



Surgical Strategies for Apical Pelvic Organ Prolapse: A Systematic Review and Network Meta-Analysis

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Abstract

Introduction and Hypothesis Comparative effectiveness of surgical approaches to apical pelvic organ prolapse (POP) remains uncertain, particularly regarding recurrence, reoperation and mesh-related outcomes over the available follow-up. The objective was to compare the effectiveness and safety of surgical treatments for primary apical pelvic organ prolapse (POP) using a systematic review and network meta-analysis of randomised controlled trials (RCTs).

Methods Comprehensive searches were conducted in Web of Science, Scopus, Embase, Medline, Cochrane Library, WHO, and ICTRP databases from inception to 30 June 2025. English-language RCTs comparing surgical interventions for apical POP, alone or with other compartment repairs, were included if they reported anatomical recurrence after ≥ 1 -year follow-up. Studies on non-surgical interventions were excluded. The primary outcome was anatomical recurrence; secondary outcomes included subjective recurrence, reoperation rates and mesh complications. Risk of bias was assessed using the Cochrane tool, and study integrity was evaluated with the Trustworthiness in Randomised Controlled Trials checklist. A random-effects network meta-analysis (NMA; NMAstudio 2.0) was performed, grouping interventions by clinical similarity. Native tissue repair (NTR) served as the reference.

Results Fifty-eight RCTs (6,846 participants) were included. Vaginal, abdominal and laparoscopic mesh repairs significantly reduced anatomical recurrence versus NTR (relative risk 0.59–0.66). Vaginal mesh and laparoscopic sacrocolpopexy with posterior plication lowered subjective recurrence (relative risk 0.22–0.51). Abdominal sacrocolpopexy was associated with fewer recurrence-related reoperations (relative risk 0.40), whereas vaginal mesh had higher mesh-related reoperations (relative risk 5.19).

Conclusions Mesh-augmented vaginal, laparoscopic and abdominal repairs reduce prolapse recurrence compared with NTR but carry increased mesh-related risks. Sacrocolpopexy was associated with favourable anatomical durability for apical POP.

Keywords Apical prolapse · Native tissue repair · Network meta-analysis · Pelvic organ prolapse surgery · Sacrocolpopexy · Transvaginal mesh

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Abbreviations

Abs	Absorbable suture
ASC	Abdominal sacrocolpopexy
Barb	Barbed suture
CI	Confidence interval
LSC	Laparoscopic sacrocolpopexy/cervicopexy
NMA	Network meta-analysis
NTR	Native tissue repair
Perm	Permanent suture
POP-Q	Pelvic Organ Prolapse Quantification
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised controlled trial
RoB	Risk of bias

SSLF	Sacrospinous ligament fixation
TRACT	Trustworthiness in Randomised Controlled Trials
TVM	Transvaginal mesh
USLS	Uterosacral ligament suspension
VM	Vaginal mesh

Introduction

Apical prolapse is vaginal apex descent, which is particularly more common in women post-hysterectomy. Abdominal sacrocolpopexy (ASC) is considered the gold standard for surgical management owing to its great effectiveness and durability in preventing recurrence [1–6]. Note that ASC involves suspending the vaginal apex to the anterior longitudinal ligament overlying the sacrum with synthetic mesh, autologous or biologic graft, which has shown long-term success rates between 78 and 100% [1, 7]. Minimally invasive techniques are increasingly preferred to optimise patient outcomes, offering reduced postoperative pain and faster recovery while maintaining surgical efficacy. With advances in technology and surgical expertise, laparoscopic and robotics-assisted approaches have become the favoured methods for performing ASC. However, abdominal approaches are more invasive and technically demanding than vaginal techniques, such as sacrospinous ligament fixation (SSLF) and uterosacral ligament suspension (USLS), which are associated with shorter recovery times and fewer complications [8, 9].

Recent systematic reviews provide a nuanced comparison of these techniques. Maher et al. analysed randomised controlled trials (RCTs) and found that vaginal approaches, such as SSLF and USLS, offer benefits in reduced recovery time and cost-effectiveness but have a higher risk of recurrence of prolapse than ASC [10]. Although these vaginal procedures are less invasive, they may have higher recurrence rates in some cases, gluteal pain in 15% and other side effects [11, 12]. Selecting the appropriate surgical technique depends on individual patient anatomy and goals [9, 11].

Surgical materials, such as sutures and mesh, have also contributed to advancements in apical prolapse surgery. There has been a shift from permanent to absorbable sutures, such as Vicryl (polyglycolic acid) and polydioxanone (PDS), which reduce complications but may not provide the same long-term support [2, 13, 14]. Yeung et al. [15] evaluated transvaginal mesh (TVM) versus native tissue repair (NTR) and found that although mesh-based procedures may lower recurrence rates, they pose a greater risk of mesh exposure and revision surgery, necessitating cautious selection.

Considering the wide range of available surgical techniques for apical prolapse repair, previous systematic reviews and pairwise meta-analyses have primarily focused

on selected head-to-head comparisons, limiting comprehensive evaluation across all available interventions [10, 15, 16]. Our study expands on this evidence by using a network meta-analysis (NMA), which integrates direct and indirect evidence to enable simultaneous comparison of multiple surgical approaches within a single analytical framework, including interventions that have not been directly compared in randomised trials.

This is a systematic review and NMA of RCTs evaluating the effectiveness and safety of surgical treatment modalities for primary apical prolapse, including anatomical and subjective recurrence, Pelvic Organ Prolapse Quantification (POP-Q) measurements, reoperation rates and mesh-related complications at 1–3 years of follow-up. Using NMA, direct and indirect comparisons were performed across a network of RCTs, enabling comparisons between interventions that had not been evaluated in head-to-head trials.

Materials and Methods

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for NMA [17]. The study protocol was registered in the International Prospective Register of Systematic Reviews (CRD42024467290).

Study Inclusion Criteria

We included RCTs published in English full text that involved surgical interventions for pelvic organ prolapse (POP) in a general population of women. NTR was defined as apical suspension procedures performed without synthetic mesh or biologic graft augmentation, including SSLF, USLS, hysteropexy, Manchester procedures, and related suture-based reconstructive techniques. The control groups were required to include alternative surgical procedures addressing the same condition. The primary outcome was the rate of anatomical recurrence at 1–3 years post-surgery.

Secondary outcomes included subjective recurrence, reoperation rates (for prolapse recurrence and mesh erosion), and mesh complications.

The studies included focused on apical prolapse, whether alone or in combination with other prolapse compartments. We excluded studies focusing on non-surgical interventions. In cases where the same study was reported across multiple publications, particularly for different follow-up periods, we treated them as a single study (Tables 1, 2).

Systematic Search Strategy

A comprehensive systematic search was conducted up to June 2025 using a predefined combination of keywords.

Table 1 Characteristics of the randomised controlled trials (RCTs) included

Reference	Year	Country	Longest follow-up (years)	Intervention (population)	Control (population)	Age at intervention, mean ($\pm$ SD)	Age of control, mean ($\pm$ SD)
Benson et al. [18]	1996	USA	1	AS_Syn_Mesh (38)	Vag_NTR (42)	66.2 ($\pm$ 9.7)	63.6 ($\pm$ 9.3)
Lo and Wang [19]	1998	China	1	AS_Syn_Mesh (52)	Vag_NTR (66)	63.1 ($\pm$ 9.1)	60.1 ($\pm$ 9.9)
Maher et al. [20]	2004	Australia	2	AS_Syn_Mesh (46)	Vag_NTR (42)	63.4 ($\pm$ 10.3)	62.9 ($\pm$ 10.3)
Roovers et al. [21]	2004	Netherlands	1	AS_Syn_Mesh (41)	Vag_NTR (41)	57.9 ($\pm$ 8.8)	56.4 ($\pm$ 10.9)
Culligan et al. [22]	2005	USA	1	AS_Bio_Mesh (44)	AS_Syn_Mesh (45)	57.5 ($\pm$ 10.8)	60.4 ($\pm$ 10.1)
Dietz et al. [23]	2010	Netherlands	1	Vag_NTR_Hpxy (34)	Vag_NTR (31)	61.5 ($\pm$ 9.6)	63.7 ($\pm$ 9.0)
Lopes et al. [24]	2010	Brazil	1	Vag_Syn_Mesh (14)	Vag_NTR (16)	65.5	63.1
Natale et al. [25]	2010	Italy	1	Vag_Syn_Mesh_M (116)	Vag_Syn_Mesh (113)	65.2	63.7
Maher et al. [26]	2011	Australia	2	Vag_Syn_Mesh (55)	LS_Syn_Mesh (53)	63.0 ($\pm$ 8.8)	63.0 ($\pm$ 8.1)
Paraiso et al. [27]	2011	USA	1	RS_Syn_Mesh (26)	LS_Syn_Mesh (23)	61.0 ($\pm$ 9.0)	60.0 ($\pm$ 11.0)
Detollenaere et al. [28]	2011	Netherlands	5	Vag_NTR_Hpxy (102)	Vag_NTR (100)	62.7	61.9
Halaska et al. [29]	2012	Czech Republic	1	Vag_Syn_Mesh (79)	Vag_NTR (72)	63.4 ($\pm$ 10.1)	66.4 ($\pm$ 9.6)
Sokol et al. [30]	2012	USA	3	Vag_Syn_Mesh (32)	Vag_NTR (33)	64.4 ($\pm$ 10.8)	63.5 ($\pm$ 8.9)
Ray et al. [31]	2013	India	2	Vag_NTR_PDS (80)	Vag_NTR (82)	48.2 ($\pm$ 10.9)	49.5 ($\pm$ 10.6)
Nygaard et al. [3]	2013	USA	7	AS_Syn_Mesh_Burch (69)	AS_Syn_Mesh (76)	61.9 ($\pm$ 10.0)	61.9 ($\pm$ 10.0)
Culligan et al. [32]	2013	USA	1	AS_Bio_Mesh (57)	AS_Syn_Mesh (50)	57.7 ($\pm$ 8.3)	56.2 ($\pm$ 8.5)
Barber et al. [33]	2014	USA	2	Vag_NTR_USLF (155)	Vag_NTR (149)	57.2	57.3
Noé et al. [34]	2014	Germany	3	LS_Syn_Mesh_P (41)	LS_Syn_Mesh (41)	62.1	61.1
Da Silveira et al. [35]	2020	Brazil	5	Vag_Syn_Mesh (94)	Vag_NTR (90)	66.3 ($\pm$ 7.0)	64.9 ($\pm$ 7.5)
Švábík et al. [36]	2014	Czech Republic	1	Vag_Syn_Mesh (36)	Vag_NTR (34)	63.4 ($\pm$ 8.6)	62.5 ($\pm$ 10.8)
Tan-Kim et al. [37]	2015	USA	1	LS_Syn_Mesh_Barbed (28)	LS_Syn_Mesh (26)	57.7 ($\pm$ 9.1)	59.8 ($\pm$ 9.7)
Costantini et al. [38]	2013	Italy	2	LS_Syn_Mesh (60)	AS_Syn_Mesh (60)	60.6 ($\pm$ 8.2)	61.3 ($\pm$ 10.5)
El-agwany et al. [39]	2015	Egypt	1	LS_Syn_Mesh (15)	AS_Syn_Mesh (15)	56.6 ($\pm$ 9.4)	48.8 ($\pm$ 8.34)
Damiani et al. [40]	2016	Italy	1	Vag_Syn_Mesh (28)	Vag_NTR (30)	56.9 ($\pm$ 4.4)	55.6 ($\pm$ 8.6)
Rondini et al. [41]	2015	Chile	1	AS_Syn_Mesh (56)	Vag_NTR (54)	57.1 ($\pm$ 10.4)	57.3 ($\pm$ 10.1)
Kenton et al. [42]	2016	USA	1	RS_Syn_Mesh (33)	LS_Syn_Mesh (33)	58.5 ($\pm$ 10.5)	60.6 ($\pm$ 9.2)
Coolen et al. [6]	2017	Netherlands	1	LS_Syn_Mesh (29)	AS_Syn_Mesh (29)	65.2	66.7
Van Oudheusden et al. [4]	2023	Netherlands	1	LS_Syn_Mesh (31)	Vag_NTR (30)	61.7 ($\pm$ 9.7)	66.0 ($\pm$ 11.8)
Ow et al. [43]	2018	Australia	4	Vag_Syn_Mesh (39)	AS_Syn_Mesh (43)	65.3 ($\pm$ 7.9)	66.5 ($\pm$ 7.4)
Nager et al. [44]	2019	USA	5	Vag_Syn_Mesh (87)	Vag_NTR (85)	65.5 ($\pm$ 7.3)	66.2 ($\pm$ 7.4)
Steures et al. [45]	2019	Netherlands	2	Vag_Syn_Mesh (71)	Vag_NTR (69)	65.0 ($\pm$ 10.5)	65.4 ($\pm$ 8.5)
Illiano et al. [46]	2019	Italy	1	RS_Syn_Mesh (49)	LS_Syn_Mesh (51)	60.2 ($\pm$ 10.3)	60.3 ($\pm$ 8.6)
De Castro et al. [47]	2019	Brazil	1	Vag_Syn_Mesh (35)	AS_Syn_Mesh (36)	64.1 ($\pm$ 4.8)	64.8 ($\pm$ 4.8)
Enklaar et al. [48]	2023	Netherlands	2	Vag_NTR_Manch (195)	Vag_NTR_Hpxy (196)	63.0	61.0
Galad et al. [49]	2020	Slovakia	3	Vag_Syn_Mesh (52)	Vag_NTR (50)	63.1 ($\pm$ 8.7)	63.6 ($\pm$ 8.7)
Kowalski et al. [50]	2021	USA	1	Vag_NTR_Perm (22)	Vag_NTR (22)	62.1 ($\pm$ 13.7)	63.6 ($\pm$ 10.2)
Matthews et al. [51]	2020	USA	1	AS_Syn_Mesh_Perm (95)	AS_Syn_Mesh (87)	59.7 ($\pm$ 10.7)	59.7 ($\pm$ 10.2)
Hemming et al. [52]	2020	UK	1	Vag_NTR_Hpxy (280)	Vag_NTR (283)	63.4 ($\pm$ 10.2)	66.4 ($\pm$ 9.6)
Hemming et al. [52]	2020	UK	1	AS_Syn_Mesh (104)	Vag_NTR (104)	64.4 ($\pm$ 10.8)	63.5 ($\pm$ 8.9)
Van IJsselmuiden et al. [53]	2020	Netherlands	1	LS_Syn_Mesh (55)	Vag_NTR_Hpxy (58)	61.1 ($\pm$ 9.8)	60.8 ($\pm$ 10.7)

Table 1 (continued)

Reference	Year	Country	Longest follow-up (years)	Intervention (population)	Control (population)	Age at intervention, mean ($\pm$ SD)	Age of control, mean ($\pm$ SD)
Başer et al. [54]	2020	Turkey	2	Vag_NTR (73)	Vag_NTR_NoApical (77)	53.8 ($\pm$ 9.7)	51.9 ($\pm$ 8.8)
Berger et al. [55]	2020	USA	1	LS_Syn_Mesh_Anchor (21)	LS_Syn_Mesh (25)	62.1 ($\pm$ 8.6)	59.3 ($\pm$ 8.9)
Obut et al. [56]	2021	Turkey	1	LS_Syn_Mesh_P (32)	LS_Syn_Mesh (30)	41.3 ($\pm$ 9.2)	42.5 ($\pm$ 8.1)
Ferrando and Paraiso [57]	2021	USA	2	LS_Syn_Mesh_Flat (24)	LS_Syn_Mesh (20)	62.4 ($\pm$ 8.1)	60.3 ($\pm$ 7.3)
Cengiz et al. [58]	2021	Turkey	1	LS_Syn_Mesh (15)	Vag_NTR (19)	56.3 ($\pm$ 0.6)	57.8 ($\pm$ 0.6)
Castro et al. [59]	2021	Brazil	1	Vag_NTR_Perm (49)	Vag_NTR (40)	63.0 ($\pm$ 8.0)	64.0 ($\pm$ 8.0)
Tagliaferri et al. [60]	2021	Italy	1	LS_Syn_Mesh_Abs (75)	LS_Syn_Mesh (75)	59.0 ($\pm$ 8.0)	58.0 ($\pm$ 6.0)
Gamal et al. [61]	2022	Egypt	1	AS_Bio_Mesh (15)	AS_Syn_Mesh (15)	32.1 ($\pm$ 4.0)	33.7 ($\pm$ 3.7)
Isenlik et al. [62]	2022	Turkey	1	LS_Syn_Mesh_LS (40)	LS_Syn_Mesh (40)	59.4 ($\pm$ 8.6)	59.4 ($\pm$ 8.8)
Karadag et al. [63]	2023	Turkey	1	LS_Syn_Mesh (33)	Vag_NTR (35)	62.1 ($\pm$ 7.7)	65.2 ($\pm$ 9.1)
Daneshpajooch et al. [64]	2022	Iran	1	LS_Syn_Mesh (16)	Vag_NTR (16)	63.1	65.4
De Tayrac et al. [65]	2022	France	1	Vag_Syn_Mesh (20)	LS_Syn_Mesh (19)	61.0	65.0
Morciano et al. [66]	2022	Italy	1	LS_Syn_Mesh_CLS (38)	LS_Syn_Mesh (37)	62.0	64.0
Chen et al. [67]	2022	China	1	Vag_Syn_Mesh_Self-cut (169)	Vag_Syn_Mesh (167)	63.8 ($\pm$ 5.8)	62.8 ($\pm$ 5.9)
Morciano et al. [68]	2023	Italy	1	LS_Syn_Mesh_PP (62)	LS_Syn_Mesh (60)	66.0	65.0
Hwang et al. [69]	2024	Japan	1	LS_Syn_Mesh (55)	Vag_NTR_USLF (57)	68.1 ($\pm$ 6.4)	69.7 ($\pm$ 7.1)
Menefee et al. [70]	2024	USA	3	LS_Syn_Mesh (113)	Vag_NTR (122)	65.4 ($\pm$ 8.6)	66.4 ($\pm$ 8.5)
Di Biasi et al. [71]	2025	Italy	1	LS_Syn_Mesh_NoPost (60)	LS_Syn_Mesh (60)	62.4	60.9

Abs absorbable suture, *AS* abdominal surgery, *Bio* biologic graft, *CLS* continuous locked suture, *Hpxy* Hysteropexy, *LS* laparoscopic surgery, *Manch* Manchester, *NTR* native tissue repair, *P* pectopexy, *PDS* polydioxanone, *Perm* permanent suture, *PP* posterior plication, *RS* robotic surgery, *Syn* synthetic mesh, *USLF* uterosacral ligament fixation, *Vag* vaginal mesh

Databases searched included Web of Science, Scopus, Embase, Medline, Cochrane Library, World Health Organization, and the International Clinical Trial Registry. We also manually checked the references of the studies included to identify additional relevant studies. All references were imported into Covidence and were independently screened by at least two reviewers. Any disagreements were resolved through consensus by at least three reviewers.

Data Extraction

The data extraction was performed in Covidence. Variables covering study characteristics, details of the intervention and control arms, primary and secondary outcomes, and follow-up periods beyond. Data extraction was performed by at least two reviewers, with any inconsistencies resolved by a third reviewer.

Risk of Bias Assessment

The risk-of-bias (RoB) assessment for the studies included was evaluated using the Cochrane evidence quality tool [73].

Integrity Screening

The Trustworthiness in Randomized Controlled Trials (TRACT) tool [74] was used to screen RCTs for data integrity. The TRACT tool evaluates seven domains: governance, author group, plausibility of intervention usage, timeframe, drop-out rates, baseline characteristics and outcomes, to determine whether an RCT raises concerns regarding data integrity. Two reviewers independently screened all RCTs and categorised them as having “no concerns”, “some concerns” or “major concerns”. Studies with “no concerns” were indicated to be low risk, “some concerns” indicated a

Table 2 Recurrence rate of prolapse after primary prolapse surgery

Reference	Intervention (Int)	Control (Ctrl)	1- to 3-year recurrence rate, intervention group, <i>N</i> /population (%)	1- to 3-year recurrence rate, control group, <i>N</i> /population (%)
Benson et al.* [18]	AS_Syn_Mesh	Vag_NTR	6/38 (15.8%)	14/42 (33.3%)
Lo and Wang* [19]	AS_Syn_Mesh	Vag_NTR	3/52 (5.8%)	13/66 (19.7%)
Maher et al.** [26]	AS_Syn_Mesh	Vag_NTR	11/46 (23.9%)	13/42 (31.0%)
Roovers et al.* [21]	AS_Syn_Mesh	Vag_NTR	2/41 (4.9%)	2/41 (4.9%)
Culligan et al.* [22]	AS_Bio_Mesh	AS_Syn_Mesh	14/44 (31.8%)	4/45 (8.9%)
Dietz et al.* [23]	Vag_NTR_Hpxy	Vag_NTR	7/34 (20.6%)	1/31 (3.2%%)
Lopes et al.* [24]	Vag_Syn_Mesh	Vag_NTR	8/14 (57.1%)	7/16 (43.8%)
Natale et al.* [25]	Vag_Syn_Mesh_M	Vag_Syn_Mesh	4/116 (3.4%)	2/113 (1.8%)
Maher et al.** [20]	Vag_Syn_Mesh	LS_Syn_Mesh	22/55 (40.0%)	12/53 (22.6%)
Paraiso et al.* [27]	RS_Syn_Mesh	LS_Syn_Mesh	3/26 (11.5%)	2/23 (8.7%)
Detollenaere et al.** [28]	Vag_NTR_Hpxy	Vag_NTR	2/102 (2.0%)	7/100 (7.0%)
Halaska et al.* [29]	Vag_Syn_Mesh	Vag_NTR	13/79 (16.5%)	28/72 (38.9%)
Sokol et al.** [30]	Vag_Syn_Mesh	Vag_NTR	20/32 (62.5%)	23/33 (69.7%)
Freeman et al.** [72]	LS_Syn_Mesh	AS_Syn_Mesh	0/33	4/34 (11.8%)
Ray et al.** [31]	Vag_NTR_PDS	Vag_NTR	5/80 (6.2%)	4/82 (4.9%)
Nygaard et al.** [3]	AS_Syn_Mesh_Burch	AS_Syn_Mesh	5/69 (7.2%)	8/76 (10.5%)
Culligan et al.* [32]	AS_Bio_Mesh	AS_Syn_Mesh	11/57 (19.3%)	8/50 (16.0%)
Barber et al.** [33]	Vag_NTR_USLF	Vag_NTR	55/155 (35.5%)	55/149 (36.9%)
Noé et al.** [34]	LS_Syn_Mesh_P	LS_Syn_Mesh	1/41 (2.4%)	4/41 (9.8%)
Da Silveira et al.** [35]	Vag_Syn_Mesh	Vag_NTR	7/94 (7.4%)	16/90 (17.8%)
Švabík et al.* [36]	Vag_Syn_Mesh	Vag_NTR	1/36 (2.8%)	22/34 (64.7%)
Tan-Kim et al.* [37]	LS_Syn_Mesh_Barbed	LS_Syn_Mesh	3/28 (10.7%)	2/26 (7.7%)
Costantini et al. [38]	LS_Syn_Mesh	AS_Syn_Mesh	0/60	0/60
El-agwany et al.* [39]	LS_Syn_Mesh	AS_Syn_Mesh	0/15	0/15
Damiani et al.* [40]	Vag_Syn_Mesh	Vag_NTR	1/28 (3.6%)	15/59 (25.4%)
	Vag_Bio_Mesh			
Rondini et al.* [41]	AS_Syn_Mesh	Vag_NTR	0/56	10/54 (18.5%)
Kenton et al.* [42]	RS_Syn_Mesh	LS_Syn_Mesh	0/33	1/33 (3.0%)
Coolen et al.* [6]	LS_Syn_Mesh	AS_Syn_Mesh	9/29 (31.0%)	10/29 (34.5%)
Van Oudheusden et al.* [4]	LS_Syn_Mesh	Vag_NTR	14/31 (45.2%)	19/30 (63.3%)
Ow et al.** [43]	Vag_Syn_Mesh	AS_Syn_Mesh	16/39 (41.0%)	16/43 (37.2%)
Nager et al.** [44]	Vag_Syn_Mesh	Vag_NTR	10/87 (11.5%)	20/85 (23.5%)
Steures et al.** [45]	Vag_Syn_Mesh	Vag_NTR	39/71 (54.9%)	47/69 (68.1%)
Illiano et al.* [46]	RS_Syn_Mesh	LS_Syn_Mesh	2/49 (4.1%)	7/51 (13.7%)
De Castro et al.* [47]	Vag_Syn_Mesh	AS_Syn_Mesh	0/35	1/36 (2.8%)
Enklaar et al.** [48]	Vag_NTR_Manch	Vag_NTR_Hpxy	1/195 (0.5%)	6/196 (3.1%)
Galad et al.** [49]	Vag_Syn_Mesh	Vag_NTR	4/52 (7.7%)	15/50 (30.0%)
Kowalski et al.* [50]	Vag_NTR_Perm	Vag_NTR	4/22 (18.2%)	2/22 (9.1%)
Matthews et al.* [51]	AS_Syn_Mesh_Perm	AS_Syn_Mesh	20/95 (21.1%)	17/87 (19.5%)
Hemming et al.* [52]	Vag_NTR_Hpxy	Vag_NTR	74/233 (31.8%)	78/229 (34.1%)
Hemming et al.* [52]	AS_Syn_Mesh	Vag_NTR	28/86 (32.6%)	38/81 (46.9%)
Van IJsselmuiden et al.* [53]	LS_Syn_Mesh	Vag_NTR_Hpxy	35/55 (63.6%)	36/58 (62.1%)
Başer et al.** [54]	Vag_NTR	Vag_NTR_NoApical	1/73 (1.4%)	5/77 (6.5%)
Berger et al.* [55]	LS_Syn_Mesh_Anchor	LS_Syn_Mesh	1/21 (4.8%)	1/25 (4.0%)
Obut et al.* [56]	LS_Syn_Mesh_P	LS_Syn_Mesh	1/32 (3.1%)	0/30
Ferrando and Paraiso** [57]	LS_Syn_Mesh_Flat	LS_Syn_Mesh	4/24 (16.7%)	5/20 (25.0%)
Cengiz et al.* [58]	LS_Syn_Mesh	Vag_NTR	0/15	0/19
Castro et al.* [59]	Vag_NTR_Perm	Vag_NTR	5/49 (10.2%)	8/40 (20.0%)

Table 2 (continued)

Reference	Intervention (Int)	Control (Ctrl)	1- to 3-year recurrence rate, intervention group, <i>N</i> /population (%)	1- to 3-year recurrence rate, control group, <i>N</i> /population (%)
Tagliaferri et al.* [60]	LS_Syn_Mesh_Abs	LS_Syn_Mesh	0/75	0/75
Gamal et al.* [61]	AS_Bio_Mesh	AS_Syn_Mesh	1/15 (6.7%)	0/15
Isenlik et al.* [62]	LS_Syn_Mesh_LS	LS_Syn_Mesh	3/40 (7.5%)	0/40
Karadag et al.* [63]	LS_Syn_Mesh	Vag_NTR	3/33 (9.1%)	12/35 (34.3%)
Daneshpajooch et al.* [64]	LS_Syn_Mesh	Vag_NTR	1/16 (6.3%)	1/16 (6.3%)
De Tayrac et al.* [65]	Vag_Syn_Mesh	LS_Syn_Mesh	3/20 (15.0%)	10/19 (52.6%)
Morciano et al.* [66]	LS_Syn_Mesh_CLS	LS_Syn_Mesh	1/38 (2.6%)	2/37 (5.4%)
Chen et al.* [67]	Vag_Syn_Mesh_Selfcut	Vag_Syn_Mesh	6/169 (3.6%)	13/167 (7.8%)
Morciano et al.* [68]	LS_Syn_Mesh_PP	LS_Syn_Mesh	1/62 (1.6%)	3/60 (5.0%)
Hwang et al.* [69]	LS_Syn_Mesh	Vag_NTR_USLS	9/55 (16.4%)	9/57 (15.8%)
Menefee et al.***[70]	LS_Syn_Mesh Vag_Syn_Mesh	Vag_NTR	35/113 (31.0%)	54/122 (44.3%)
Di Biasi et al.*[71]	LS_Syn_Mesh_NoPost	LS_Syn_Mesh	5/60 (8.3%)	5/60 (8.3%)

Abs absorbable suture, *AS* abdominal surgery, *Bio* biologic graft, *CLS* continuous locked suture, *Hpxy* Hysteropexy, *LS* laparoscopic surgery, *M* myorrhaphy, *Manch* Manchester, *NTR* native tissue repair, *P* pectopexy, *Perm* permanent suture, *PDS* polydioxanone, *PP* posterior plication, *RS* robotic surgery, *Syn* synthetic mesh, *USLF* uterosacral ligament fixation, *Vag* vaginal mesh

^a1-year follow-up

^b2-year follow-up

^c3-year follow-up

moderate risk and “major concerns” indicated a high risk. All categorisations were confirmed by a third reviewer. We planned to exclude from the analysis studies judged to raise major concerns.

Data Synthesis and Analysis

Data from the studies on apical POP included were summarised descriptively. Given the variety of surgical approaches reported, we opted for an NMA, which allows for the simultaneous comparison of multiple interventions. The NMA was conducted using the NMAstudio 2.0 [75]. For the NMA to be valid, all the studies included must be interconnected, ensuring that no intervention is isolated without a comparator. NMAstudio 2.0 [75] software had constraints of two-arm studies only. Hence, for three-arm RCTs, only one main intervention versus the control group was included in the analysis. Sensitivity analyses were subsequently conducted using the alternative intervention arms to evaluate the potential influence of this selection on the network estimates.

To standardise the analysis, interventions with similar surgical approaches were grouped under the same label based on consensus. The largest sample size and prevalence were set as a control group in the studies.

The network plot was visualised using nodes and edges, where the size of the nodes represented the sample size for each treatment, and the colour coding reflected the RoB. Edge thickness indicated the number of studies comparing

the two connected treatments. In addition to the main network plot, we performed head-to-head comparisons for each intervention versus control, focusing on studies with the same intervention type and control group. We conducted NMA for all four outcomes and individual comparisons for all treatment pairs.

Network consistency was assessed separately for each outcome using both global and local approaches. Global inconsistency was evaluated with the design-by-treatment interaction model, whereas local inconsistency was assessed using the node-splitting method, which separates direct and indirect evidence for each eligible treatment comparison and tests for differences between the resulting estimates. Consistency assessments were restricted to comparisons informed by both direct and indirect evidence and supported by at least two trials contributing to the direct comparison. Statistical inconsistency was considered present when the corresponding *p* value was < 0.05.

Statistical Analysis

Effect estimates for anatomical recurrence, subjective recurrence, reoperation and mesh complication rates were reported as risk ratios with 95% confidence intervals (CIs). POP-Q measurements were analysed using mean differences with standard deviations between treatment groups. Heterogeneity was assessed using the *I*² statistic,

where values below 40% were considered to indicate low or insignificant heterogeneity.

Results

In this review, 102 studies were selected from an initial pool of 5,254. Of these, 59 reports evaluated apical prolapse surgery. One report by Hemming et al. [52] contained data from two independent RCTs; therefore, 58 RCTs involving 6,846 participants were included in the NMA (Fig. 1). These RCTs were published between 1996 and 2025, encompassing a total population of 6,846 individuals. The studies originated from the USA (15 studies), the Netherlands (8), Italy (8), Turkey (5), Brazil (4), the UK (2), Australia (3), the Czech Republic (2), Egypt (2), China (2), France, Germany, India, Iran, Slovakia, Chile and Japan (1 each). All studies had follow-up for at least 1 year. Nine studies followed patients for at least 3 years, with four extending the follow-up to 5 years or more. Additionally, 28 studies were multicentric. Also, RCT characteristics are presented in Tables 1 and 2. Two of the studies included had three arms [40, 70]. Because the NMA could only allow two-arm comparisons, one arm from each study was excluded from the analysis: the vaginal biological mesh group ($n=30$) in Damiani et al. [40] and the vaginal synthetic mesh group ($n=110$) in Menefee et al. [70]. These excluded groups were replaced with the primary intervention versus control comparison. Sensitivity analyses using the excluded arms yielded similar results and did not alter the main findings of the NMA.

Of the 58 included RCTs, two came from a single publication that reported two independent trials. Of the 58 studies included, 54 (93.1%) defined anatomical recurrence as POP-Q $\geq$ stage 2, whereas the remaining four (6.9%) did not specify the POP-Q definition and used alternative criteria [18, 24, 61, 72]. Note that POP-Q measurements and secondary outcomes were not consistently reported across all studies. Among the 58 RCTs, 26 (44.8%) reported postoperative POP-Q assessments, 23 (39.7%) assessed subjective recurrence rates, 31 (53.4%) reported mesh complication rates, 15 (25.9%) reported reoperation for mesh complications and 29 (50.0%) reported reoperation for prolapse recurrence.

Risk of Bias

The RoB assessment was evaluated using the Cochrane evidence quality tool [73] and presented in Fig. 2. In the NMA coding scheme, the overall RoB was classified as low if all seven categories were rated low.

Integrity Screening

In general, no major concerns were identified. Although many studies showed no concerns in governance or authorship, some inconsistencies were noted in other domains, particularly regarding the plausibility of methods and reported results. Several studies demonstrated discrepancies in p values, questionable baseline imbalances, incomplete reporting (e.g. missing CONSORT diagrams) or issues with registration, many being retrospectively registered or not registered at all (Table 3).

Network Meta Analysis

The network presented in Fig. 3 comprised 24 interventions evaluated across 58 studies, including 6,846 participants. Of these, 1,253 experienced anatomical prolapse recurrence within 1–3 years post-surgery, corresponding to an overall anatomical recurrence rate of 18.3%, with rates of 24.1% for NTR, 14.0% for vaginal mesh (VM), 12.5% for laparoscopic sacrocolpopexy/cervicopexy (LSC) and 13.5% for ASC.

Vaginal NTR was used as the reference treatment because it contributed the largest sample size and served as the most frequent comparator arm across the trials included, making it the most connected node in the treatment network. This provided a statistically stable baseline for estimating relative risks.

Primary Outcomes

Anatomical Recurrence Rate After 1–3 Years The primary forest plot (Fig. 4), using vaginal NTR as the reference, indicated that three interventions were associated with a significantly lower risk of anatomical recurrence after 1–3 years of follow-up. In the NMA, indirect relative risks reflected estimates derived from network interactions, whereas direct relative risks were based on head-to-head comparisons from the studies included:

- Vaginal synthetic mesh: indirect relative risk = 0.59 [0.44–0.79] (Fig. 4); direct relative risk from nine studies with 1,001 participants = 0.54 [0.45, 0.65] (Fig. 5a).
- Abdominal synthetic mesh: indirect relative risk = 0.59 [0.40–0.87] (Fig. 4); direct relative risk from six studies with 645 participants = 0.55 [0.41, 0.74] (Fig. 5b).
- Laparoscopic synthetic mesh: indirect relative risk = 0.66 [0.47–0.94] (Fig. 4); direct relative risk from four studies with 396 participants = 0.65 [0.49, 0.85] (Fig. 5c).

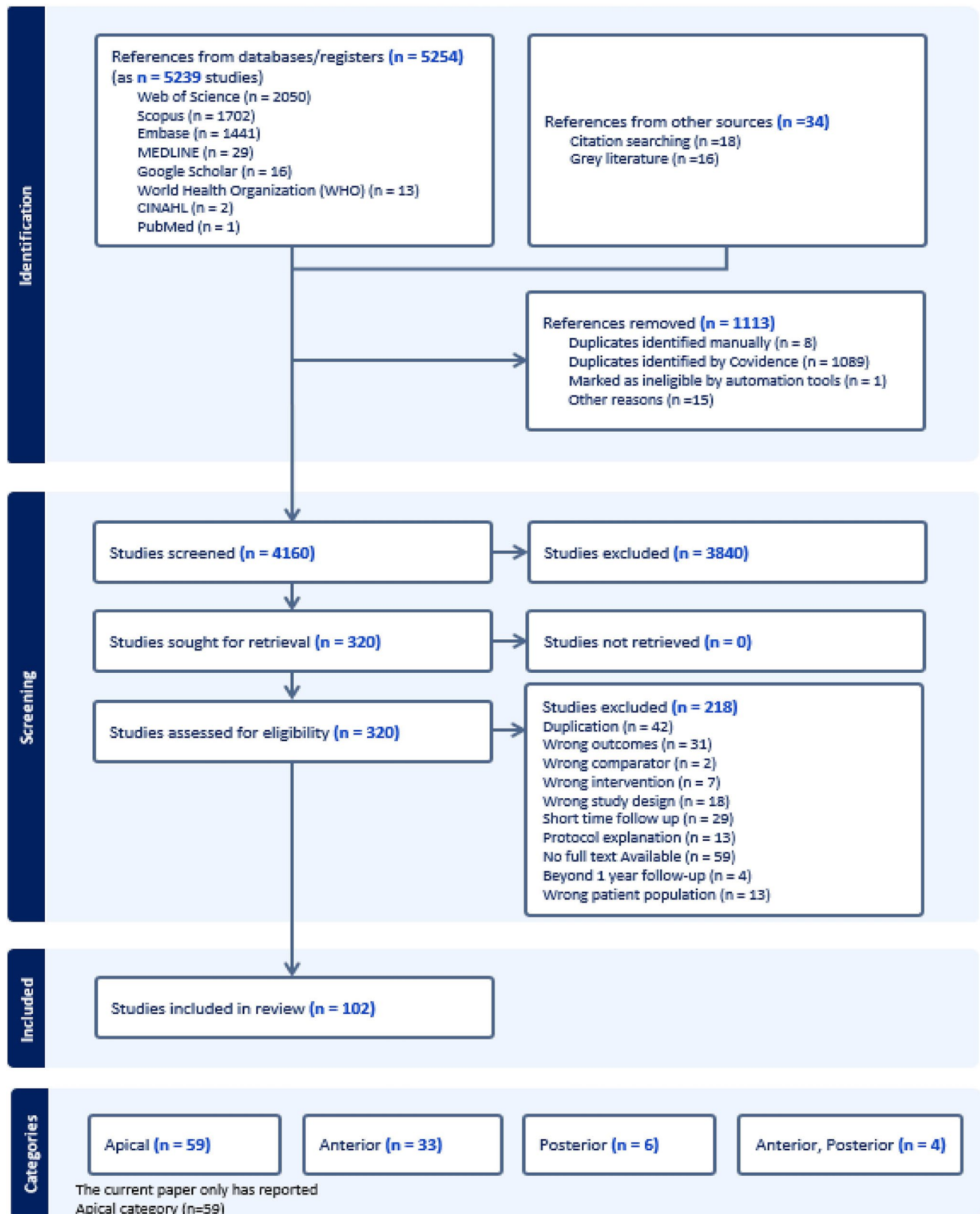
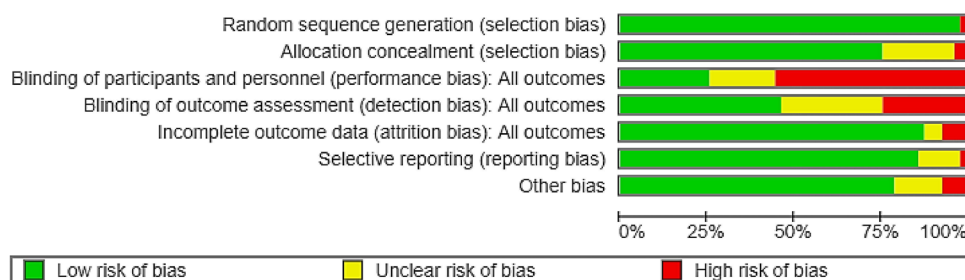


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram illustrating the study selection process, including the number of records identified, screened, assessed

for eligibility and included in the final review. Reasons for exclusion at each stage are also documented

Fig. 2 Risk of bias (RoB) assessment for the 58 studies included



Vaginal synthetic mesh using the self-cut approach, compared with NTR, demonstrated significant effectiveness in indirect analysis (relative risk = 0.27; 95% CI, 0.08–0.88), although no direct comparative study was available. Other interventions did not show statistically significant differences when compared with vaginal NTR.

POP-Q Mean Differences 1–3 Years After Surgery Between Interventions Twenty-six studies, encompassing 12 treatment modalities, reported POP-Q outcomes 1–3 years following surgery. Indirect network comparisons of mean differences (MDs) did not demonstrate statistically significant differences in POP-Q measurements between treatments (Fig. 6). Direct pairwise analyses demonstrated clinically meaningful effects. A single study comparing abdominal synthetic mesh with NTR reported a significant difference favouring the abdominal approach for improved POP-Q measurements (MD = 1.00 [0.24–1.76]) [52]. Abdominal synthetic mesh with permanent sutures was associated with improved POP-Q outcomes compared with absorbable sutures using the same approach (MD = 0.50 [0.27–0.73]) [51]. Another significant direct comparison was observed between laparoscopic synthetic mesh with lateral suspension and standard laparoscopic synthetic mesh, favouring the lateral suspension technique (MD = 1.00 [0.02, 1.98]) [62].

Secondary Outcomes

Subjective Recurrence Rate After 1–3 Years Twenty-three studies, comprising 17 different interventions, reported subjective recurrence rates during follow-up. Across 3,589 participants, there were 792 cases of subjective recurrence, corresponding to an overall rate of 22.1%, with rates of 34.1% for NTR, 6.2% for TVM, 9.3% for LSC and 26.1% for ASC.

In indirect NMA comparisons, vaginal synthetic mesh was associated with a significantly lower risk of subjective recurrence than NTR (relative risk = 0.51 [0.28–0.92]). Consistent results were observed in direct meta-analysis comparing vaginal synthetic mesh with NTR from four randomised studies [30, 35, 44, 45] yielding a pooled risk ratio of 0.49 [0.26–0.92] favouring VM.

Further indirect network estimates indicated that both laparoscopic synthetic mesh with posterior plication and vaginal synthetic mesh with the self-cut approach were associated with significantly lower risks of subjective recurrence than NTR (relative risk = 0.22 [0.06–0.75] and relative risk = 0.25 [0.09–0.73] respectively). No direct head-to-head studies were available to evaluate these treatment pairs.

In direct comparisons, Morciano et al. (66) reported a statistically significant finding where laparoscopic synthetic mesh with posterior plication demonstrated a lower risk of subjective recurrence than conventional laparoscopic synthetic mesh surgery (relative risk = 2.51 [1.12–5.62]).

Mesh Complications After 1–3 Years Thirty-one studies including 3,509 participants reported complications associated with mesh implantation. Among these, 11 studies included a control arm without mesh; therefore, mesh complication rates were calculated only from arms with mesh, yielding 150 events among 2,883 mesh surgeries (overall 5.2%; TVM 8.4%, ASC 7.1%, LSC 1.5%). Table 4 presents both direct and indirect comparisons of mesh surgeries versus NTR, with respect to mesh-related complications. The results indicate which procedures were associated with a significantly higher incidence of mesh-related events.

Comparing vaginal synthetic mesh with other types of mesh surgeries did not reveal any significant differences in the occurrence rates of mesh complications.

Reoperation Rate Owing to Recurrence After 1–3 Years A total of 4,265 participants across 29 studies reported reoperation for recurrence. The NMA showed a significant difference between ASC and vaginal NTR hysterectomy (relative risk = 0.40, 95% CI 0.17–0.94), favouring ASC.

Reoperation for mesh complications was reported in 15 studies involving 1,823 participants; the NMA showed a significantly higher reoperation rate for vaginal synthetic mesh than NTR (relative risk = 5.19, 95% CI 1.71–15.75), favouring NTR.

Table 3 Integrity screening outcome of the randomised controlled trials (RCTs) included

Reference	Governance	Author group	Plausibility of methods	Timeframe	Drop-out rates	Baseline characteristics	Outcomes
Benson et al. [18]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Lo and Wang [19]	Some concerns	Some concerns	Some concerns	No concerns	No concerns	Some concerns	Some concerns
Maher et al. [20]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Roovers et al. [21]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Culligan et al. [22]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Dietz et al. [23]	Some concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Lopes et al. [24]	No concerns	No concerns	Some concerns	No concerns	No concerns	No concerns	Some concerns
Natale et al. [25]	Some concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns	No concerns
Detollenaere et al. [28]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Maher et al. [26]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Paraíso et al. [27]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Halaska et al. [29]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Sokol et al. [30]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Costantini et al. [38]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Culligan et al. [32]	Some concerns	No concerns	Some concerns	No concerns	No concerns	No concerns	No concerns
Nygaard et al. [3]	Some concerns	Some concerns	Some concerns	No concerns	No concerns	No concerns	No concerns
Ray et al. [31]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Barber et al. [33]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Švábík et al. [36]	No concerns	No concerns	Some concerns	No concerns	No concerns	No concerns	Some concerns
El-agwany et al. [39]	Some concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns	Some concerns
Noé et al. [34]	Some concerns	Some concerns	Some concerns	No concerns	No concerns	Some concerns	Some concerns
Rondini et al. [41]	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns	Some concerns
Tan-Kim et al. [37]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Damiani et al. [40]	Some concerns	No concerns	Some concerns	No concerns	No concerns	No concerns	Some concerns
Kenton et al. [42]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Coolen et al. [6]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Ow et al. [43]	Some concerns	No concerns	Some concerns	No concerns	Some concerns	Some concerns	No concerns
Illiano et al. [46]	No concerns	No concerns	No concerns	Some concerns	No concerns	No concerns	Some concerns
Nager et al. [44]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Steures et al. [45]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Başer et al. [54]	No concerns	Some concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns
Berger et al. [55]	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns	No concerns
Da Silveira et al. [35]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
De Castro et al. [47]	Some concerns	No concerns	No concerns	No concerns	No concerns	Some concerns	Some concerns
Galad et al. [49]	Some concerns	Some concerns	Some concerns	Some concerns	No concerns	No concerns	Some concerns
Hemming et al. [52]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Hemming et al. [52]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Matthews et al. [51]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Van IJsselmuiden et al. [53]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Castro et al. [59]	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns	No concerns
Cengiz et al. [58]	Some concerns	No concerns	Some concerns	Some concerns	Some concerns	No concerns	No concerns

Table 3 (continued)

Reference	Governance	Author group	Plausibility of methods	Timeframe	Drop-out rates	Baseline characteristics	Outcomes
Ferrando and Paraiso [57]	No concerns	Some concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Kowalski et al. [50]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Obut et al. [56]	Some concerns	Some concerns	Some concerns	No concerns	No concerns	No concerns	Some concerns
Tagliaferri et al. [60]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Chen et al. [67]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Daneshpajoo et al. [64]	No concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns	No concerns
De Tayrac et al. [65]	Some concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Gamal et al. [61]	No concerns	No concerns	No concerns	Some concerns	No concerns	No concerns	No concerns
Morciano et al. [66]	No concerns	No concerns	No concerns	Some concerns	No concerns	No concerns	No concerns
Enklaar et al. [48]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	Some concerns
Isenlik et al. [62]	No concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns	No concerns
Karadag et al. [63]	Some concerns	No concerns	Some concerns	Some concerns	No concerns	No concerns	Some concerns
Morciano et al. [68]	No concerns	No concerns	No concerns	Some concerns	No concerns	No concerns	No concerns
Van Oudheusden et al. [4]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Hwang et al. [69]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Menefee et al. [70]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns
Di Biasi et al. [71]	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns	No concerns

Assessment of Network Consistency For anatomical recurrence, subjective recurrence, mesh complications, reoperation owing to recurrence, and reoperation owing to mesh complications, the global inconsistency tests demonstrated no evidence of inconsistency across the treatment networks (all $p > 0.05$). Furthermore, node-splitting analyses showed no statistically significant differences between direct and indirect estimates for any eligible treatment comparison (all $p > 0.05$), supporting the assumption of consistency and indicating agreement between sources of evidence.

In contrast, for POP-Q mean difference at 1–3 years after surgery, the global inconsistency test identified significant inconsistency within the network ($Q = 21.57$, $df = 3$, $p < 0.0001$). Local inconsistency assessment further revealed a statistically significant discrepancy between direct and indirect evidence of the comparison of ASC with synthetic mesh versus native tissue vaginal repair ($p = 0.036$). All other node-splitting comparisons for this outcome were non-significant. These findings suggest that inconsistency within the POP-Q network was primarily driven by this specific treatment comparison and should be

considered when interpreting the corresponding network estimates (Table 5).

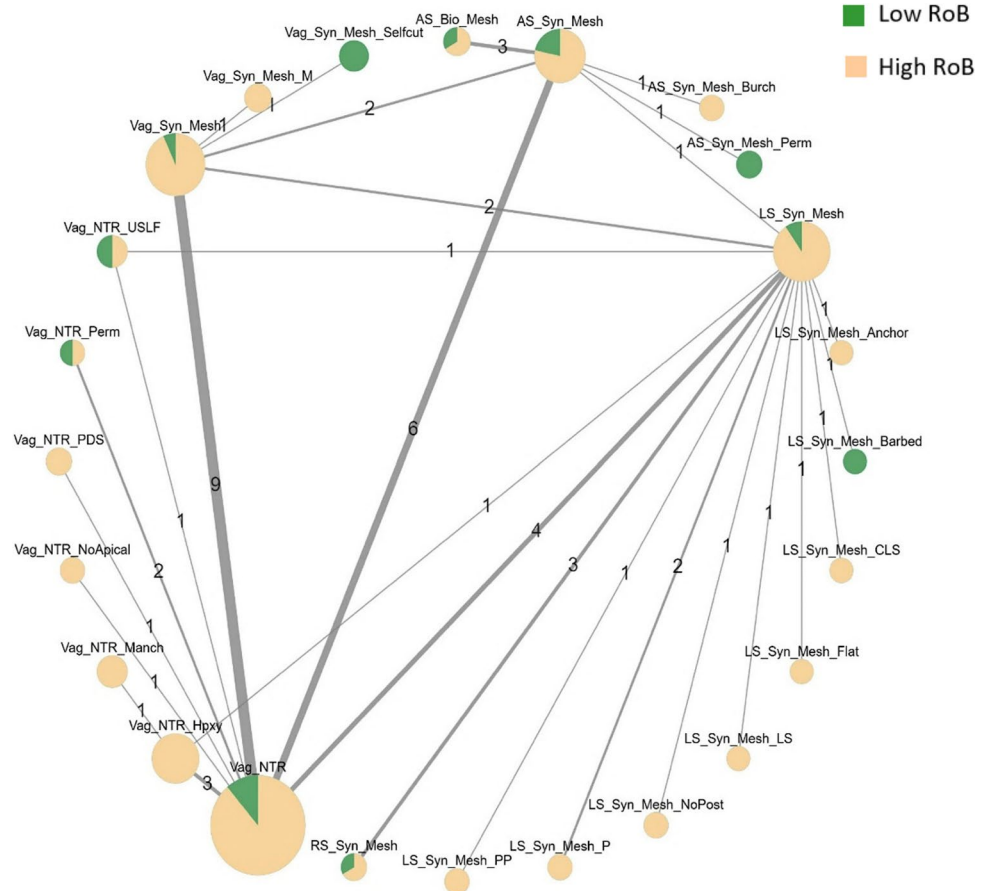
All indirect and direct comparisons are provided in the Supplementary material.

Discussion

Main Findings

There were 58 studies in the NMA including 24 different interventions for 6,846 participants. This NMA demonstrated that VM repair (relative risk = 0.59 [0.44–0.79]), abdominal mesh sacrocolpopexy (relative risk = 0.59 [0.40–0.87]) and laparoscopic mesh sacrocolpopexy (relative risk = 0.66 [0.47–0.94]) were associated with significantly lower anatomical recurrence rates than NTR. These findings support the role of sacrocolpopexy as an established surgical option for apical prolapse repair, with published studies reporting high cure rates (85%–100%) and favourable durability [10, 15, 16].

Fig. 3 Network diagram for the network meta-analysis, illustrating the comparative connections between 24 different interventions derived from 58 studies. Each node represents an intervention, and each line represents one or more direct comparisons between interventions. Node colour in the network indicates the risk of bias, whereas node size reflects the sample size for each intervention. *AS* abdominal surgery, *Bio* biologic graft, *CLS* continuous locked suture, *Hpxy* Hysteropexy, *LS* laparoscopic surgery, *M* myorrhaphy, *Manch* Manchester, *NTR* native tissue repair, *P* pectopexy, *Perm* permanent suture, *PDS* polydioxanone, *PP* posterior plication, *RoB* risk of bias, *RS* robotic surgery, *Syn* synthetic mesh, *USLF* uterosacral ligament fixation, *Vag* vaginal mesh



The NMA findings for POP-Q measurements did not identify significant differences between interventions, in contrast to the findings for anatomical recurrence. Although most of the studies included defined anatomical failure using POP-Q criteria, fewer than half (26 studies) reported continuous POP-Q point C data, potentially limiting the generalisability of these findings. An important consideration is the relationship between anatomical and symptomatic recurrence, particularly in the apical compartment. Observational data suggest that the symptomatic threshold for apical descent may differ from that of anterior compartment prolapse, with symptoms of vaginal bulge and pressure occurring even when point C remains above the hymen. Consequently, POP-Q and anatomical recurrence outcomes should be interpreted alongside validated patient-reported outcome measures, as the absence of vaginal bulge symptoms and improvement in condition-specific quality-of-life scores correlate more strongly with patient-perceived treatment success than strict anatomical definitions alone. Furthermore, consistency assessment demonstrated significant global inconsistency within the POP-Q network ($Q = 21.57$, $df = 3$, $p < 0.0001$). Local node-splitting analysis indicated statistically significant inconsistency for the comparison

between ASC with synthetic mesh and vaginal NTR ($p = 0.036$), suggesting disagreement between direct and indirect evidence for this outcome. A similar pattern was noted in the Cochrane review by Maher et al. [10], where fewer than half of the studies included reported quantitative POP-Q C data. However, unlike our NMA, their meta-analysis (two studies, $n = 142$) indicated that sacrocolpopexy resulted in significantly better point C outcomes at 1 year than vaginal procedures. In our analysis, only the direct comparison from Hemming et al. [52] supported a statistically significant difference consistent with that finding.

In the NMA of subjective recurrence rates, vaginal synthetic mesh, laparoscopic synthetic mesh with posterior plication and vaginal synthetic mesh with a self-cut approach demonstrated significantly higher success rates than NTR. Although our findings align with those of Yeung et al. [15] (17 studies, $n = 2,932$), they differ from Maher et al. [10] (four studies, $n = 346$), who reported ASC to be significantly superior to all vaginal procedures for subjective recurrence, and from Larouche et al. [16] (eight studies, $n = 1,363$), who found no significant differences in subjective outcomes between approaches. The discrepancy may stem from methodological differences.

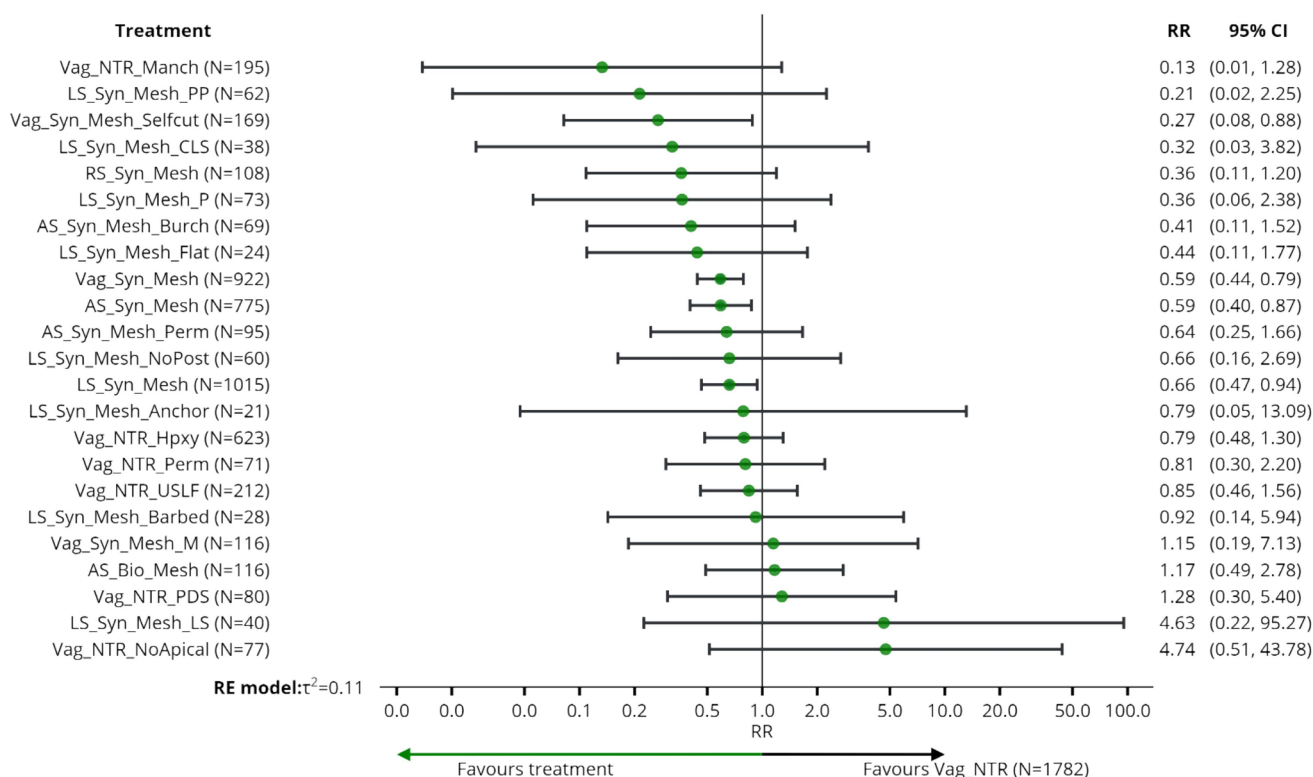


Fig. 4 Forest plot of the network meta-analysis comparing anatomical recurrence rates at 1–3 years of follow-up, using vaginal native tissue repair (NTR) as the reference treatment. AS abdominal surgery,

LS laparoscopic surgery, NTR native tissue repair, PDS polydioxanone, Perm permanent suture, Syn synthetic mesh, USLF uterosacral ligament fixation, Vag vaginal mesh

Our NMA categorised interventions based on specific surgical techniques, providing a more granular comparison. Furthermore, unlike conventional meta-analyses that rely solely on direct comparisons, an NMA incorporates both direct and indirect evidence, which can lead to differences in estimated comparative effects [76].

The NMA showed a significant difference between ASC and NTR hysteropexy, favouring ASC with less prolapse recurrence. Reoperation for mesh complications in the NMA showed a significantly higher reoperation rate for vaginal synthetic mesh than NTR. These findings partly align with those of previous systematic reviews. Maher et al. [10] (six studies, $n = 497$) similarly reported fewer repeat surgeries after sacrocolpopexy compared with vaginal procedures. Yeung et al. [15] (27 studies, $n = 3,916$) also found higher rates of repeat surgery in the VM group than NTR, consistent with our mesh reoperation results. In contrast, Larouche et al. [16] (18 studies, $n = 11,850$) found no significant differences in reoperation rates across apical surgical approaches. The

discrepancies among these studies may be explained by variations in inclusion criteria and definitions of repeat surgery.

The mesh erosion rate across the studies included in this review was 5.2%, which aligns with the previously reported range of 0.5% to 5% [16]. In this NMA, there were significantly more mesh complications in synthetic mesh procedures across laparoscopic, abdominal and vaginal approaches than with non-mesh NTR surgery. However, direct head-to-head analyses only confirmed a statistically significant difference for vaginal synthetic mesh, consistent with Maher et al.'s findings (five studies, $n = 499$), which also demonstrated a higher risk of mesh exposure in the VM group than NTR [10]. As the direct comparisons did not confirm a significant difference for the abdominal and laparoscopic mesh approaches, the observed overall significance in the NMA likely reflects the influence of indirect comparisons. Therefore, these NMA findings should be interpreted with caution.

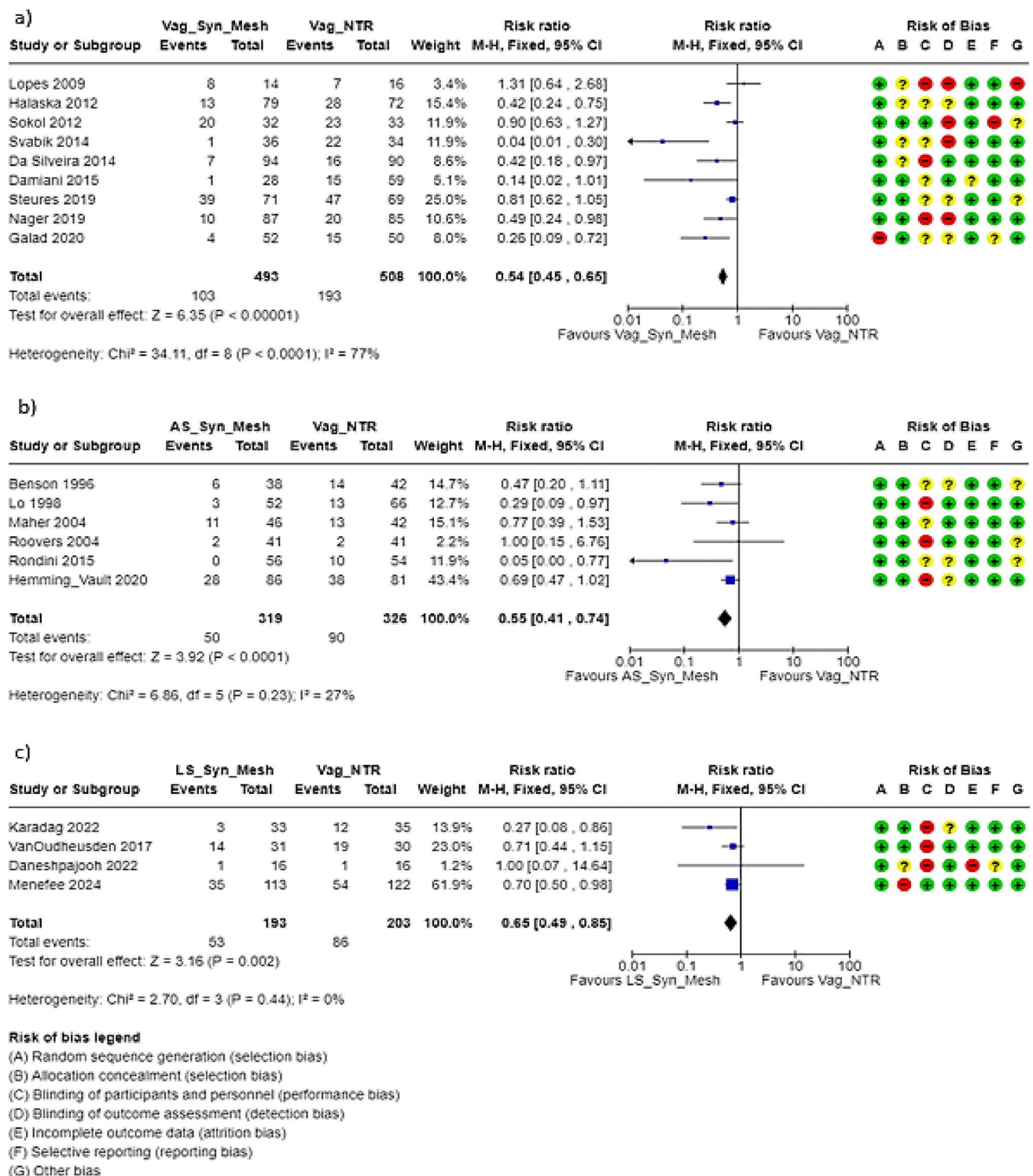


Fig. 5 Pairwise meta-analyses comparing recurrence rates among different surgical interventions. Forest plots showing the direct estimates for all pairwise comparisons are provided in the Supplementary material. **a** Nine studies involving 1,001 women comparing vaginal synthetic mesh with native tissue repair (NTR). **b** Six studies with 645

participants comparing abdominal mesh sacrocolpopexy with NTR. **c** Four studies with 396 women comparing laparoscopic mesh sacrocolpopexy with NTR. AS abdominal surgery, LS laparoscopic surgery, M-H mantel-haenszel, Syn synthetic mesh, Vag vaginal mesh

Fig. 6 Comparison of postoperative pelvic organ prolapse quantification outcomes across 12 treatments, based on data from 26 studies reporting results 1–3 years postoperatively. *Abs* absorbable suture, *AS* abdominal surgery, *Hpxy* Hysteropexy, *LS* laparoscopic surgery, *MD* mean difference, *Perm*, *NTR* native tissue repair, *RE* random-effects, *RS* robotic surgery, *Syn* synthetic mesh, *Vag* vaginal mesh

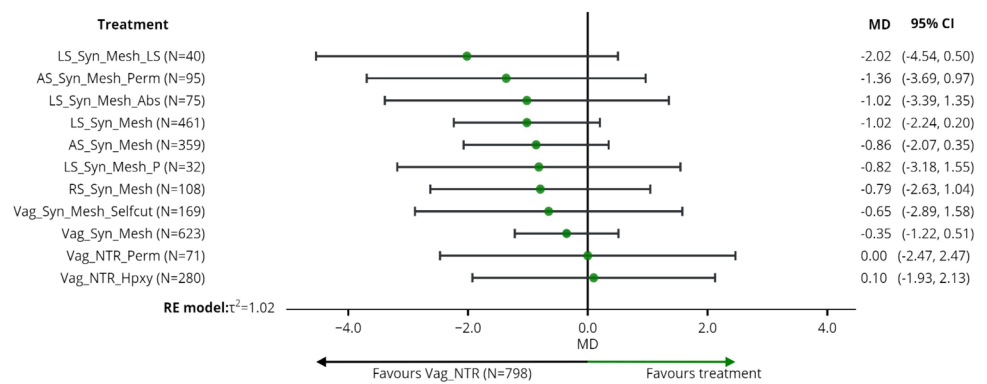


Table 4 Mesh complications compared with native tissue repair

Mesh surgeries	Indirect NMA relative risk	Indirect NMA 95% CI	Direct relative risk (no. of studies)	Direct 95% CI
AS_Bio_Mesh	12.47	0.39–404.00	NA	NA
AS_Syn_Mesh	4.73	1.15–19.43	2.74 (1) [35]	0.11–65.51
LS_Syn_Mesh	5.24	1.26–21.77	5.64 (2) [36, 37]	0.66–48.04
RS_Syn_Mesh	5.84	0.73–46.40	NA	NA
Vag_Syn_Mesh	9.65	3.63–25.70	10.10 (7) [25, 30, 32, 33, 38–40]	3.39–30.07

AS abdominal surgery, LS laparoscopic surgery, NMA network meta-analysis, RS robotic surgery, Syn synthetic mesh, Vag vaginal mesh

Entries are in italics whenever the 95% CI excludes 1, which means the result is statistically significant

Strengths

To our knowledge, this study is the first NMA on apical prolapse surgical management, allowing both direct and indirect comparisons across multiple surgical approaches. The inclusion of 58 RCTs provides a comprehensive and generalisable evidence base, with methodological quality assessed to ensure result validity. By integrating anatomical and subjective success, and rates of repeat surgery due to recurrence or mesh complications, this study offers a comprehensive evaluation of short- to mid-term surgical effectiveness that reflects outcomes most relevant to patients and clinical practice [77].

Limitations

Despite its strengths, this study has several limitations. The main challenge is the heterogeneity of the surgical techniques; differences in approach (abdominal, vaginal, laparoscopic or robotic), uterine preservation, suture material, implant type (synthetic or biologic), concurrent procedures and novel methods introduce significant

variability, complicating direct comparisons [5]. A key limitation of the NMA is the assumption of transitivity, requiring comparable populations, interventions and contexts across studies; any violation may compromise the validity of pooled estimates [78]. Although NMA offers advantages of pooling data and synthesises a broader assessment of available treatments to inform clinical decisions, it relies on the assumption of transitivity, meaning that patients across trials are sufficiently similar for indirect comparisons to be valid.

A further limitation is the short follow-up duration reported in 40 of the 58 studies included (69.0%), with most reporting outcomes only 1 year post-intervention. This may underestimate late recurrences and mesh complications, which can appear several years after surgery [79]. Accordingly, conclusions regarding long-term durability should be interpreted cautiously, as relatively few studies reported follow-up beyond 3 years. Although VM has shown favourable anatomical outcomes, its withdrawal owing to safety concerns, and subsequent restriction or ban in many countries, reduces its relevance to current clinical practice.

Table 5 Global and local consistency assessment of the network meta-analysis across primary and secondary outcomes

Treatment comparison (node-splitting analysis)	Anatomical recurrence (<i>p</i> value)	POP-Q mean difference (<i>p</i> value)	Subjective recurrence (<i>p</i> value)	Mesh complications (<i>p</i> value)	Reoperation owing to recurrence (<i>p</i> value)	Reoperation owing to mesh complications (<i>p</i> value)
AS_Syn_Mesh vs LS_Syn_Mesh	0.627	0.423	0.911	0.237	0.353	NA
AS_Syn_Mesh vs Vag_NTR	0.769	<i>0.036</i>	0.856	0.706	0.534	0.473
AS_Syn_Mesh vs Vag_Syn_Mesh	0.942	0.291	0.726	0.191	0.962	0.473
LS_Syn_Mesh vs Vag_NTR	0.749	0.322	0.619	0.929	0.524	NA
LS_Syn_Mesh vs Vag_NTR_Hpxy	0.416	NA	NA	NA	0.961	NA
LS_Syn_Mesh vs Vag_NTR_USLF	0.519	NA	0.289	NA	NA	NA
LS_Syn_Mesh vs Vag_Syn_Mesh	0.731	0.951	NA	0.243	NA	NA
Vag_NTR_Hpxy vs Vag_NTR	0.416	NA	NA	NA	0.961	NA
Vag_NTR_USLF vs Vag_NTR	0.519	NA	0.289	NA	NA	NA
Vag_Syn_Mesh vs Vag_NTR	0.741	0.338	0.726	0.852	0.962	0.473
Global inconsistency test (design-by-treatment interaction model)	<i>Q</i> = 3.68, <i>df</i> = 5, <i>p</i> = 0.597	<i>Q</i> = 21.57, <i>df</i> = 3, <i>p</i> < 0.0001	<i>Q</i> = 1.26, <i>df</i> = 3, <i>p</i> = 0.738	<i>Q</i> = 2.23, <i>df</i> = 3, <i>p</i> = 0.527	<i>Q</i> = 0.89, <i>df</i> = 3, <i>p</i> = 0.827	<i>Q</i> = 0.51, <i>df</i> = 1, <i>p</i> = 0.473

Node-splitting analyses were only feasible for comparisons informed by both direct and indirect evidence and supported by at least two studies in the direct comparison

AS abdominal surgery, *df* degrees of freedom, *Hpxy* Hysteropexy, *LS* laparoscopic surgery, *NA* not applicable (indicating that node-splitting assessment could not be performed because insufficient direct evidence was available, *NTR* native tissue repair, *POP-Q* Pelvic Organ Prolapse Quantification, *Q* Cochrane's *Q* statistic for inconsistency (quantifies the amount of disagreement between direct and indirect evidence in the network), *Syn* synthetic mesh, *USLF* uterosacral ligament fixation, *Vag* vaginal mesh

Statistically significant inconsistency is highlighted in italics (*p* < 0.05)

Clinical Implications

Based on the findings of this NMA, abdominal and laparoscopic sacrocolpopexy with mesh, as well as VM repair, were associated with significantly lower anatomical recurrence rates than NTR. Subjective success rates were also higher with several mesh-based techniques, indicating a potential balance between anatomical durability and patient satisfaction. However, mesh complications were more frequent in synthetic mesh procedures, particularly with the vaginal approach; a finding consistent with previous studies that ultimately led to the withdrawal or restriction of vaginal synthetic mesh in several countries [15, 80]. These results support sacrocolpopexy as an important surgical option for apical prolapse repair, with improved anatomical outcomes over the available follow-up, while underscoring the need for individualised surgical decision making [81]. They also highlight

the ongoing need for developing surgical materials or techniques that can provide the durability of mesh repairs without the associated complication risks.

Conclusion

Apical-prolapse procedures using synthetic mesh (vaginal, laparoscopic, abdominal) showed lower anatomical recurrence than NTR, suggesting improved anatomical durability during the available follow-up. This NMA showed lower recurrence-related reoperation rates with ASC than with vaginal NTR hysteropexy, but higher mesh-related reoperations with vaginal synthetic mesh than with NTR. Overall, these findings highlight the continued value of sacrocolpopexy as the gold standard for apical repair while underscoring the need for innovation in safer materials and techniques that maintain anatomical success without increasing adverse events.

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Data Availability Statement All extracted data, analysis code and materials are available upon reasonable request from the corresponding author.

Declarations

Ethics Approval Not applicable. This review synthesised data from previously published RCTs.

Conflicts of Interest None.

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References

1. Maher C, Feiner B, Baeßler K, Schmid C. Surgical management of pelvic organ prolapse in women. *Cochrane Database Syst Rev*. 2013;30(4):CD004014.
2. McFerrin C, Pilkington JE, Pilet H, Frilot C, Gomelsky A. Abdominal versus robotic sacral colpopexy: a detailed analysis of outcomes. *Neurourol Urodyn*. 2021;40(7):1811–9.
3. Nygaard I, Brubaker L, Zyczynski HM, Cundiff G, Richter H, Gantz M, et al. Long-term outcomes following abdominal sacrocolpopexy for pelvic organ prolapse. *JAMA*. 2013;309(19):2016–24.
4. Van Oudheusden AMJ, Eissing J, Terink IM, Vink MDH, van Kuijk SMJ, Bongers MY, et al. Laparoscopic sacrocolpopexy versus abdominal sacrocolpopexy for vaginal vault prolapse: long-term follow-up of a randomized controlled trial. *Int Urogynecol J*. 2023;34(1):93–104.
5. Ciortea R, Roman M-P, Măluțan AM, Bucuri CE, Ormindean CM, Nati ID, et al. Comparison of laparoscopic sacrocolpopexy with vaginal reconstructive procedures and abdominal sacrocolpopexy for the surgical management of vaginal vault prolapse: a systematic review and meta-analysis. *Front Med*. 2023;10:1269214.
6. Coolen ALWM, van Oudheusden AMJ, Mol BWJ, van Eijndhoven HWF, Roovers JPWR, Bongers MY. Laparoscopic sacrocolpopexy compared with open abdominal sacrocolpopexy for vault prolapse repair: a randomised controlled trial. *Int Urogynecol J*. 2017;28(10):1469–79.
7. Khan A, Alperin M, Wu N, Clemens JQ, Dubina ED, Pashos CL, et al. Comparative outcomes of open versus laparoscopic sacrocolpopexy among Medicare beneficiaries. *Int Urogynecol J*. 2013;24(11):1883–91.
8. Withagen MIJ, Vierhout ME, Milani AL, Mannaerts GHH, Kluijvers KB, van der Weiden RMF. Laparoscopic sacral colpopexy versus total vaginal mesh for vault prolapse; comparison of cohorts. *Gynecol Surg*. 2013;10(2):143–50.
9. Moen MD, Gebhart JB, Tamussino K. Systematic reviews of apical prolapse surgery: are we being misled down a dangerous path? *Int Urogynecol J*. 2015;26(7):937–9.
10. Maher C, Yeung E, Haya N, Christmann-Schmid C, Mowat A, Chen Z, et al. Surgery for women with apical vaginal prolapse. *Cochrane Database Syst Rev*. 2023;7(7):CD012376.
11. Luo J, Betschart C, Chen L, Ashton-Miller JA, DeLancey JO. Using stress MRI to analyze the 3D changes in apical ligament geometry from rest to maximal Valsalva: a pilot study. *Int Urogynecol J*. 2013;25(2):197–203.
12. Unger CA, Walters MD. Gluteal and posterior thigh pain in the postoperative period and the need for intervention after sacrospinous ligament colpopexy. *Female Pelvic Med Reconstr Surg*. 2014;20(4):208–11.
13. Maarouf T. Sacrohysteropexy without mesh for apical prolapse versus a vaginal approach. *Evid Based Womens Health J*. 2012;2(3):80–3.
14. Russo E, Guevara MMM, Saçintı KG, Misasi G, Falcone M, Morganti R, et al. Minimal invasive abdominal sacral colpopexy and abdominal lateral suspension: a prospective, open-label, multicenter, non-inferiority trial. *J Clin Med*. 2023;12(8):2926.
15. Yeung E, Baessler K, Christmann-Schmid C, Haya N, Chen Z, Wallace SA, et al. Transvaginal mesh or grafts or native tissue repair for vaginal prolapse. *Cochrane Database Syst Rev*. 2024;3(3):CD012079.
16. Larouche M, Belzile E, Geoffrion R. Surgical management of symptomatic apical pelvic organ prolapse: a systematic review and meta-analysis. *Obstet Gynecol*. 2021;137(6):1061–73.
17. Chaimani A, Caldwell DM, Li T, Higgins JP, Salanti G. Undertaking network meta-analyses. In: Higgins JPT, Thomas J, Chandler J, editors. *Cochrane handbook for systematic reviews of interventions*. New York: Wiley; 2019. p. 285–320.
18. Benson JT, Lucente V, McClellan E. Vaginal versus abdominal reconstructive surgery for the treatment of pelvic support defects: a prospective randomized study with long-term outcome evaluation. *Am J Obstet Gynecol*. 1996;175(6):1418–21; discussion 1421–2.
19. Lo T-S, Wang AC. Abdominal colposacropexy and sacrospinous ligament suspension for severe uterovaginal prolapse: a comparison. *J Gynecol Surg*. 1998;14(2):59–64.
20. Maher CF, Qatawneh AM, Dwyer PL, Carey MP, Cornish A, Schluter PJ. Abdominal sacral colpopexy or vaginal sacrospinous colpopexy for vaginal vault prolapse: a prospective randomized study. *Am J Obstet Gynecol*. 2004;190(1):20–6.
21. Roovers JPWR, Van Der Vaart CH, Van Der Bom JG, Schagen Van Leeuwen JH, Scholten PC, Heintz APM. A randomised controlled trial comparing abdominal and vaginal prolapse surgery: effects on urogenital function. *BJOG*. 2004;111(1):50–6.
22. Culligan PJ, Blackwell L, Goldsmith LJ, Graham CA, Rogers A, Heit MH. A randomized controlled trial comparing fascia lata and synthetic mesh for sacral colpopexy. *Obstet Gynecol*. 2005;106(1):29–37.
23. Dietz V, Van Der Vaart CH, Van Der Graaf Y, Heintz P, Schraffordt Koops SE. One-year follow-up after sacrospinous hysterectomy and vaginal hysterectomy for uterine descent: a randomized study. *Int Urogynecol J*. 2010;21(2):209–16.

24. Lopes ED, De Barros Moreira Lemos NL, Da Silva Carramão S, Lunardelli JL, Ruano JMC, Aoki T, et al. Transvaginal polypropylene mesh versus sacrospinous ligament fixation for the treatment of uterine prolapse: 1-year follow-up of a randomized controlled trial. *Int Urogynecol J*. 2010;21(4):389–94.
25. Natale F, La Penna C, Padoa A, Agostini M, Panei M, Cervigni M. High levator myorrhaphy versus uterosacral ligament suspension for vaginal vault fixation: a prospective, randomized study. *Int Urogynecol J*. 2010;21(5):515–22.
26. Maher CF, Feiner B, Decuyper EM, Nichlos CJ, Hickey KV, O'Rourke P. Laparoscopic sacral colpopexy versus total vaginal mesh for vaginal vault prolapse: a randomized trial. *Am J Obstet Gynecol*. 2011;204(4):360.e1–7.
27. Paraiso MFR, Jelovsek JE, Frick A, Chen CCG, Barber MD. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. *Obstet Gynecol*. 2011;118(5):1005–13.
28. Detollenaere RJ, den Boon J, Stekelenburg J, Alhafidh AHH, Hakvoort RA, Vierhout ME, et al. Treatment of uterine prolapse stage 2 or higher: a randomized multicenter trial comparing sacrospinous fixation with vaginal hysterectomy (SAVE U trial). *BMC Womens Health*. 2011;11:4.
29. Halaska M, Maxova K, Sottner O, Svabik K, Mlcoch M, Kolarik D, et al. A multicenter, randomized, prospective, controlled study comparing sacrospinous fixation and transvaginal mesh in the treatment of posthysterectomy vaginal vault prolapse. *Am J Obstet Gynecol*. 2012;207(4):301.e1–7.
30. Sokol AI, Iglesia CB, Kudish BI, Gutman RE, Shveiky D, Bercik R, et al. One-year objective and functional outcomes of a randomized clinical trial of vaginal mesh for prolapse. *Am J Obstet Gynecol*. 2012;206(1):86.e1–9.
31. Ray S, Halder A, Gangopadhyay M, Halder S, Pal PP. Comparison of two different suture materials for transvaginal sacrospinous fixation of the vault: a prospective randomized trial. *J Gynecol Surg*. 2013;29(6):281–6.
32. Culligan PJ, Salamon C, Priestley JL, Shariati A. Porcine dermis compared with polypropylene mesh for laparoscopic sacrocolpopexy: a randomized controlled trial. *Obstet Gynecol Surv*. 2013;68(4):282–4.
33. Barber MD, Brubaker L, Burgio KL, Richter HE, Nygaard I, Weidner AC, et al. Comparison of 2 transvaginal surgical approaches and perioperative behavioral therapy for apical vaginal prolapse: the OPTIMAL randomized trial. *JAMA*. 2014;311(10):1023–34.
34. Noé KG, Schiermeier S, Alkatout I, Anapolski M. Laparoscopic pectopexy: a prospective, randomized, comparative clinical trial of standard laparoscopic sacral colpopervicopexy with the new laparoscopic pectopexy—postoperative results and intermediate-term follow-up in a pilot study. *J Endourol*. 2015;29(2):210–5.
35. Da Silveira SDRB, Auge APF, Jarmy-Dibella ZIK, Margarido PFR, Carramao S, Alves Rodrigues C, et al. A multicenter, randomized trial comparing pelvic organ prolapse surgical treatment with native tissue and synthetic mesh: a 5-year follow-up study. *Neurourol Urodyn*. 2020;39(3):1002–11.
36. Švabík K, Martan A, Mašata J, El-Haddad R, Hubka P. Comparison of vaginal mesh repair with sacrospinous vaginal colpopexy in the management of vaginal vault prolapse after hysterectomy in patients with levator ani avulsion: a randomized controlled trial. *Ultrasound Obstet Gynecol*. 2014;43(4):365–71.
37. Tan-Kim J, Nager CW, Grimes CL, Lubner KM, Lukacz ES, Brown HW, et al. A randomized trial of vaginal mesh attachment techniques for minimally invasive sacrocolpopexy. *Int Urogynecol J Pelvic Floor Dysfunct*. 2015;26(5):649–56.
38. Costantini E, Pietropaolo A, Nunzi E, Bini V, Salvini E, Bruno R, et al. Prospective randomized trial comparing abdominal vs laparoscopic sacropexy for the treatment of advanced pelvic organ prolapse (Abstract number 61). *Neurourol Urodyn*. 2013;32(S1):S55–6.
39. El-agwany AS, Salem HA, Nagaty AM, Hanafy TM. Comparative study between abdominal versus laparoscopic sacral colpopexy. *Prog Obstet Gynecol*. 2015;58(8):341–9.
40. Damiani GR, Riva D, Pellegrino A, Gaetani M, Tafuri S, Turoli D, et al. Conventional fascial technique versus mesh repair for advanced pelvic organ prolapse: analysis of recurrences in treated and untreated compartments. *J Obstet Gynaecol*. 2016;36(3):410–5.
41. Rondini C, Braun H, Alvarez J, Urzúa MJ, Villegas R, Wenzel C, et al. High uterosacral vault suspension vs sacrocolpopexy for treating apical defects: a randomized controlled trial with twelve months follow-up. *Int Urogynecol J*. 2015;26(8):1131–8.
42. Kenton K, Mueller ER, Tarney C, Bressee C, Anger JT. One-year outcomes after minimally invasive sacrocolpopexy. *Female Pelvic Med Reconstr Surg*. 2016;22(5):382–4.
43. Ow LL, Lim YN, Lee J, Murray C, Thomas E, Leitch A, et al. RCT of vaginal extraperitoneal uterosacral ligament suspension (VEULS) with anterior mesh versus sacrocolpopexy: 4-year outcome. *Int Urogynecol J*. 2018;29(11):1607–14.
44. Nager CW, Visco AG, Richter HE, Rardin CR, Rogers RG, Harvie HS, et al. Effect of vaginal mesh hysteropexy vs vaginal hysterectomy with uterosacral ligament suspension on treatment failure in women with uterovaginal prolapse: a randomized clinical trial. *JAMA*. 2019;322(11):1054–65.
45. Steures P, Milani AL, van Rumpst-van de Geest DA, Kluivers KB, Withagen MIJ. Partially absorbable mesh or native tissue repair for pelvic organ prolapse: a randomized controlled trial. *Int Urogynecol J*. 2019;30(4):565–73.
46. Illiano E, Dittonno P, Giannitsas K, De Rienzo G, Bini V, Costantini E. Robot-assisted vs laparoscopic sacrocolpopexy for high-stage pelvic organ prolapse: a prospective, randomized, single-center study. *Urology*. 2019;134:116–23.
47. De Castro EB, Brito LGO, Juliato CRT. Vaginal hysterectomy with bilateral sacrospinous fixation plus an anterior mesh versus abdominal sacrocervicopexy for the treatment of primary apical prolapse in postmenopausal women: a randomized controlled study. *Int Urogynecol J*. 2020;31(2):365–72.
48. Enklaar RA, Schulten SF, van Eijndhoven HW, Weemhoff M, van Leijssen SA, van der Weide MC, et al. Manchester procedure vs sacrospinous hysteropexy for treatment of uterine descent: a randomized clinical trial. *JAMA*. 2023;330(7):626–35.
49. Galad J, Papcun P, Dudic R, Urdzik P. Single-incision mesh vs sacrospinous ligament fixation in posthysterectomy women at a three-year follow-up: a randomized trial. *Bratislava Med J*. 2020;121(9):640–7.
50. Kowalski JT, Genadry R, Ten Eyck P, Bradley CS. A randomized controlled trial of permanent vs absorbable suture for uterosacral ligament suspension. *Int Urogynecol J*. 2021;32(4):785–90.
51. Matthews CA, Geller EJ, Henley BR, Kenton K, Myers EM, Dieter AA, et al. Permanent compared with absorbable suture for vaginal mesh fixation during total hysterectomy and sacrocolpopexy: a randomized controlled trial. *Obstet Gynecol*. 2020;136(2):355–64.
52. Hemming C, Constable L, Goulao B, Kilonzo M, Boyers D, Elders A, et al. Surgical interventions for uterine prolapse and for vault prolapse: the two VUE RCTs. *Health Technol Assess*. 2020;24(13):1–219.
53. Van IJsselmuiden MN, van Oudheusden AMJ, Veen J, van de Pol G, Vollebregt A, Radder CM, et al. Hysteropexy in the treatment of uterine prolapse stage 2 or higher: laparoscopic sacrohysteropexy versus sacrospinous hysteropexy—a multicentre randomised controlled trial (LAVA trial). *BJOG*. 2020;127(10):1284–93.

54. Başer E, Seçkin KD, Kadiroğullari P, Kiyak H. The effect of sacrospinous ligament fixation during vaginal hysterectomy on post-operative de novo stress incontinence occurrence: a prospective study with 2-year follow-up. *Turk J Med Sci*. 2020;50(4):978–84.
55. Berger AA, Tan-Kim J, Menefee SA. Anchor vs suture for the attachment of vaginal mesh in a robotic-assisted sacrocolpopexy: a randomized clinical trial. *Am J Obstet Gynecol*. 2020;223(2):258.e1-8.
56. Obut M, Oğlak SC, Akgöl S. Comparison of the quality of life and female sexual function following laparoscopic pectopexy and laparoscopic sacrohysteropexy in apical prolapse patients. *Gynecol Minim Invasive Ther*. 2021;10(2):96–103.
57. Ferrando CA, Paraiso MFR. A prospective randomized trial comparing Restorelle® Y mesh and flat mesh for laparoscopic and robotic-assisted laparoscopic sacrocolpopexy: 24-month outcomes. *Int Urogynecol J*. 2021;32(6):1565–70.
58. Cengiz H, Yildiz S, Alay I, Kaya C, Eren E, Ilman D. Vaginal-assisted laparoscopic sacrohysteropexy and vaginal hysterectomy with vaginal vault suspension for advanced uterine prolapse: 12-month preliminary results of a randomized controlled study. *Gynecol Minim Invasive Ther*. 2021;10(1):30–6.
59. Castro RA, Bortolini MAT, Pascom ALG, Ledesma M, Sardi JJJ, Monteiro MVC, et al. Vaginal sacrospinous ligament fixation using tissue anchoring system versus a traditional technique for women with apical vaginal prolapse: a randomized controlled trial. *Female Pelvic Med Reconstr Surg*. 2021;27(1):e215–22.
60. Tagliaferri V, Ruggieri S, Taccaliti C, Gentile C, Didonna T, D'asta M, et al. Comparison of absorbable and permanent sutures for laparoscopic sacrocervicopexy: a randomized controlled trial. *Acta Obstet Gynecol Scand*. 2021;100(2):347–52.
61. Gamal AA, Nasraddeen MAM, Nagueib AH, Elsayed MA, Elmaraghy AM. Modified Purandare's cervicopexy versus abdominal sacral hysteropexy as conservative surgeries for genital prolapse: a randomized controlled trial. *Vopr Ginekolog Akusherstva Perinatol*. 2022;21(3):36–44.
62. Isenlik BS, Aksoy O, Erol O, Mulayim B. Comparison of laparoscopic lateral suspension and laparoscopic sacrocolpopexy with concurrent total laparoscopic hysterectomy for the treatment of pelvic organ prolapse: a randomized controlled clinical trial. *Int Urogynecol J*. 2023;34(1):231–8.
63. Karadag B, Mulayim B, Karadag C, Akdaş BA, Karataş S, Yüksel BA, et al. McCall culdoplasty vs. vaginally assisted laparoscopic sacrocolpopexy in the treatment of advanced uterine prolapse: a randomized controlled study. *Taiwan J Obstet Gynecol*. 2023;62(2):325–9.
64. Daneshpajoo A, Pakmanesh H, Sohbati S, Mirzaei M, Yar EZ, Dehesh T. Comparing laparoscopic sacrocolpopexy with vaginal sacrospinous ligament fixation in the treatment of vaginal apical prolapse; the first randomized clinical trial: a pilot study. *Urol J*. 2022;19(2):131–7.
65. De Tayrac R, Cosson M, Panel L, Compan C, Zemmache MZ, Bouvet S, et al. Urinary and sexual impact of pelvic reconstructive surgery for genital prolapse by surgical route. A randomized controlled trial. *Int Urogynecol J*. 2022;33(7):2021–30.
66. Morciano A, Caliandro D, Campagna G, Panico G, Giaquinto A, Fachechi G, et al. Laparoscopic ventral rectopexy plus sacral colpopexy: continuous locked suture for mesh fixation. A randomized clinical trial. *Arch Gynecol Obstet*. 2022;306(5):1573–9.
67. Chen J, Yu J, Morse A, Tao G, Gong J, Wang B, et al. Effectiveness of self-cut vs mesh-kit titanium-coated polypropylene mesh for transvaginal treatment of severe pelvic organ prolapse: a multicenter randomized noninferiority clinical trial. *JAMA Netw Open*. 2022;5(9):E2231869.
68. Morciano A, Ercoli A, Caliandro D, Campagna G, Panico G, Giaquinto A, et al. Laparoscopic posterior vaginal plication plus sacral colpopexy for severe posterior vaginal prolapse: a randomized clinical trial. *Neurourol Urodyn*. 2023;42(1):98–105.
69. Hwang WY, Jeon MJ, Suh DH. Minimally invasive sacrohysteropexy versus vaginal hysterectomy with uterosacral ligament suspension for pelvic organ prolapse: a prospective randomized non-inferiority trial. *J Minim Invasive Gynecol*. 2024;31(5):406–13.
70. Menefee SA, Richter HE, Myers D, Moalli P, Weidner AC, Harvie HS, et al. Apical suspension repair for vaginal vault prolapse: a randomized clinical trial. *JAMA Surg*. 2024;159(8):845–55.
71. Di Biasi J, Ruggieri S, Taccaliti C, Ciocca M, Di Florio C, Stabile G, et al. Posterior mesh fixation versus non-fixation in sacrocolpopexy: a randomized clinical trial. *Eur J Obstet Gynecol Reprod Biol*. 2025;309:1–6.
72. Freeman RM, Pantazis K, Thomson A, Frappell J, Bombieri L, Moran P, et al. A randomised controlled trial of abdominal versus laparoscopic sacrocolpopexy for the treatment of post-hysterectomy vaginal vault prolapse: LAS study. *Int Urogynecol J Pelvic Floor Dysfunct*. 2013;24(3):377–84.
73. Chandler J, Cumpston M, Li T, Page MJ, Welch V. *Cochrane handbook for systematic reviews of interventions*, vol. vol. 4. New York: Wiley; 2019.
74. Mol BW, Lai S, Rahim A, Bordewijk EM, Wang R, van Eekelen R, et al. Checklist to assess Trustworthiness in RAndomised Controlled Trials (TRACT checklist): concept proposal and pilot. *Res Integ Peer Rev*. 2023;8(1):6.
75. Metelli S, Yu T, Chaimani A, editors. *NMAstudio: a fully interactive web-application for producing and visualising network meta-analyses*. *Cochrane Colloquium*; 2023. <https://abstracts.cochrane.org/2023-london/nmastudio-fully-interactive-web-application-producing-and-visualizing-network-meta>
76. Jaiswal N, Field R. Network meta-analysis: the way forward for evidence-based decisions. *Clin Epidemiol Glob Health*. 2024;26:101531.
77. Barber MD, Brubaker L, Nygaard I, Wheeler TL, Schaffer J, Chen Z, et al. Defining success after surgery for pelvic organ prolapse. *Obstet Gynecol*. 2009;114(3):600–9.
78. Spinelli LM, Papadimitropoulou K, Kalyvas C. Exploring the transitivity assumption in network meta-analysis: a novel approach and its implications. *Stat Med*. 2025;44(7):e70068.
79. Nassif J, Yadav GS, Orejuela FJ, Turrentine MA. Rate of mesh erosion after sacrocolpopexy with concurrent supracervical compared with total hysterectomy: a systematic review and meta-analysis. *Obstet Gynecol*. 2022;140(3):412–20.
80. Schimpf MO, Abed H, Sanses T, White AB, Lowenstein L, Ward RM, et al. Graft and mesh use in transvaginal prolapse repair: a systematic review. *Obstet Gynecol*. 2016;128(1):81–91.
81. Costantini E, Brubaker L, Cervigni M, Matthews CA, O'Reilly BA, Rizk D, et al. Sacrocolpopexy for pelvic organ prolapse: evidence-based review and recommendations. *Eur J Obstet Gynecol Reprod Biol*. 2016;205:60–5.

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