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REVIEW ARTICLE

Barbed Sutures for Total Hip and Knee Arthroplasty Have Shorter Wound Closure Time and are Cost-Effective in Comparison to Traditional Sutures: A Systematic Review and Meta-analysis of 16 Randomized Controlled Trials

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Abstract

Purpose Surgical wound closure is of paramount importance, especially in total joint replacement surgeries wherein correct closure technique not only aids in rapid healing, but with lesser complications, we would be looking at a quicker rehabilitation of the patients. Bidirectional barbed sutures appear to reduce the wound closure time in all the planes and are cost-effective in comparison with traditional sutures. This study is aimed at evaluating the efficacy and superiority of bidirectional barbed sutures in comparison to traditional suturing techniques.

Methods Electronic databases like Embase, PubMed, Cochrane Library, Lilacs were searched up to February 2021. 16 high-quality randomized-controlled trials (RCT) were selected in this study. The search method identified 2168 total knee replacements (TKR) and 229 total hip replacements (THR) among 2397 patients. All the studies compared barbed sutures with traditional wound closure techniques. Data of wound closure time, overall cost, length of hospital stay, overall wound complications, suture-related complications, range of motion data, and knee society scores were collected and further analyzed.

Results The baseline patient characteristics were identical among all the included studies. Compared to traditional sutures a significantly decreased wound closure time in both THR and TKRs ($p < 0.00001$) and cost ($p < 0.00001$) was noted, although no statistically significant difference was found in overall complications in THRs ($p = 0.95$) and TKRs ($p = 0.69$). ROM ($p = 0.54$—6 weeks after surgery and $p = 0.68$—3 months after surgery) and Knee society scores ($p = 0.92$) in both the groups of patients undergoing TKR. However, the length of hospital stay was prolonged in the barbed suture group ($p = 0.01$), pinpricks ($p = 0.02$), and broken sutures ($p = 0.02$).

Conclusions Novel methods of wound closure such as barbed sutures achieve satisfactory surgical implementation being more efficient in the form of decreasing the overall wound closure time, with comparable wound complication rates and being cost-effective. But the drawbacks like the incidence of broken sutures and pinpricks are more. Overall using barbed sutures in place of traditional sutures may be considered safe and a viable alternative choice for suturing in total joint replacements.

Level of Evidence Level I, Systematic review and Meta-analysis of RCT.

Keywords Total knee arthroplasty · Total hip arthroplasty · Barbed suture · Wound closure time · Wound complications · Cost-efficacy · Wound closure

Introduction

Joint replacement surgical procedures are highly successful worldwide. With the number of arthroplasty surgical procedures on the rise over the years, newer methods and implants are seeing greater acceptance. Kurtz et al. predicted an increase in 174% in primary total hip replacements (THRs) and 673% in primary Total knee replacements (TKRs)

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surgeries by 2030 from 2005 in the US population which in general shows the increasing trends of joint replacement surgeries in the western world [1]. The closure of the joint is an important component in the resounding success of arthroplasty surgeries along with reduction of post-operative complications and rehabilitation wherein, a tight and appropriate soft-tissue closure helps in increasing the patient satisfaction and cosmetic scores along with decreasing the infection chances [2, 3].

Barbed sutures were introduced by Mckenzie in 1967 with a focus on decreasing the time required for the closure and increasing cost-effectiveness [4]. US FDA (United States Food and Drug Administration) approved its use in soft tissue surgeries in 2007 [5, 6]. These sutures differ from the traditional method of interrupted or continuous sutures with knots and having higher cyclical tension [7, 8]. The need of applying knots is avoided and theoretically, the cost of the sutures is being decreased along with decreasing the probability of infection [9]. The utilization of these sutures in the field of arthroplasty is controversial. A decrease in surgical time and a decreased rate of wound complications are often held as a significant advantage [2, 3, 10, 11]. Although the barbed sutures may provide dexterity in the hands of surgeons, their specific disadvantages such as broken sutures may pose the risk of delayed mobilization in replacement surgeries [12, 13].

Level I evidence, in the form of systematic reviews in the field of arthroplasty for the use of barbed sutures is relatively rare and few have more than seven RCTs included [7, 8, 14, 15]. There exists little consensus on the use of these sutures in the field of arthroplasty. The meta-analysis by Sun et al. (2020) focused on RCTs, had included two dissertations in their study, and predominantly focused on total knee replacement [15]. Five RCTs have been further published since then and there is a need for a systematic review. The purpose of our study was to analyze the level I studies in the use of barbed sutures in arthroplasty surgeries with a focus on hip and knee replacement. The primary outcomes of interest for the meta-analysis were wound closure time and cost-effectiveness of barbed sutures in total joint arthroplasty (THR and TKR). The secondary outcomes of interest were a range of motion (ROM), breakage of sutures, length of hospital stay and knee society scores (KSS).

Materials and Methods

Literature Search

The search and the study were conducted according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines [16]. The search was performed in PubMed, EMBASE, and Cochrane Library databases for articles from the date of inception to March 2021. Two authors (B.S.R and S.P) independently screened the databases for the eligible articles. The search terms included ‘barbed’, 'barbed sutures', 'knotless sutures', 'knotless', 'arthroplasty', 'joint replacement', 'knee replacement', 'hip replacement', 'TKR', 'THR', 'total joint replacement', 'randomized controlled trial’, 'randomized clinical trial' along with Boolean operators “OR” and “AND”. In PUBMED ‘the related-articles function’ was used to identify additional studies. A thorough search of the reference list of the selected articles was also performed along with searching high-impact journals of arthroplasty for by title and then subsequent abstract review. Any disagreements between the authors were assessed by the senior author (R.B.K) and a final consensus was made after discussion.

Criteria for Selection of Articles and Data Extraction

Randomized controlled trials on primary total knee replacement (TKR) or total hip replacement (THR) that compared barbed sutures with traditional sutures with at least of the below-mentioned outcomes were included for the study. The exclusion criteria included studies in languages other than English, case reports or case series, letter to editors, nonrandomized studies, biomechanical or cadaver studies, reviews, meta-analysis, or studies with insufficient data and outcomes not in the inclusion criteria.

The primary outcomes were wound closure time, cost, and complications such as infection, stitch abscess, wound discharge, wound dehiscence, pinpricks, broken sutures, or allergy. The secondary outcomes were knee ROM and KSS. Two authors (A.K. C and A.K.S.G) independently collected the data (Fig. 1). The data were extracted on author, Journal, area of study, date of publication, study design, demographics, primary and secondary outcomes. Any discrepancy present was resolved by another author (R.B.K).

Quality Assessment and Risk of Bias

The quality assessment of the included studies was done using the Cochrane Collaboration tool for assessing the risk of bias by two authors (B.S.R and S.P) [17]. The quality assessment included random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessments, attrition bias, reporting bias, and other bias (Table 2) [17, 18]. The level of bias risk was judged as "low risk", "high risk", "unclear risk". Any discrepancy present was resolved by another author [R.B.K].

Statistical Analysis

The data were collected and then tabulated using Microsoft Excel software. The review meta-analysis and forest

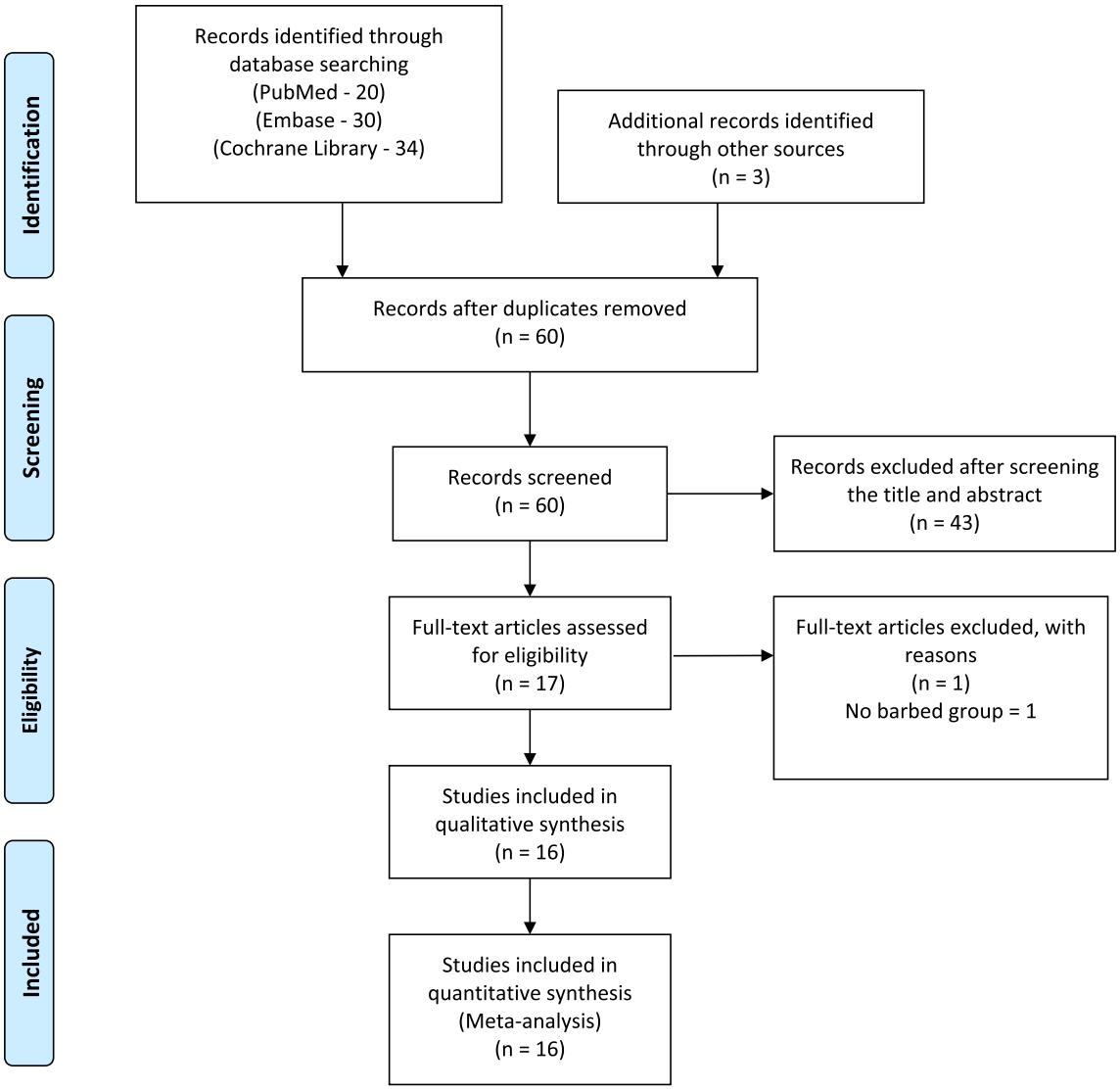


Fig. 1 PRISMA Flow diagram for Barbed sutures Search Methodology

plots were generated using the Review Manager (RevMan) software (Version 5.3, The Nordic Cochrane Centre, The Cochrane Collaboration, 2008). Risk ratio/Odds ratio with 95% confidence intervals were used for dichotomous outcomes. Mean differences with 95% confidence intervals were used for continuous outcomes. The outlying studies were identified using funnel plots. Heterogeneity among studies was analyzed using I^2 statistics. Fixed effects meta-analysis was used when the I^2 was less than 50% and random-effects meta-analysis was used when I^2 was more than 50%. Subgroup analysis was performed wherever possible when the I^2 was more than 50%.

Results

Search Results

Our search initially yielded 87 articles. Twenty-seven duplicates were removed. Forty-three articles were excluded after reviewing the title and abstract. Seventeen full-text articles were searched and one was excluded from the analysis. Sixteen RCTs were included in the final list with 2,168 TKR and 229 THR totaling 2,397 patients who underwent wound closure with barbed sutures. Three

studies were added after a thorough search of the bibliography of selected articles and searching various journals individually. A detailed flow diagram of the search is given in Fig. 1.

Study Characteristics

The study included 16 RCTs for the analysis. Of these articles, three were published before 2015 and 13 after 2015. The RCT by Smith et al. had a retrospective chart review clubbed into our study [19]. The outcome from the retrospective analysis has not been included in the present analysis. The study demographics with the year of publication, area, and parent journal are listed in Table 1. The dataset for the study included a total of 2,397 patients with 2,168 TKR and 229 THR. Of these above-mentioned, 1,235 TKR and 137 THR were closed using the barbed suture technique (BS) and 933 TKR and 92 THR closed with traditional suture technique (TS) [10, 19–33]. The type of sutures and the method of closure are listed in Table 2. In the barbed group, 12 studies closed the arthrotomy with barbed sutures [10, 19-24, 26-29, 31]. Four studies did not mention the technique used in the closure of arthrotomy [25, 30, 32, 33]. Sixteen studies used barbed sutures for the fascia and subcutaneous closure of the wounds [10, 19–33]. The demographics like age, sex, and BMI noticed between the groups were comparable.

Quality Assessment

The quality of the included studies was reported by the Cochrane tool for risk assessment. The results are given in Fig. 2. Thirteen studies mentioned random sequence generation, eight reported detailed the blinding of participants and personnel, eleven showed adequate allocation concealment and thirteen studies described consistency in the assessment of results. Selective reporting bias was avoided in 11 studies and all included studies retained complete outcome data. The quality of the overall studies included in the data was considered adequate. Funnel plots for the study are given in Fig. 3a, b. Limits of publication bias of the included studies are diagrammatically represented with the help of funnel plots (Fig. 3), suggesting that they were within the acceptable limits of heterogenicity.

Outcome Analysis

Wound Closure Time Barbed vs Traditional

Fourteen studies reported wound closure time [10, 20–30, 32, 33]. The meta-analysis revealed a lesser wound closure time for both TKR and THR in the BS group in comparison with the TS group. We found statistical heterogeneity in the wound closure meta-analysis of both TKR and THR with (I^2: 99%, Mean difference: – 5.94, 95% CI [–8.01, – 3.88], $p < 0.00001$; ►Fig. 4a) for TKR and (I^2: 96%, Mean difference: – 3.73, 95% CI [–5.86, – 1.60], $p = 0.0006$; ►Fig. 4b) for THR.

Cost Comparison Barbed vs Traditional

Six studies compared the cost between the barbed group and the traditional group [19–21, 24, 27, 29]. The BS group were found to have a significantly lesser cost in comparison to the TS group ($I^2 = 99\%$, Mean difference = – 282.74, 95%CI: [– 446.16, – 119.32], $P < 0.00001$ ► Fig. 5a) using a random-effects model.

Length of Stay

Two studies compared the length of stay between the BS and TS groups [21, 22]. A fixed-effects model was used for the analysis and it revealed a longer length of stay for the BS group ($I^2 = 0\%$, Mean difference = 0.29, 95%CI: [0.06, 0.53], $P = 0.01$ ►Fig. 5b).

Overall Complications

Sixteen studies compared the complication rates between the two groups [10, 19–33]. We found no heterogeneity among the study groups and a fixed-effects model was used for analysis ($I^2 = 36\%$, Odds ratio = 1.06, 95% CI: [0.78, 1.44], $P = 0.69$►Fig. 6a) in TKR group and ($I^2 = 0\%$, Odds ratio = 1.03, 95% CI: [0.42, 2.53], $P = 0.95$►Fig. 6b) in THR group. The analysis revealed no difference in overall wound complication rates between BS and the TS group in THR and TKR. As there was no heterogeneity and a small number of studies performed of THR, no subgroup analysis was performed.

Superficial Infection Barbed vs Traditional in TKR

Eight studies compared superficial infection between the BS and TS groups [10, 20–24, 29, 31]. A fixed-effects model was used for the analysis and revealed no difference between groups. It further on revealed a longer length of hospital stay for the BS group ($I^2 = 0\%$, Odds ratio = 1.23, 95% CI: [0.76, 1.98], $P = 0.40$ ► Fig. 7a).

Stitch Abscess Barbed vs Traditional in TKR

Five studies compared stitch abscess between the BS and TS groups [10, 20, 24, 25, 27]. A fixed-effects model was used for the analysis and revealed no difference between groups ($I^2 = 22\%$, Odds ratio = 0.55, 95% CI: [0.24, 1.28], $P = 0.17$ ► Fig. 7b).

Table 1 Study characteristics of included randomized controlled trials

Authors	Journal	Surgery	Location of study	Suture type	Sample size, Age, M/F	BMI	Follow-up period
Chinchilla 2021 [30]	SECOT	THA	SPAIN	Barbed	39, 66.61 ± 13.3, 21/18	27.6 ± 4.1	36 ± 3.6 D
				Conventional	43, 65.62 ± 12.47, 19/23	30.45 ± 5.2	36 ± 3.6 D
Wang W 2020 [21]	JOS	TKA	China	Barbed	91(80C), 66.6 + 6.1, 21/69	26.84 + 3.34	30–42 D
				Conventional	93 (83C), 67.4 + 5.7, 23/66	26.28 + 3.14	
Feng S 2020 [22]	MSM	TKA	CHINA	Barbed (JC + SC)	193, 64.8 ± 8.7, 53/143	24.1 ± 2.7	NA
				Barbed (JC)	195, 66.0 ± 9.2, 49/146	24.4 ± 2.9	NA
				Conventional	194, 65.0 ± 8.7, 54/140	24.0 ± 2.7	NA
Sundaram K 2020 [28]	HI	THA	USA	Barbed	30, 61 ± 13, 17/13	29 ± 4.8	90 D
				Conventional	30, 66 ± 10, 11/19	30 ± 4.8	
Sundaram K 2020 [10]	MS	TKA	USA	Barbed	30, 68 ± 7, 14/16	32.6 ± 5.76	90 D
				Conventional	30, 66 ± 7, 13/17	32.3 ± 4.95	
Gamba 2019 [23]	JKS	TKA	SPAIN	Barbed	41, 74.2 ± 8.2, 38.6% / 61.4%	30.2 ± 5	30 D
				Conventional	44, 73.8 ± 7.5, 31.7% / 68.3%	30.6 ± 4.6	
Li R 2018 [25]	MSM	TKA/THA	CHINA	Barbed Conventional	THA: 46, 43.76, 32/14 TKA: 38, 60.11, 8/30	THA: 23.78 ± 2.98 TKA: 26.76 ± 3.22	42 D
Chan 2017 [20]	JOA	TKA	CHINA	Barbed	55, 70.5 ± 8.2, 9/46	26.8 ± 1.2	90 D
				Conventional	54, 70.4 ± 8.9, 7/47	26.5 ± 3.9	
Chugaev 2017 [31]	*Surgery. Journal them. N.I. Pirogov*	TKA	RUSSIA	Barbed	200, 63.09, NA/NA	NA	90 D
				Conventional	102, 63.1, NA/NA	NA	
Malhotra 2017 [26]	IO	TKA	INDIA	Barbed	80, 63.1 ± 8.8, 21/59	NA	42 D
				Conventional	90, 60.0 ± 10.2, 20/70	NA	
Zhao G 2017 [33]	JPO	TKA	CHINA	Barbed	31, NA, NA	NA	90 D
				Conventional	31, NA, NA	NA	15 D
Zhao H 2015 [32]	SDXYB	TKA	CHINA	Barbed	13, NA, NA	NA	NA
				Conventional	16, NA, NA	NA	
Sah 2015 [27]	CORR	TKA	USA	Barbed	50, 68.1 ± 8.5, 29/21	30.1 ± 4.6	365 D
				Conventional	50, 68.1 ± 8.5, 29/21	30.1 ± 4.6	

Table 1 (continued)

Authors	Journal	Surgery	Location of study	Suture type	Sample size, Age, M/F	BMI	Follow-up period
Gililland 2014 [24]	JOA	TKA	USA	Barbed	191, 64 ± 10, 114/77	33 ± 8	45 D
				Conventional	203, 63 ± 10, 126/77	33 ± 8	
Smith 2014 [19]	JOA	THA/TKA	USA	Barbed	THA: 8, 59.6, 4/4 TKA: 10, 59.2, 5/5 18 (TOTAL)	THA: 33.8 (21.3–48.9) TKA: 33.7 (25.5–42.7)	NA
				Conventional	THA: 8, 57.9, 3/5 TKA: 8, 70.6, 3/5 16 (8 TKA/8 THA),	THA: 30.1 (22.7–44.4) TKA: 30.1 (24.4–39)	
Ting 2012 [29]	JOA	THA (25) /TKA (35)	USA	Barbed	31, 64.4 (41–86), 8/23	30.4 (20.5–45.5)	90 D
				Conventional	29, 63.5 (30–80), 8/21	32.2 (22.2–48.2)	

JOS: Journal of Orthopaedic Surgery; JOA: Journal of Arthroplasty, MSM: Medical Science Monitor; HI: Hip International, MS: Musculoskeletal Surgery, JKS: Journal of Knee surgery, IO: International Orthopaedics, CORR: Clinical Orthopedic Related Research; SDXYB: Shandong Daxue Xuebao Yixue Ban, JPO; Journal of Practical Orthopaedics; TKA: Total Knee replacement, THR: Total hip replacement, JC: joint closure, SC: subcutaneous closure, C: completed, NA: not available, D: days, Ms: months, M: male, F: female, BMI: body mass index and D: Days

Wound Discharge Barbed vs Traditional in TKR

Four studies compared wound discharge between the BS and TS groups [10, 21, 25, 27]. A fixed-effects model was used for the analysis and revealed no difference between groups ($I^2 = 0\%$, Odds ratio = 0.77, 95% CI: [0.19, 3.16], $P = 0.72$ ► Fig. 7c).

Wound Dehiscence Barbed vs Traditional in TKR

Seven studies compared wound dehiscence between the BS and TS groups [10, 20–23, 27, 31]. A fixed-effects model was used for the analysis and revealed no difference between groups ($I^2 = 0\%$, Odds ratio = 0.53, 95% CI: 0.24, 1.43, $P = 0.24$ ► Fig. 7d).

Pinpricks Barbed vs Traditional in TKR

Two studies compared pinpricks between the BS and TS groups [24, 26]. A fixed-effects model was used for the analysis and revealed an increased incidence of pinpricks in TS groups ($I^2 = 0\%$, Odds ratio = 0.14, 95% CI: [0.02, 0.76], $P = 0.02$ ► Fig. 8a).

Broken Sutures Barbed vs Traditional in TKR

Five studies compared broken sutures between the BS and TS groups [23, 24, 26, 27, 30]. A Random-effects model was used for the analysis and revealed an increased incidence of broken sutures in BS groups ($I^2 = 64\%$, Odds ratio = 12.01, 95% CI: [1.41, 102.35], $P = 0.02$ ► Fig. 8b).

ROM Barbed vs Traditional in TKR

Four studies compared ROM between the BS and TS group [20, 21, 23, 27]. A Random effects model was used for the analysis and revealed no difference between groups </ = 6 weeks ($I^2 = 0\%$, Mean difference = – 0.74, 95% CI: [– 3.13, 1.65], $P = 0.54$ ► Fig. 9a) and > / = 3 months ($I^2 = 70\%$, Mean difference = – 1.05, 95% CI: [– 5.99, 3.88], $P = 0.68$ ► Fig. 9b).

Knee Society Score [KSS] Barbed vs Traditional in TKR

Four studies compared KSS between the BS and TS groups [20, 22, 24, 27]. A fixed-effects model was used for the analysis and revealed no difference between groups ($I^2 = 50\%$, Mean difference = 0.14, 95% CI: [– 0.63, 0.92], $P = 0.72$ ► Fig. 9c).

Table 2 Various stitch materials used in the randomized controlled trials

Author	Barbed suture	Traditional suture
Chinchilla 2021 [30]	Fascia: # 2 continuous barbed suture (Quill ®; Ethicon-Johnson & Johnson, Miami, Florida, USA) BD Subcutaneous: # 0 continuous barbed suture (Quill ®; Ethicon-Johnson & Johnson, Miami, Florida, USA) BD	Fascia: # 2 discontinuous polyglactin 91 suture (Vicryl ® Ethicon-Johnson & Johnson, Miami, Florida, USA) Subcutaneous: # 0 discontinuous polyglactin 91 suture (Vicryl ® Ethicon-Johnson & Johnson, Miami, Florida, USA)
Wang W 2020 [21]	Arthrotomy: Running STRATAFIX Symmetric PDS Plus Subcuticular: STRATAFIX Spiral PGA-PCL Knotless Tissue Control Device Skin: DERMABOND TM AdvanceTM Skin Closure System	Arthrotomy: CR8 VICRYL® Plus (interrupted) Subcuticular: STRATAFIX Spiral PGA-PCL Knotless Tissue Control Device Skin: DERMABOND TM AdvanceTM Skin Closure System
Feng S 2020 (a) [22]	Arthrotomy: Stratafix1-0, BD Subcutaneous: Stratafix2-0 < BD Subcuticular: Stratafix3-0, BD Skin: not clear	Arthrotomy: (Ethicon VICRYL* Plus 1–0) Subcutaneous: (Ethicon VICRYL* Plus 2–0) Skin: Staples
Feng S 2020 (b) [22]	Arthrotomy: Stratafix1-0, BD Subcutaneous: Ethicon VICRYL* Plus 2–0 Skin: Staples	Arthrotomy: (Ethicon VICRYL* Plus 1–0) Subcutaneous: (Ethicon VICRYL* Plus 2–0) Skin: Staples
Sundaram K 2020 (HI) [28]	Capsule: #2 Polyester suture Arthrotomy: #1 PDO suture with symmetric barbs Subcutaneous: 2–0 Polyglactin 910 braided absorbable sutures Subcuticular: 3–0 Monofilament poliglecaprone 25 absorbable suture Skin: Adhesive strips with glue	Capsule: #2 Polyester suture Arthrotomy: #1 Polyglactin 910 braided absorbable sutures Subcutaneous: 2–0 Polyglactin 910 braided absorbable sutures Subcuticular: 3–0 Monofilament poliglecaprone 25 absorbable suture Skin: Adhesive strips with glue
Sundaram K 2020 [10]	Arthrotomy: PDO #1 suture with symmetric barbs Subcutaneous: 2–0 braided absorbable sutures Subcuticular: 3–0 Monofilament absorbable suture Skin: Adhesive strips with glue	Arthrotomy: #1 braided absorbable sutures Subcutaneous: 2–0 braided absorbable sutures Subcuticular: 3–0 Monofilament absorbable suture Skin: Adhesive strips with glue
Gamba 2019 [23]	Arthrotomy:Size 2 Quill (Angiotech, Vancouver, British Columbia, Canada), BD Subcutaneous: Size 2–0 Quill (Angiotech, Vancouver, British Columbia, Canada), BD Skin: Staples	Arthrotomy: Size 2 polyglactin 910 (Vicryl, Ethicon, Somerville, NJ), Interrupted Subcutaneous: 2–0 polyglactin 910 (Vicryl, Ethicon, Somerville, NJ), Interrupted Skin: Staples
Li R 2018 [25]	Fascia (hip)/joint capsular (knee): #2 Quill running Fat: #2 Quill running Subcutaneous: #2–0 Vicryl, interrupted suturing Skin: Staples	Fascia (hip) /joint capsular (knee):#1 Vicryl, successive chain shaped suturing Fat: #2–0 Vicryl, (VCP751D) interrupted suturing Subcutaneous: #2–0 Vicryl, (VCP751D) interrupted suturing Skin: Staples
Chan 2017 [20]	Arthrotomy: Running BD, #1 Quill STRATAFIX Subcutaneous: Running #0 Quill STRATAFIX Skin: Staples	Arthrotomy: Interrupted #1Vicryl Subcutaneous: Continous 2/0Vicryl Skin: Staples
Chugaev 2017 [31]	Arthrotomy: Stratafix seam, BD Subcutaneous: Stratafix seam, BD Skin: non-absorbable removable polycaproamide monofilament	Arthrotomy: Vicryl 2, running Subcutaneous: Vicryl 2/0, running Skin: non-absorbable removable polycaproamide monofilament
Malhotra 2017 [26]	Joint capsular: Running #2 Quill SRS® PDO (Angiotech, Vancouver, BC, Canada), BD Fat: Interrupted #2-0Vicryl Subdermal: Interrupted #2-0Vicryl Skin: Staples	Joint capsular: Interrupted #5Ethibond and #1Vicry1 alternatively Fat: Interrupted #2-0Vicryl Subdermal: Interrupted #2-0Vicryl Skin: Staples
Zhao 2017 [33]	Fascia: # 0 Stratafix Subcutaneous: 2–0 Vicryl Skin: 4–0 Vicryl	Fascia: # 1 Vicryl Subcutaneous: 2–0 Vicryl Skin: 4–0 Vicryl
Zhao 2015 [32]	Fascia: # 2 Quill SRS PDO, BD Subcutaneous: 0 Vicryl Skin: 0 Vicryl	Fascia: # 1 Vicryl Subcutaneous: 0 Vicryl Skin: 0 Vicryl

Table 2 (continued)

Author	Barbed suture	Traditional suture
Sah 2015 [27]	Arthrotomy: Running 2–0 Quill (QuillTM Knotless Tissue-Closure Device) Subcutaneous: Running 2-0Quill Subcuticular: Running 2–0 Quill Skin: Unclear	Arthrotomy: Interrupted 2-0Vicryl Subcutaneous: Running2-0 Monocryl Subcuticular: Running 3–0 Monocryl Skin: Unclear
Gililland 2014 [24]	Arthrotomy: Running #2 Quill (QuillTM SRS PDO (Angiotech, Vancouver, BC, Canada) Subdermal: Running #0 Quill Skin: Staples	Arthrotomy: Interrupted #1Ethibond Subdermal: Interrupted 2–0 Monocryl Skin: Staples
Smith 2014 [19]	Arthrotomy for TKA: Running #2 Quill ((SRS; Angiotech Pharmaceuticals, Inc. Vancouver, Canada) Fascia for THA: Running #2 Quill Subcutaneous: Running #0 Quill Subcuticular: Running 2-0Quill Skin: Unclear	Arthrotomy for TKA: Interrupted#1Ethibond Fascia for THA: Interrupted#1Ethibond Subcutaneous: Interrupted 2.0Vicryl Subcuticular: Running3-0Monocryl Skin: Unclear
Ting 2012 [29]	Arthrotomy: Running #2 Quill (PDO) Fascia for THA: Subcutaneous: Running #0 Quill Subcuticular: Running 2-0Quill Skin: Adhesive DERMABOND and staples	Arthrotomy for TKA: Interrupted#1Vicryl Fascia for THA: Interrupted#1Vicryl Subcutaneous: Interrupted 2.0Vicryl Subcuticular: Running2-0Monocryl Skin: Adhesive DERMABOND and staples

BD- bidirectional, PDO- polydioxanone; SRS- Self retaining system, TKA- Total knee arthroplasty: THA- total hip arthroplasty; N/A- Not available

Discussion

The important findings of our review suggest that the use of barbed sutures in total joint arthroplasty is associated with a significantly reduced time for closure, a decreased overall cost, and lesser pinpricks in comparison to the traditional sutures. However, the barbed sutures were also associated with longer hospital stays and more broken sutures. Overall complication rates along with Knee ROM and KSS were similar between barbed and traditional groups.

Barbed sutures or quill sutures were introduced to anchor the sutures in tissues without a knot [7, 34]. These sutures have 3D small barbs within their surface which help in self anchorage and maintain tissue tension without the requirement of knots [35]. In total joint replacement surgeries, the surgeons strive for better wound closure and soft tissue healing. It has been shown that a meticulous and well-closed wound is associated with better patient satisfaction or cosmetic outcomes [7, 9, 15, 34]. A well-closed wound enables early rehabilitation and minimizes the risk of infection [15]. Jamsen et al. noted that wound infection wound hematoma and necrosis to be the three most important causes of reoperation following TKR [36]. Galat et al. reported that those patients who required early surgical interventions for wound complications for TKR are more prone to subsequent revision surgeries or flap coverage [37]. Hence, it would be prudent for any new wound closure modalities to be thoroughly evaluated for these complications. Barbed sutures theoretically provide even soft tissue tension on application, negates the need for knots therein increases the vascularity, and decreases the surgical time [9, 34]. Among the papers encompassed, Sun et al. [15] in their meta-analysis of 12 RCTs, had included 2 dissertations [38, 39].

In our study, the use of barbed sutures was associated with decreased operative time, especially wound closure. It was found to be true in both THR and TKR. The use of barbed sutures decreased the meantime of closure by 6.02 min in TKR and 3.92 min in THR. The knotless design of the suture and the continuous suture technique makes the barbed suture more efficient while wound closure. A decrease in operative time helps to decrease the cost of surgery in settings where time is a factor [9, 27]. However, it may not be a factor in public institution settings where the surgical time is not incorporated in the cost inquired [26]. Moreover, an increased operative time is often associated with more chance of postoperative infection [30, 40].

The overall cost for total joint surgeries is observed to be increasing around the globe [41]. Barbed sutures are costlier than the traditional counterparts. However, we found that the use of barbed sutures is associated with a lesser overall cost in this study. This is because in traditional TKR or THR, the capsule and the soft tissues are sutured intermittently and this uses more sutures. While barbed sutures are being used in a continuous technique without knots which increases the cost-effectiveness as fewer sutures are required. In a low-income country, even a small decrease in the cost of surgery is appreciable. Although the cost may be more

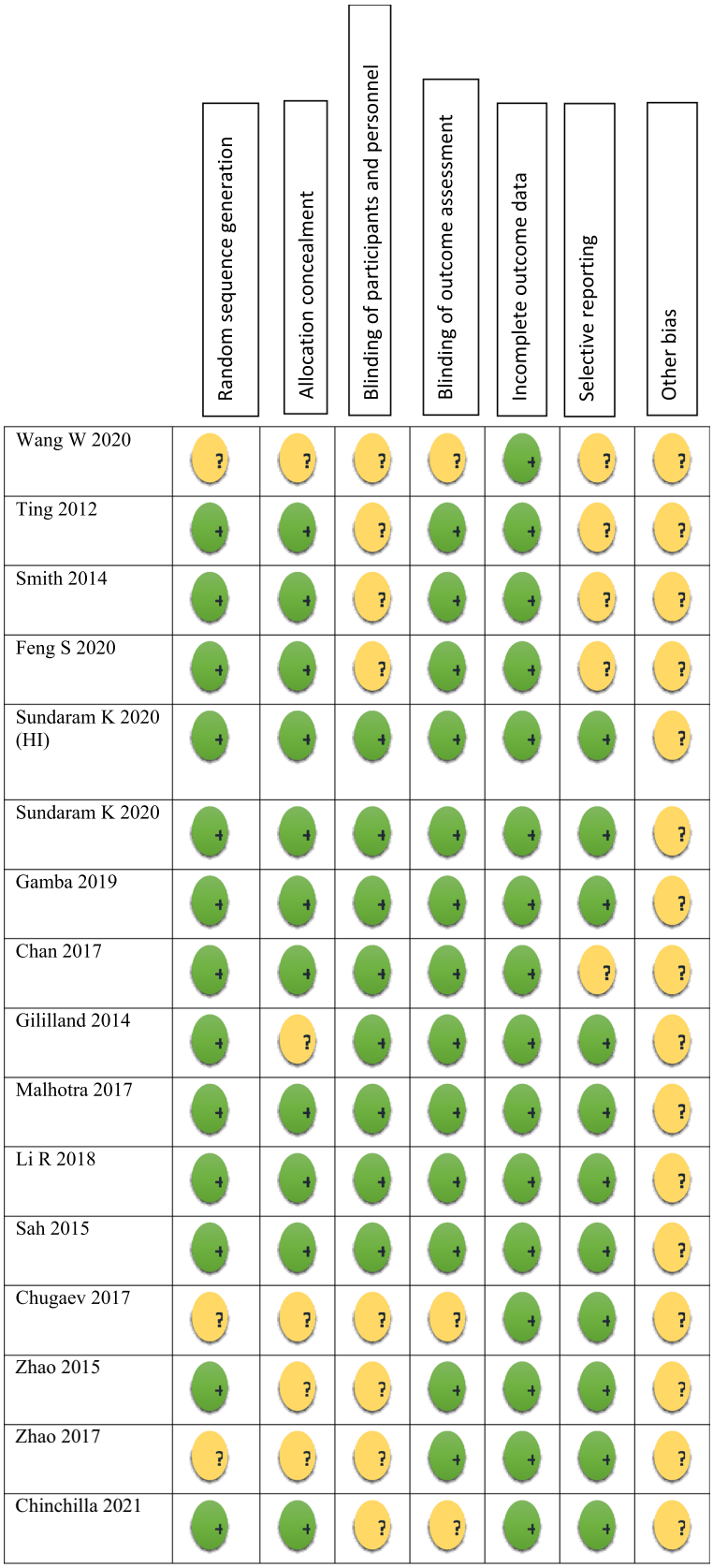
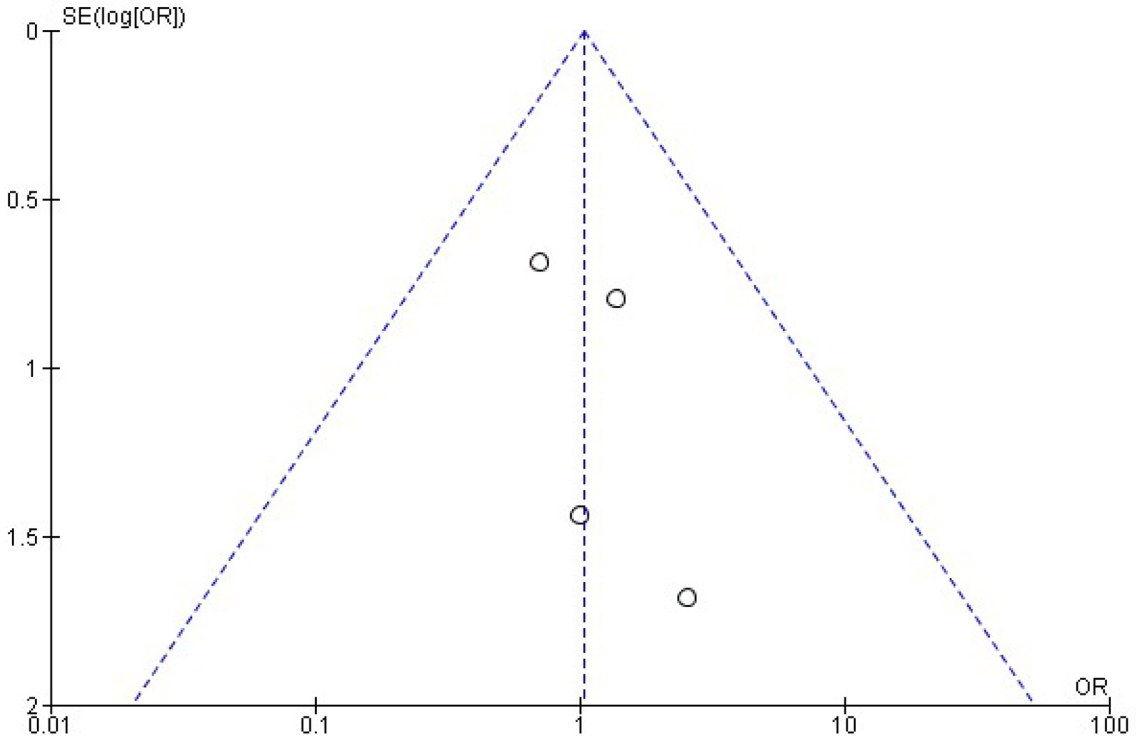
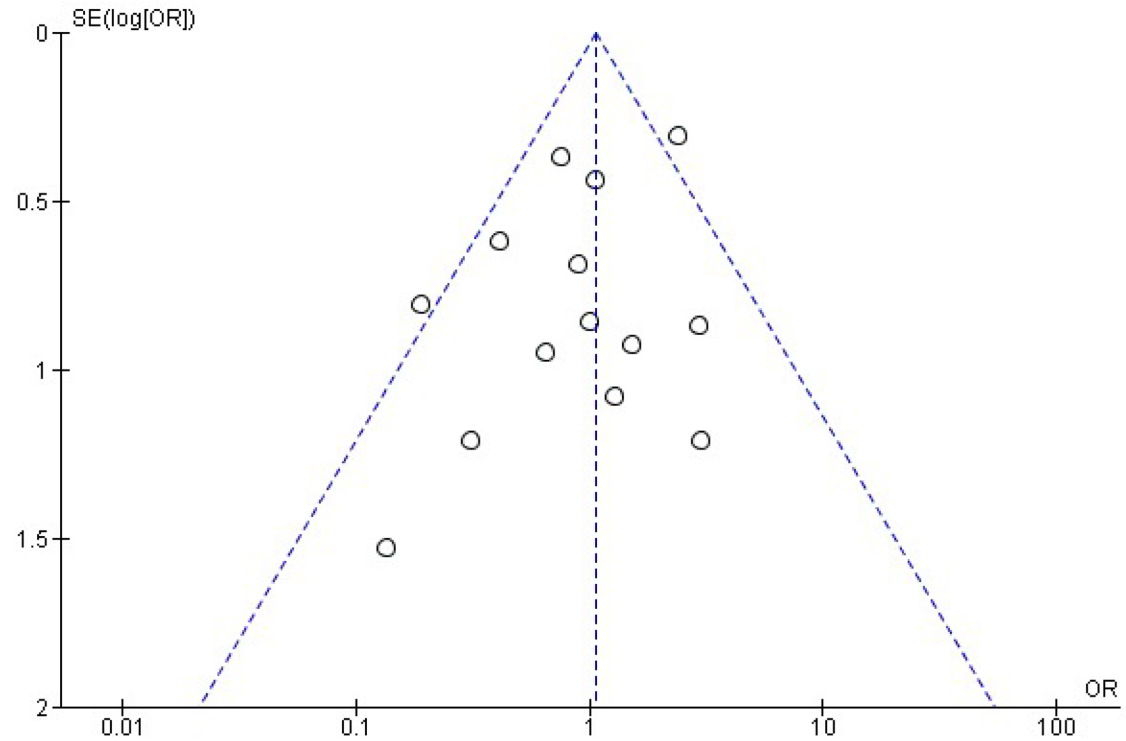


Fig. 2 Risk of bias assessed in the randomized controlled trials. +: no bias, -: bias and ?: bias unknown. Correct randomization by 16 studies. Ten studies showed sufficient allocation concealment. Eleven studies described the blinding of outcome assessment, and eight studies described the blinding of participants and personnel. All included studies retained complete outcome data and avoided selective reporting was avoided in eight studies. Overall, quality of included studies were adequate



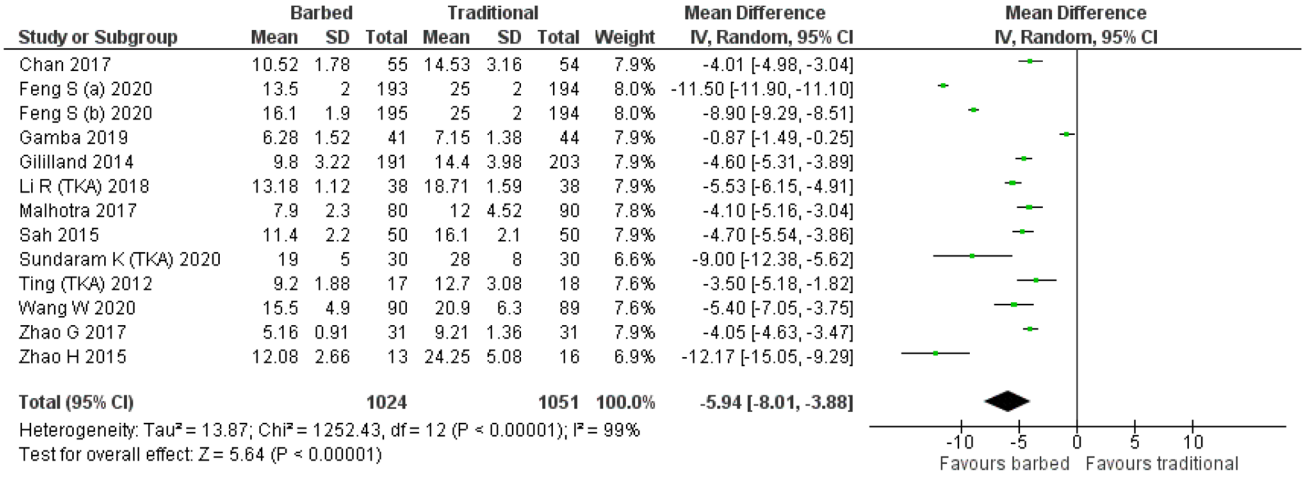
A Complications in Total Hip Replacements



B Complications in Total Knee Replacement

Fig. 3 Funnel Plots. **A** Complications in Total Hip Replacements. **B** Complications in Total Knee Replacement

A



B

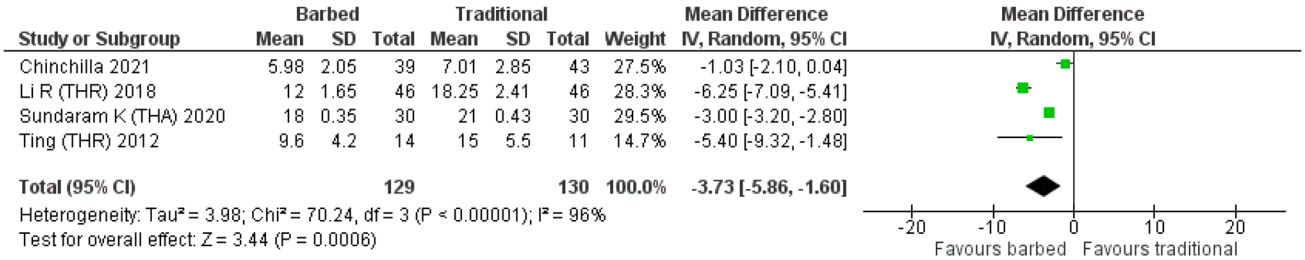
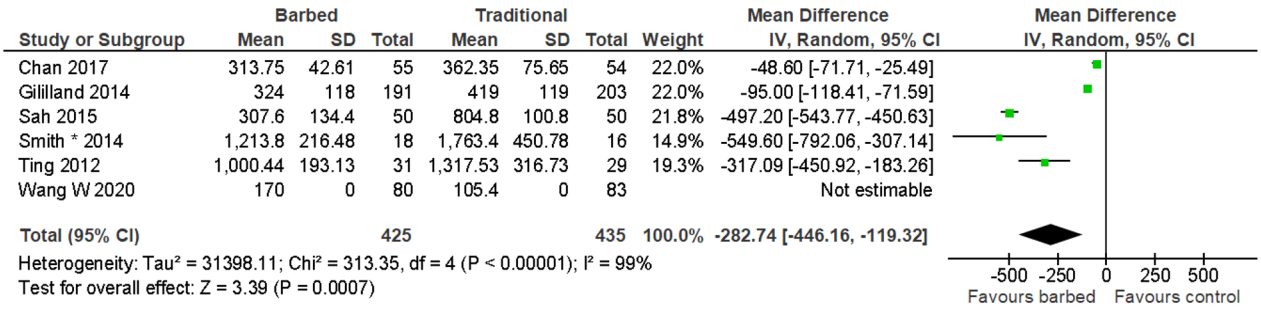


Fig. 4 Pooled analysis of wound closure time between Barbed sutures and traditional sutures. **A** Pooled data analysis of Wound closure time in TKR; **B**: pooled data analysis of Wound closure time in THR. SD: standard deviation; THR: total hip replacement; TKR: total knee replacement; CI: class interval

A



B

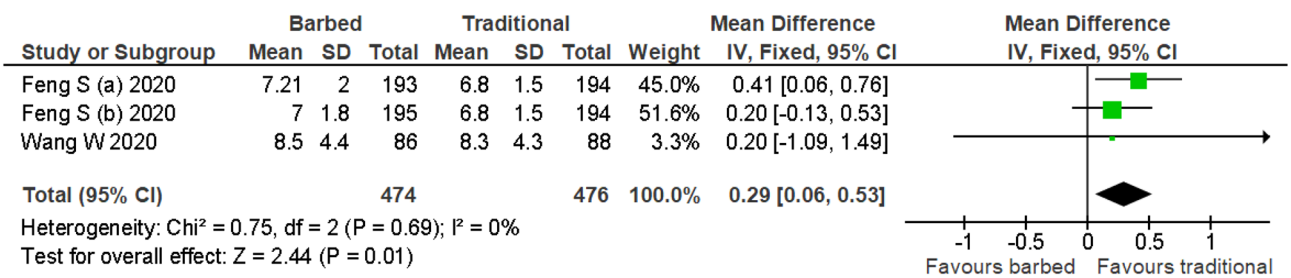


Fig. 5 Pooled data analysis comparing overall cost and length of hospital stay in barbed sutures versus traditional sutures. **A** Pooled data analysis of overall cost; **B** Pooled data analysis of length of hospital stay. SD: Standard deviation; CI: Class Interval

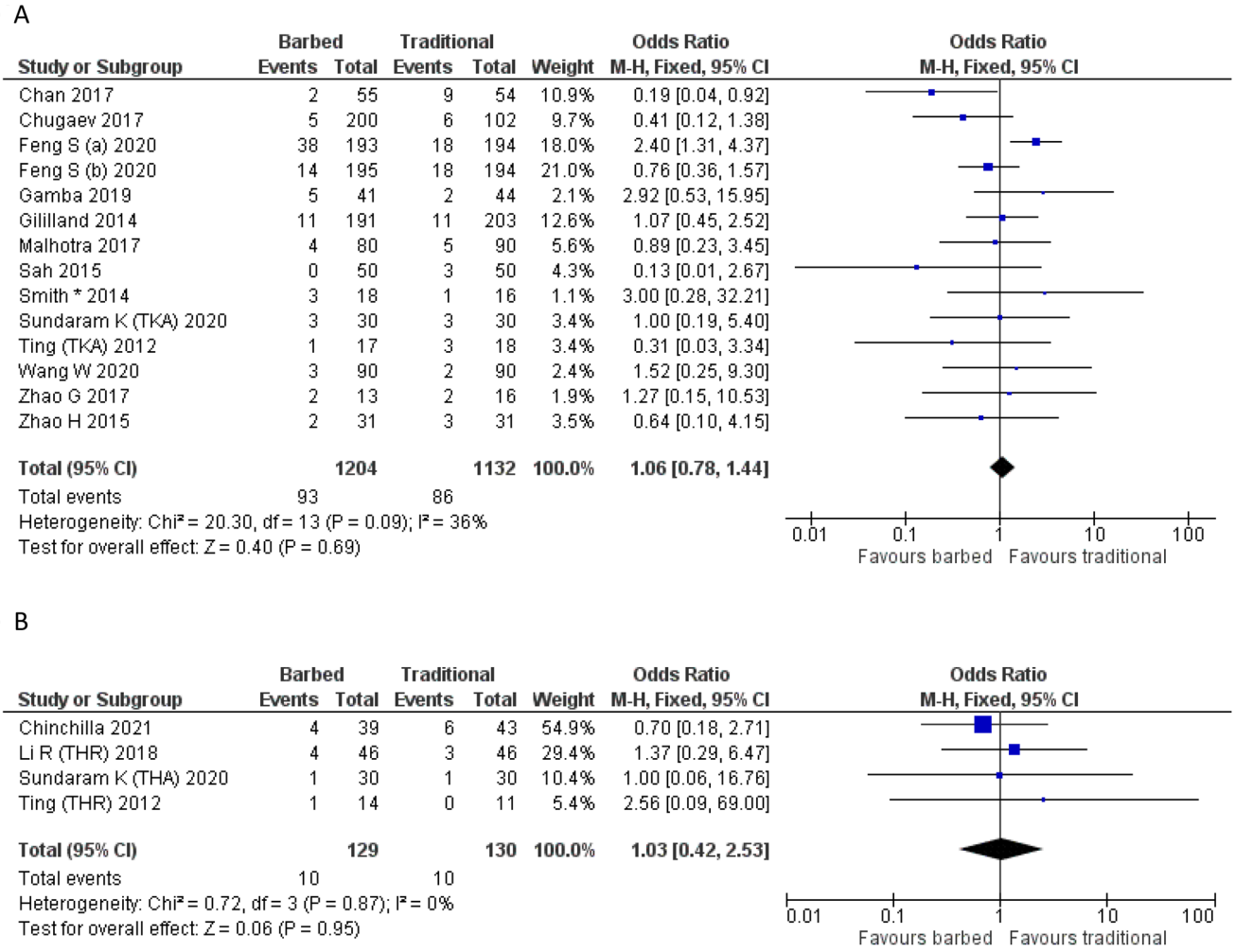


Fig. 6 Pooled analysis of wound-related complications between Barbed sutures and traditional sutures. **A** Pooled data analysis of wound-related complications in TKR; **B** pooled data analysis of wound-related complications in THR. SD: Standard deviation; THR: Total Hip Replacement; TKR: Total Knee Replacement; CI: Class Interval

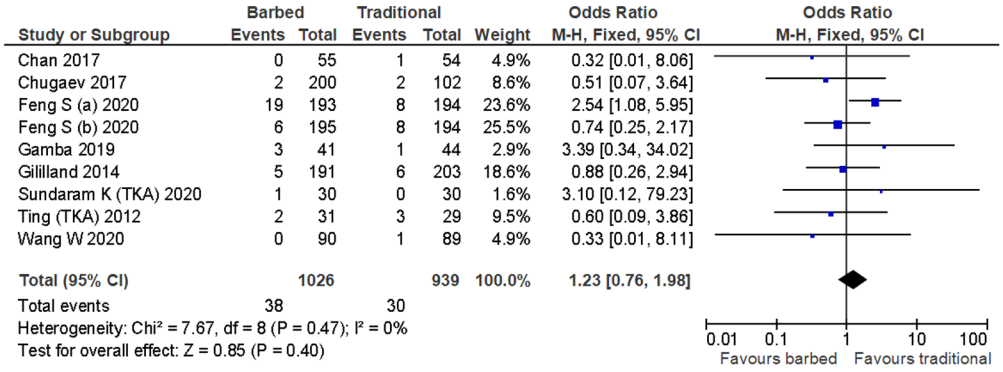
with the use of barbed sutures, the cost–benefit ratio may be highly obliging.

However, the barbed sutures in our study were seen to have significantly more incidence of broken sutures. One can attribute it to the inherent property of the barbed suture or the relative inexperience of the surgeons with the technique. Only two studies compared the length of stay between the groups in our review [21, 22]. The overall analysis revealed an increased length of stay for the barbed sutures. An increase in length of stay with joint replacement may be associated with wound complications such as increased discharge or necrosis, or fear of a new technique [42].

In our study, the use of barbed sutures was similar to the traditional sutures concerning the overall complications both in THR and TKR. Chawla et al. reported increased rates of infection following the use of barbed sutures in uni-compartmental knee arthroplasty [43]. Some studies advocate increased rates of infection with barbed sutures often citing over-tightening of the sutures leading to ischemic necrosis and secondary infection [44] and suture migration and extrusion as a portal for contamination as described by Hammond [45, 46]. However, in our study, the infection rates were found to be similar between the barbed and the traditional groups. While comparing the wound dehiscence rates between the two groups, it was found that the rate of wound dehiscence was similar between the two groups. The wound discharge rates between the two groups were also similar in TKA. The use of barbed sutures was found to have fewer pinpricks. The knotless design of the suture decreases the handling of the suture. Austin et al. assessed the reoperation

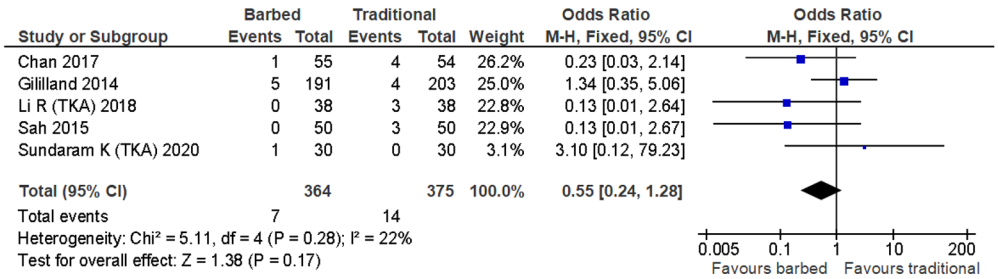
A

Superficial infection TKA



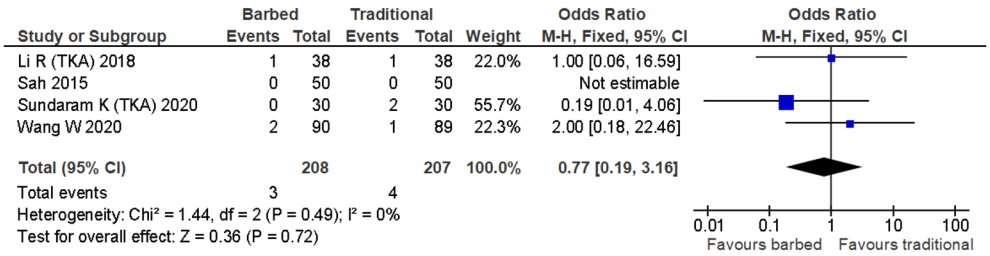
B

Stitch abscess



C

Wound discharge



D

WOUND DEHISCENCE

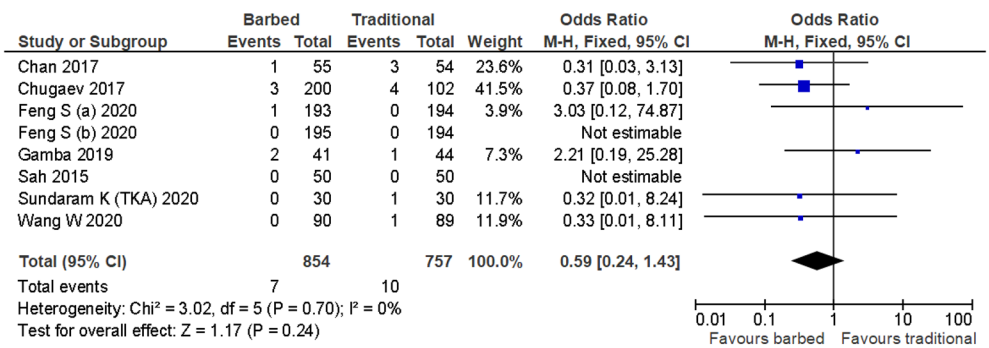
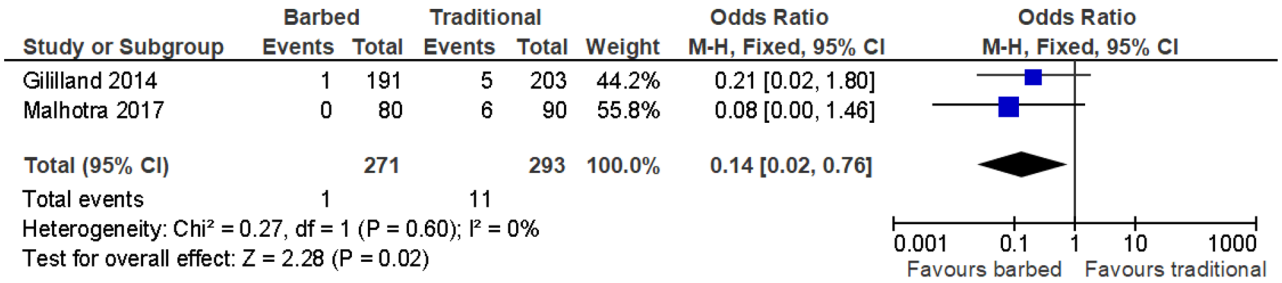


Fig. 7 Pooled analysis (subgroup) of complications between barbed sutures and traditional sutures in TKA. SD: Standard deviation; TKA: Total Knee Arthroplasty; CI: Class Interval

A

PINPRICKS



B

BROKEN SUTURES

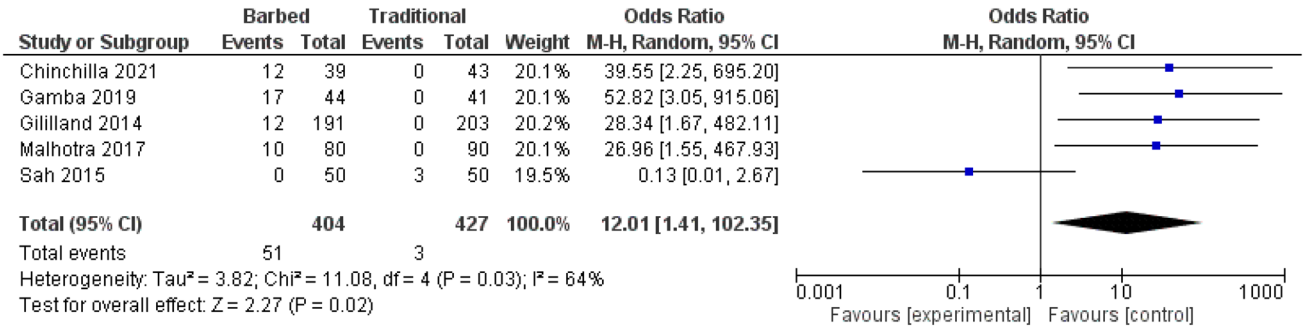


Fig. 8 Pooled data analysis comparing suture related complications between barbed sutures and traditional sutures. SD: Standard deviation; THR: Total Hip Replacement; TKR: Total Knee Replacement; CI: Class Interval

rates between suture types and found no association between the suture type used and 90 days of all-cause surgeries [47]. Similarly, our review found that the use of barbed sutures was not associated with an increased incidence of overall complications and is safe as the traditional counterpart.

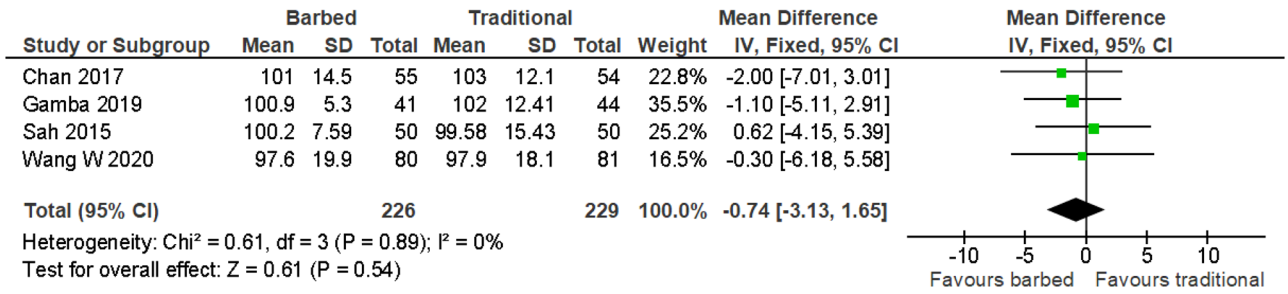
Early mobilization is paramount for patient satisfaction in total joint replacements. Kobayashi et al. in their cadaveric study noted the barbed sutures are capable of maintaining the wound tension during early mobilization and water tightness after closure [48]. Yang et al. noted similar wound holding strength and permeability for the barbed and traditional sutures [49]. Vakil et al. revealed the barbed sutures to be more resistant to cut off [50]. In our study, the range of motion of the knees sutured with the barbed sutures was similar to those with traditional sutures at less than 6 weeks and at more than 3 months follow-up. The knee society score of the two groups was also similar. The use of barbed sutures was not associated with any decreased ROM or decreased patient satisfaction in comparison to the traditional group.

The current meta-analysis has the largest series of RCTs included. The meta-analysis by Li et al. included six RCTs that looked at the effect of barbed sutures in TKR [25]. Han et al. used five RCTs for their meta-analysis [7]. Sun et al. used 12 RCTs in their studies [15]. But, two of the included studies were student dissertations and were not published [38, 39]. Our study has included 6 recent RCTs that were not included in the other meta-analyses. Moreover, the current meta-analysis is the only one in the literature to assess the operative time and overall complications using barbed sutures in both TKR and THR separately. To the best of our knowledge, it's also the first review to analyze the wound dehiscence rate and length of stay between the two groups. The previous meta-analysis reported the incidence of broken sutures to be similar in both groups [15]. In our study, the incidence of broken sutures was more in the barbed group and was significant. The significance of the meta-analysis increases as the number of included studies also increases. The current review has the best possible evidence to comment on the use of barbed sutures in total joint replacement surgeries.

The review has its limitations. Firstly, no homogeneity was seen in the studies about the type of barbed sutures used, and also PROSPERO registration was not done. Moreover, Sah et al. used barbed sutures for subcuticular closure [27]. A homogeneity of barbed suture technique was lacking in

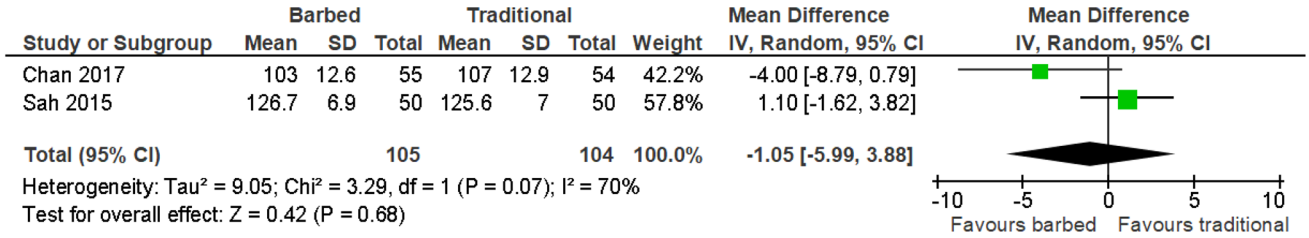
A

Knee rom </= 6 weeks



B

Knee rom >/= 3 months



C

Knee society scores at final follow up

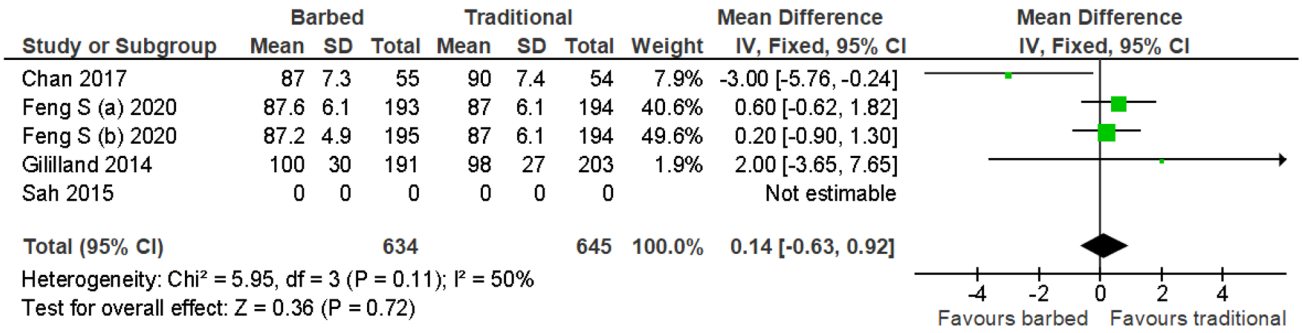


Fig. 9 Pooled data analysis comparing the knee range of motion in barbed sutures versus traditional sutures. A: subgroup analysis comparing knee ROM</=6 weeks; B: subgroup analysis comparing knee ROM>/=3 months. C: subgroup analysis comparing Knee society scores at final follow-up in barbed sutures versus traditional sutures. KSS: knee society scores, ROM: range of motion; CI; Class Interval

the studies as each author used his preferred technique. Second, few studies reported on the use of barbed sutures in THA. We couldn't perform an analysis of the functional outcomes or ROM in THA. However, due to the paucity of data, the current study to the best of our knowledge is the only one to assess the operative time, complication rates while using barbed sutures in THA. Third, we included only RCTs for the study design and hence we might lose on certain findings which may not be evident.

Conclusion

The use of barbed sutures in total joint replacement surgeries decreases the operative time and the overall cost. Pinprick incidence is also decreased. However, the increased incidence of broken sutures was seen to be more with barbed groups and is a concern. The wound complication rates, ROM, and KSS were similar between the two groups. It would be wise to consider barbed sutures as an alternative to the traditional sutures for wound closures in total joint replacement.

Author Contributions BSR: planning of study, literature search, writing the manuscript, quality assessment of the included studies; AKSG: data management, outcome assessment, manuscript preparation; AKC: data management, outcome assessment, manuscript preparation; SP: literature search, writing the manuscript, quality assessment of the included studies and RBK: planning of study, quality assessment of the included studies, writing and revising the manuscript.

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Availability of Data and Materials All included studies used in this systematic review and meta-analysis are available online. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. Data regarding this study is not available in any electronic databases.

Declarations

Conflict of interest All authors declare that they do not have any competing interest, concerning this research, authorship, and/or publication of this article.

Ethics approval Approval from the institutional ethics committee was not required for this review article.

Consent to participate No participants were enrolled for this review article. Hence, informed consent was not required.

Consent to Publish All authors have read the final prepared draft of the manuscript and approve this version, in its current format if considered further for publication.

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