion [3, 35] suggested that "SONK" is actually a misnomer and should be redefined as a fracture. After removal of fracture portion during bone cutting for UKA, poor quality of edematous remnant subchondral bone may have affected the survival of uncemented UKA [8], but have little effect on bone porosity, which affects interdigitation of bone and cement in cemented UKA [36].

Despite the worse pain and preoperative function suggested in SONK compared to MOA [18, 37], clinical outcomes were similar between SONK and MOA after UKA. Moreover, significantly higher percentage of "forgotten knee" was demonstrated in SONK group compared to MOA group (80% and 55%, $p = 0.04$) [12]. As suggested by Lustig et al., good clinical outcome of UKA in SONK might be due to less capsule and ligament retraction caused by its more painful nature compared to MOA leading to early surgery before capsular retraction [12]. Moreover, lower incidence of "forgotten knee" in patients with MOA can also be associated with postoperative progression of osteoarthritis at patellofemoral compartment causing patellar impingement [38].

Limitations

Our study has a few limitations. First, since the quality of our study depends on data from original publications used in our meta-analysis, our study may inherit some problems of potential bias and confounding effects of observational studies. Moreover, due to low number of studies included, the pooled results of the subgroup analyses needs further evaluation in longitudinal studies. Second, osteonecrosis includes not only SONK, but also secondary osteonecrosis with different characteristics. Two included studies did not distinguish SONK from osteonecrosis [8, 17]. However, due to low quality of these studies, they were excluded in the sensitivity analyses. Third, the surgical techniques used in UKA and the grade of the SONK lesion were not specified in the majority of included studies and further evaluation could not be performed. Furthermore, the mean follow-up period varied among the studies included in the meta-analysis. Lastly, radiological outcomes could not be assessed due to limited data available from the included studies.

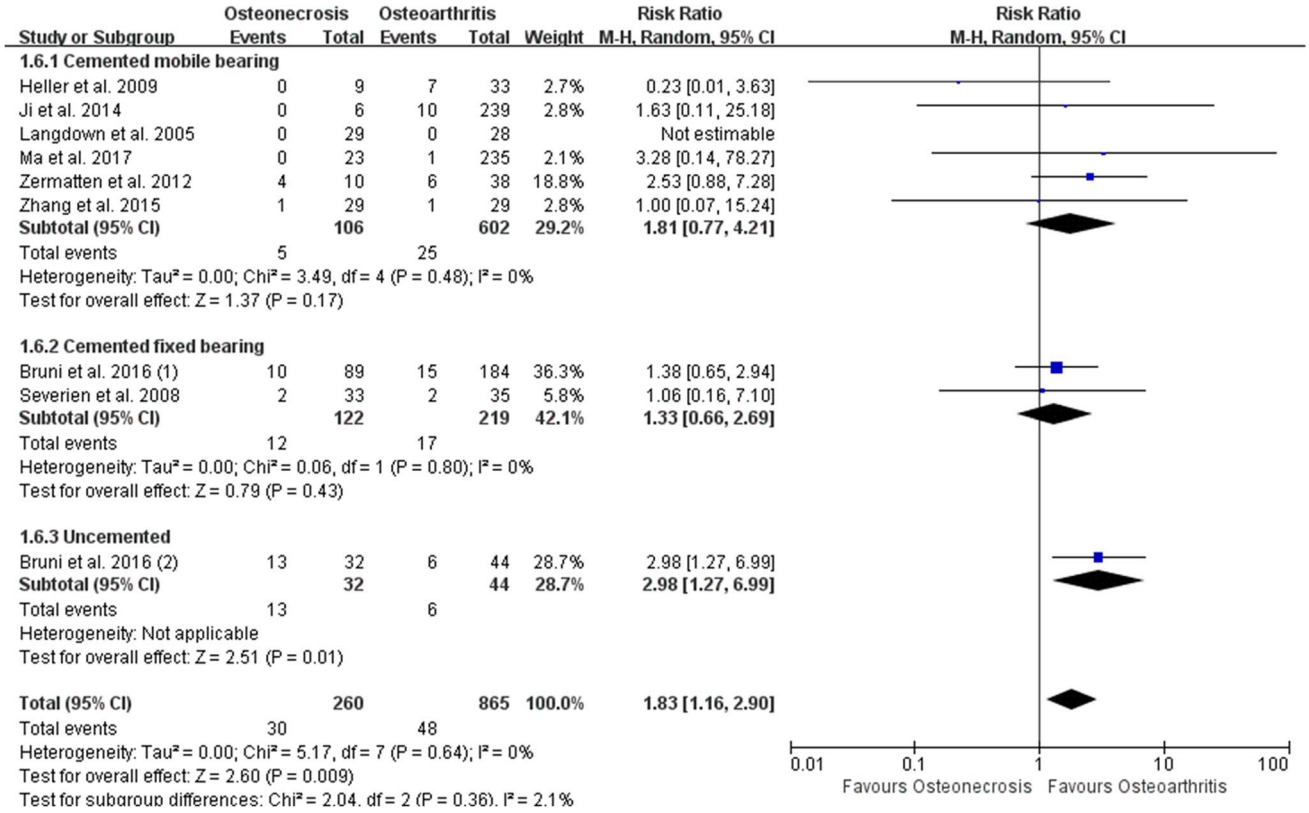

Fig. 4 A forest plot showing pooled risk ratio of revision for any reason in three subgroups: studies performed using cemented mobile bearing implant, cemented fixed bearing implant, or uncemented implant

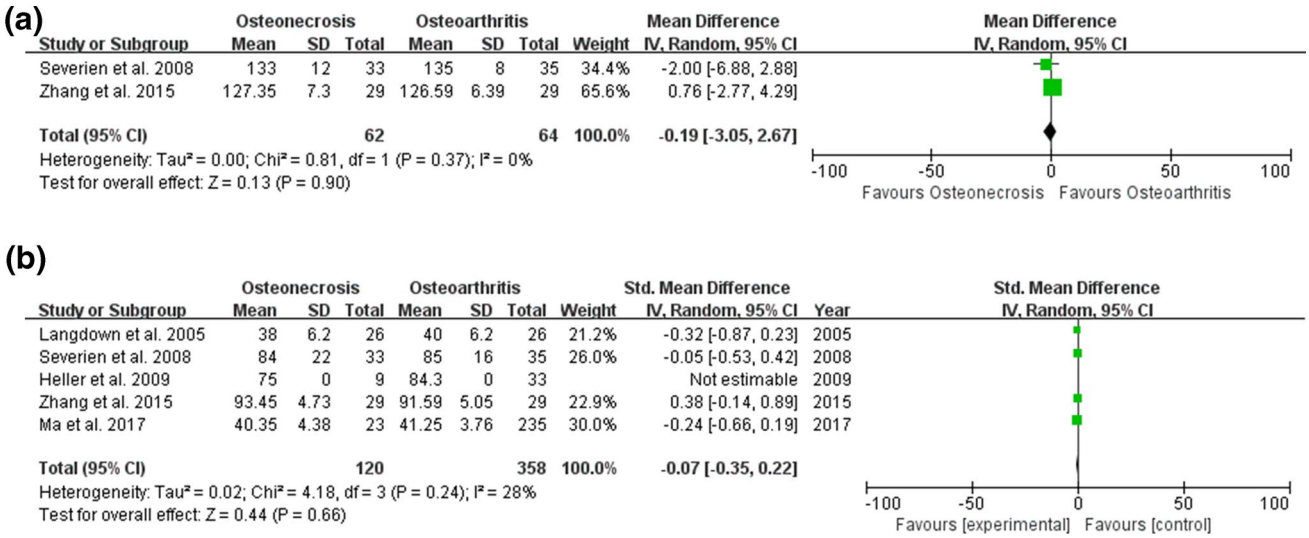

Fig. 5 Forest plots demonstrating standardized mean difference of **a** range of motion and **b** clinical outcome scores between spontaneous osteonecrosis of the knee and medial osteoarthritis

Conclusions

In our meta-analysis of retrospective observational studies, cemented UKA showed similar survival and clinical outcomes in SONK and in MOA. Our findings should be confirmed by prospective studies with large sample sizes and long-term follow-ups. Moreover, further studies designed specifically to compare the outcome of uncemented UKA in SONK and in MOA are needed.

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Compliance with ethical standards

Conflict of interest The author(s) declare that they have no competing interests.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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