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Ultrasound outcomes and surgical parameters of the double-layer purse-string uterine closure technique in cesarean delivery: a systematic review and meta-analysis of randomized trials

Mahsan Nabighadim[1], Maryam Vaezi[2], Mahsa Maghalian[3,4*] and Mojgan Mirghafourvand[5*]

Abstract

Background A cesarean scar defect is a structural abnormality in the myometrium at the site of a prior cesarean incision, primarily influenced by the closure technique. Purse-string uterine suturing (PSUS) may reduce the incidence of cesarean scar defects and improve uterine integrity. However, the literature presents inconsistent findings, necessitating a systematic evaluation. This systematic review and meta-analysis of randomized controlled trials (RCTs) aims to assess the impact of PSUS on ultrasound outcomes and surgical parameters related to cesarean scars.

Methods This systematic review and meta-analysis involved a search for relevant publications in English and Persian across multiple databases, including PubMed, the Cochrane Library, Google Scholar, Scopus, Web of Science, and SID. The search was unrestricted by date and included all available publications up to August 8, 2024. The risk of bias in the included studies was evaluated using the Risk of Bias 2 (ROB2) tool, while the certainty of the evidence was assessed through the GRADE approach. Meta-regression was employed to investigate potential risk factors for cesarean scar defects, and trial sequential analysis was conducted to mitigate Type I and Type II errors.

Results A total of 353 studies were identified through the search strategy, with 8 studies included in the analysis. The meta-analysis demonstrated a significant reduction in the rate of cesarean scar defects in the PSUS group compared to the control group (risk ratio [RR] 0.45, 95% confidence interval [CI] 0.36 to 0.58; 8 trials, 751 participants, $I^2 = 0\%$, indicating no heterogeneity). Additionally, a shorter uterine incision length was observed in the PSUS group compared to the control group (MD -3.84, 95% CI -4.97 to -2.71; 4 trials, 438 participants, $I^2 = 80\%$, suggesting substantial heterogeneity). The PSUS group also exhibited greater residual myometrium thickness (RMT) than the control group (MD 1.33, 95% CI 0.72 to 1.94; 5 trials, 417 participants, $I^2 = 92\%$, indicating considerable heterogeneity). However, no statistically significant differences were found between the PSUS and control groups regarding operation

*Correspondence:
Mahsa Maghalian
mahsamaghalian@gmail.com
Mojgan Mirghafourvand
mirghafourvand@gmail.com

Full list of author information is available at the end of the article

time ($p = 0.10$, $I^2 = 67\%$, suggesting moderate heterogeneity), length ($p = 0.14$, $I^2 = 98\%$, indicating considerable heterogeneity), height ($p = 0.10$, $I^2 = 76\%$, suggesting substantial heterogeneity) of incision defects, or blood loss during the procedure ($p = 0.94$, $I^2 = 0\%$, indicating no heterogeneity).

Conclusions The use of PSUS during cesarean sections significantly reduces the occurrence of cesarean scar defects, indicating a clear clinical benefit with moderate certainty. However, the evidence for other ultrasound evaluation outcomes and surgical parameters remains of low to very low certainty. Therefore, further research is essential to validate these findings and assess the long-term clinical implications of integrating PSUS into cesarean procedures.

Keywords Abdominal delivery, Uterine suture, Niche, Incision, Turan technique, Cesarean scar

Background

Cesarean delivery, or cesarean section, involves the surgical delivery of a fetus through incisions in the abdominal wall and uterus, rather than through the vaginal canal [1]. Over recent decades, the global rate of cesarean deliveries has significantly increased, exceeding the World Health Organization's (WHO) recommended range of 10–15%. Currently, the global incidence stands at approximately 21% [2, 3].

This rise in cesarean sections has led to a higher incidence of uterine scarring and complications, including cesarean scar defects, often referred to as "niches." These defects are characterized by a myometrial abnormality at the incision site, with a depth of at least 2 millimeters (mm) [3, 4]. While many cesarean scar defects are asymptomatic, symptomatic cases can adversely affect women's health and future pregnancies, leading to issues such as abnormal uterine bleeding (AUB), pelvic pain, subfertility, sexual dysfunction, and low self-esteem [5, 6]. During pregnancy, these defects can result in severe complications, including cesarean scar pregnancy, placenta accreta spectrum disorders, and uterine rupture [7, 8].

Older women with multiple cesarean deliveries, particularly unplanned ones, and those with a higher body mass index (BMI), have an increased risk of developing cesarean scar defects [9]. Recent research emphasizes the role of ultrasound in evaluating uterine blood flow and its implications for pregnancy outcomes. Various diagnostic imaging techniques are used to assess these defects, including transvaginal ultrasound, hysterosalpingography, saline infusion sonography, and magnetic resonance imaging (MRI). Among these, contrast-enhanced ultrasound (saline/gel) is preferred for its effectiveness, while non-contrast ultrasound typically provides less detail [10, 11]. A recent study involving 49 term pregnancies found that increased total uterine artery blood flow volume is linked to lower pulsatility indices in both the umbilical and uterine arteries, as well as heavier newborns. Monitoring uterine blood flow may be essential for managing high-risk pregnancies [12]. The pulsatility index and resistance index are reliable predictors of adverse outcomes, while the systolic/end-diastolic ratio is less effective. Further research is needed to clarify the impact of uterine blood flow on labor and fetal outcomes [13].

Surgical factors, such as incision location and closure technique, influence the development of defects. Inadequate closure or hemostasis during the procedure may increase the risk of defects. Patient-related factors affecting wound healing and angiogenesis also contribute [14]. The optimal technique for suturing the uterus after a cesarean delivery remains a topic of discussion. Several methods are available, including continuous barbed suture, double-layer closure, inverted-U closure, locking stitch technique, single-layer closure, single-layer closure using inverting Lembert or Cushing stitches, two-layer closure with an interlocking layer, two-layer closure with distinct suture materials, and uterosacral ligament suspension. Each of these techniques has its own advantages and disadvantages, contributing to the ongoing debate about the most effective approach for uterine closure [15–17].

The continuous running suture technique across two layers during cesarean closure has been shown to reduce the risk of cesarean scar defects [18]. An innovative approach is the purse-string uterine suture (PSUS) technique, introduced by Turan et al. in 2015. This method employs two layers of transverse sutures: the first is placed through the inner layers of the uterine wall, while the second encompasses the outer layers, creating a purse-string-like closure. A figure-of-eight suture addresses any residual gap [19]. The PSUS technique may reduce cesarean scar defects and enhance the strength of the uterine wall [20]. However, existing studies report conflicting results, highlighting the need for a thorough evaluation of the evidence. This systematic review and meta-analysis of randomized controlled trials (RCTs) aims to evaluate the impact of the PSUS technique on ultrasound assessments of uterine scars and various surgical parameters. The hypothesis is that the PSUS technique can positively influence these evaluations, thereby informing clinical decision-making and optimizing surgical approaches for cesarean deliveries, ultimately improving both maternal and fetal health outcomes.

Methods

The current study was undertaken after the research protocol was registered in the PROSPERO database on October 6, 2023 (PROSPERO ID: CRD42023466535). Additionally, the study was conducted in compliance with the criteria outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist [21].

Inclusion and exclusion criteria

Types of participants

This systematic review and meta-analysis included studies involving pregnant women planned for elective cesarean sections, specifically those with a gestational age exceeding 34 weeks and carrying a singleton pregnancy. The focus was on including healthy participants scheduled for elective cesarean deliveries. In contrast, studies involving women undergoing emergency cesarean sections (typically associate with different clinical considerations and surgical techniques) or those with systemic conditions, such as diabetes mellitus, were excluded from this review.

Types of interventions

Our study included investigations that utilized a double-layer PSUS technique during cesarean delivery, comparing outcomes to a control group employing alternative methods for closing the uterine incision. In the PSUS technique, also known as the Turan technique (Fig. 1), the endometrial/decidual layer is incorporated in the deepest suture. The first layer of suturing begins at one corner and progresses along the edges in a purse-string configuration, effectively traversing the inner myometrium–decidua interface. This layer incorporates both myometrial and decidual tissue in the closure, with the original thread looping back to the starting point and secured with a knot. The second layer is similarly closed, passing transversely through the outer myometrium–visceral peritoneum boundary. Additionally, the study by Turan et al., which introduced this method, includes a video demonstrating the PSUS technique as a supplementary file [19].

Types of outcome measures

The primary outcome measured was the rate of uterine scar defects, assessed via ultrasound between 6- and 24-weeks post-cesarean delivery. A defect was defined as a wedge-shaped distortion with a depth greater than 2 mm or a RMT of less than 5 mm, as evaluated by transvaginal ultrasound. This definition adheres to established criteria for identifying cesarean scar defects, which are recognized complications following cesarean delivery [22–24].

The secondary outcomes of the study included a series of postoperative ultrasound evaluations conducted by trained sonographers or obstetricians. These assessments

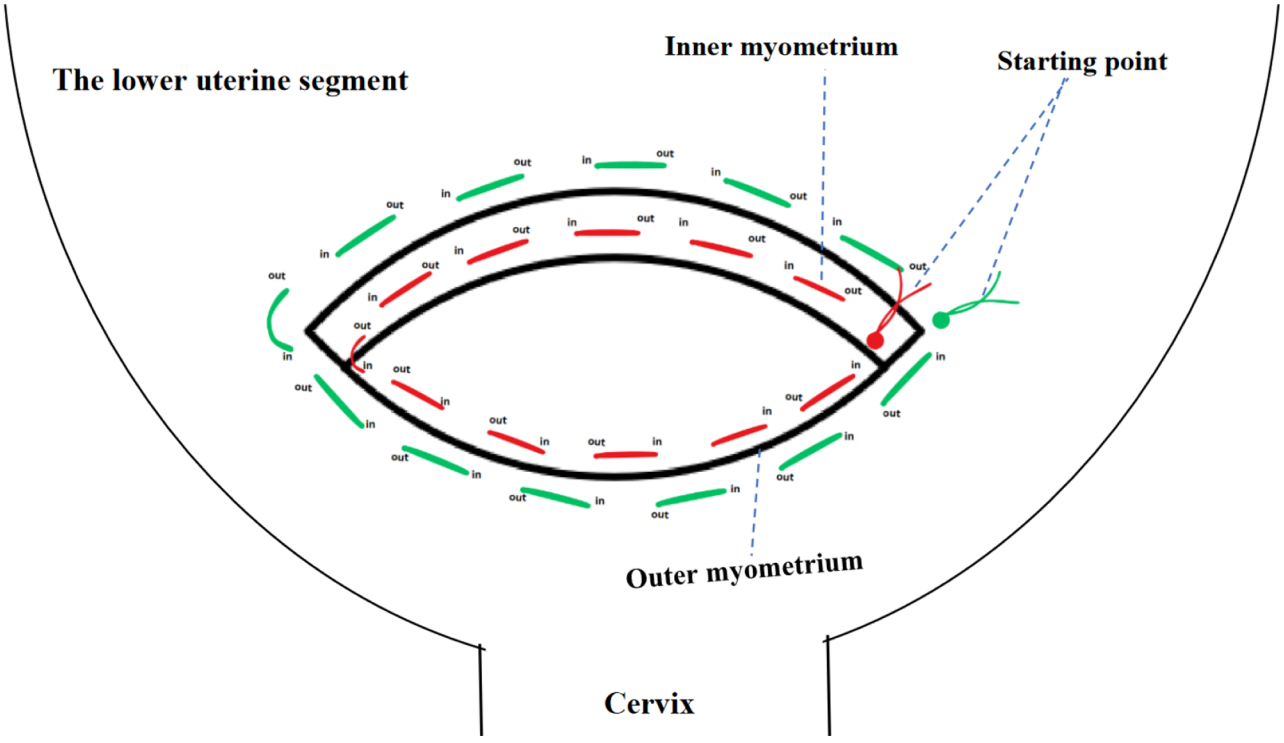

Fig. 1 The purse-string uterine suture technique, highlighting the suture path and configuration

were performed with the bladder empty and the patient in the lithotomy position, utilizing high-frequency transducers across various ultrasound devices. The evaluation of incision integrity was carried out in both transverse and sagittal planes, with particular emphasis on the transverse plane for measuring the length of the uterine incision. The following measurements were assessed:

- Length of the Uterine Incision: This refers to the linear distance from the starting point to the endpoint of the cesarean incision on the uterine wall, measured in mm.
- Length of the Incision Defect: This measurement indicates the linear extent of any complications at the site of the uterine incision, also recorded in mm.
- Height of the Incision Defect: This measurement quantifies the vertical extent of complications at the site of the uterine incision, also recorded in mm.
- RMT: This measurement assesses the thickness of the myometrium at the site of the hysterotomy, recorded in mm.

Some surgical parameters were also included:

- Duration of the Operation: Measured in minutes.
- Amount of Blood Loss During Surgery: Measured in mm.

Types of studies

The current study exclusively included RCTs. All other study designs and publication types were excluded.

Search methods for the identification of studies

For this study, we conducted a thorough and systematic search for relevant English- and Persian-language publications across the following databases: PubMed, the Cochrane Library, Google Scholar (search engine), Scopus, Web of Science, and the Scientific Information Database (SID). The search was not limited by date and covered all available publications up to August 8th, 2024. The complete search strategy used for all the databases is included in the supplementary file. The keywords used for the database searches were as follows:

(Cesarean OR cesarean OR "C-section" OR "Cesarean Section" OR "abdominal delivery" OR "Cesarean delivery" OR CS) AND (Turan technique OR "Purse-string*" OR "purse-string closure" OR "purse-string suture" OR "uterine suture" OR "double-layer purse-string*" OR "uterus closure") AND (Defect OR "cesarean scar" OR "uterine scar" OR "operating time" OR "operating duration" OR "operative time" OR "operating time" OR "operating duration" OR "Blood loss" OR "random* OR randomized controlled trial OR prospective randomized trial OR randomized OR randomized controlled trial OR RCT OR random OR "defect Height" OR niche length OR "defect length" OR "Residual myometrium thickness" OR "residual myometrium" OR "RMT" OR "Blood loss" OR "calculated Blood loss" OR "CBL" OR "Blood lost") AND (random* OR randomized controlled trial OR prospective randomized trial OR randomized OR randomized OR randomized controlled clinical trial OR RCT OR random).

Data collection

Two independent authors (MN and MMa) utilized EndNote software version 20 to facilitate the selection of studies. The initial screening phase involved reviewing titles and abstracts to quickly identify and exclude articles that did not meet the predefined inclusion criteria. For the articles that passed this preliminary review, a comprehensive full-text assessment was conducted to evaluate their suitability for inclusion in the study. In cases where the two reviewers could not reach a consensus on an article's eligibility, they engaged in collaborative discussions to resolve the matter. If they could not agree, a third reviewer (MMi) was consulted for an independent assessment, which helped to resolve any disagreements.

Data extraction and management

Data extraction and management were conducted separately by two authors using a standardized template based on the guidelines from the Cochrane Handbook for Systematic Reviews of Interventions [21]. The extracted information was compiled into a Microsoft Word (version 19) document and included the following details: first author's name, year of publication, country, final sample size, participants' age, intervention, comparator group, outcomes, and results.

Assessment of risk of bias in included studies

The quality of all included studies was evaluated by two independent authors (MN and MMa) utilizing the criteria delineated in the Cochrane Handbook [25]. The risk of bias was classified as low risk, high risk, or some concern using the Risk of Bias 2 (ROB2) tool. Disagreements among reviewers regarding the risk of bias were addressed through a systematic consensus process. Initially, each reviewer independently assessed the risk of bias using the established criteria. In cases where discrepancies arose, the reviewers engaged in discussions to clarify their evaluations, referencing specific evidence from the studies. If consensus could not be reached through discussion, a third reviewer was consulted to provide an objective assessment. This collaborative approach ensured that all evaluations were thorough and unbiased, enhancing the integrity of our findings.

Statistical methods

The meta-analysis was conducted using RevMan software version 5.4. For continuous outcomes, the mean difference (MD) with a 95% confidence interval (CI) was employed as the effect measure. For dichotomous outcomes, the relative risk (RR) with a 95% CI was utilized. In accordance with the Cochrane Handbook, we included a guide to interpreting heterogeneity in our analysis. Heterogeneity is categorized as follows: a percentage of 0–40% may not be considered important, while 30–60% may indicate moderate heterogeneity. A range of 50–90% suggests substantial heterogeneity, and values from 75 to 100% are indicative of considerable heterogeneity [25]. To evaluate the degree of heterogeneity among the included studies, we applied the I^2 statistic and the p-value from the chi-square test. If the I^2 value exceeded 50% and the p-value of the chi-square test was less than 0.05, a random effects model was preferred over a fixed effects model for the analysis [26].

Subgroup analyses were performed based on the type of uterine closure utilized in the control groups (single-layer versus double-layer techniques) for the primary outcome. Additional subgroup analyses were conducted based on the timing of imaging assessments (6 weeks, 12 weeks, and 24 weeks) and the types of postoperative imaging modalities employed as post hoc subgroup analyses (transvaginal sonography versus transvaginal sonohysterography) for postoperative ultrasound outcomes.

A post hoc sensitivity analysis was conducted for all outcomes by excluding studies that used single-layer uterine closure as a control group. According to the Cochrane Handbook, assessments of publication bias are recommended only when a meta-analysis includes at least ten studies [25]. Since our analysis included fewer than ten studies, we opted not to conduct a funnel plot or Egger's test in accordance with these guidelines.

Furthermore, a meta-regression analysis was performed for the primary outcome using Comprehensive Meta-Analysis Software version 3. The following variables were investigated as potential risk factors: mean maternal age in the intervention group (in years), the necessity for additional hemostatic sutures (expressed as a percentage), participants' BMI, gestational age at the time of the intervention, number of cesarean deliveries, and preoperative hemoglobin levels (in grams per deciliter).

Trial sequential analysis (TSA) was employed as a statistical technique to estimate the required information size (RIS) and to monitor the accumulating evidence as the trial progressed. This method establishes predefined boundaries that, if reached by the trial results, may indicate that the effect of the intervention has been sufficiently established [27].

Certainty of evidence

The quality of the available evidence was assessed via the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach [28]. This framework categorizes the certainty of evidence into four levels: high, moderate, low, and very low. The GRADE evaluation considers several factors that may affect the reliability of the evidence, including the risk of bias in study designs, the precision of the reported results, the consistency of findings across different studies, the directness of the evidence related to the research question, and the potential for publication bias [28]. If discrepancies arose, the reviewers engaged in discussions to reconcile their assessments. If consensus could not be reached, a third reviewer was consulted to provide an objective evaluation, ensuring that the final determination of evidence certainty was comprehensive and unbiased.

Results

Results of the search

A total of 353 studies were identified through the search strategy. After removing 98 duplicates, 255 studies were screened based on their titles and abstracts. Following this initial screening, 17 studies were selected for full-text review. Of these, four studies were excluded because the suture type was not PSUS [29–32], three did not assess the outcomes of interest [33–35], one lacked a randomized controlled trial (RCT) design [36], and one study was retracted [37]. Ultimately, eight studies [19, 38–44] were included in the systematic review and meta-analysis (Fig. 2).

Characteristics of the included studies

All included studies were RCTs. Two studies [19, 39] were conducted in Turkey, two in Tunisia [43, 44], and four in Egypt [38, 40–42]. Most studies were conducted between 2019 and 2023, with the exception of one study by Turan et al., published in 2015 [19]. The total sample size across the studies included 751 women, with 376 allocated to the PSUS group and 375 to the control group.

The studies enrolled women over 18 years of age with singleton pregnancies who underwent elective cesarean deliveries. Six studies focused exclusively on women with primary cesarean sections, while two studies [19, 44] included women with prior cesarean deliveries.

In the studies by Dimassi et al. [44] and Yıldız et al. [39], the control group received single-layer uterine closure, whereas the other studies used double-layer closure.

The primary imaging modality was transvaginal ultrasound, with all studies assessing postoperative outcomes via transvaginal sonography; however, two studies employed transvaginal sonohysterography [41, 43]. Transvaginal ultrasound evaluations were performed at

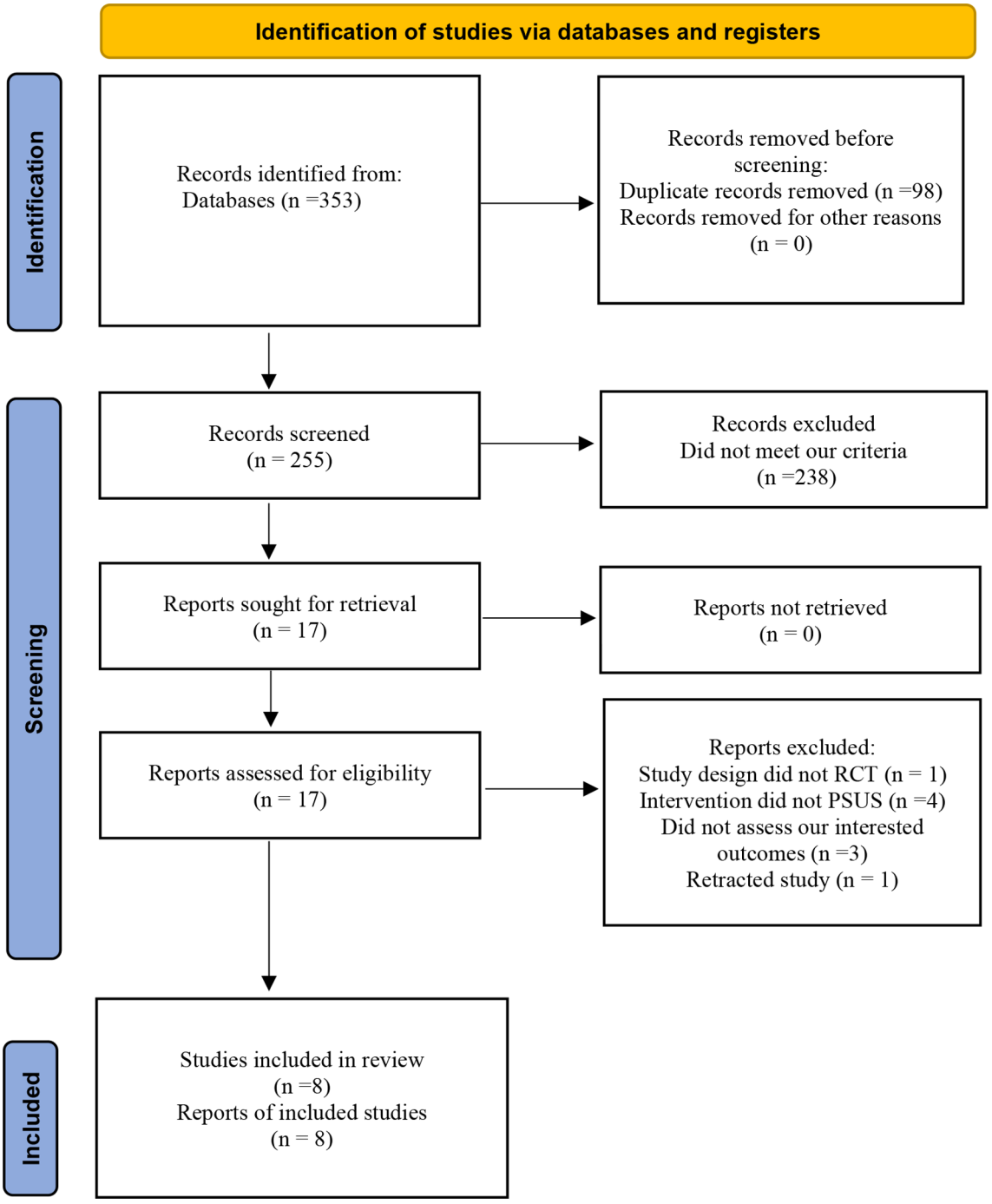

Fig. 2 Flow diagram of the systematic literature search

different time points: four studies [38, 41, 43, 44] evaluated at 24 weeks post-cesarean, three studies [19, 39, 42] at 6 weeks post-cesarean, and one study [36] at 3 months post-cesarean (Table 1).

Assessment of risk of bias

Based on this evaluation, the overall risk of bias for the RCTs was categorized as "some concern" in six studies [38–40, 42–44]. In contrast, the remaining two studies [19, 41] were assessed as having a low risk of bias. The assessment revealed that the primary domains contributing to the "some concern" rating included the randomization process, outcome measurement, and selection of reported results (see Figs. 3 and 4).

Table 1 Characteristics of the included studies

First Author and date of publication	Country	Type of clinical trial	Sample size	Age of participants (years)	Intervention	Comparison	Outcomes	Ultrasound method for scar assessment/ Ultrasound device	Results
Turan et al. 2015	Turkey	RCT	PSUS group *N* = 51 Control group *N* = 65	PSUS 29.6 ± 5.0 Control 28.5 ± 5.3	Double-layered PSUS	Double-layered uterine closure (Double-layer continuous locking suture: Holding sutures at each corner; uterine incision closed including decidua.)	Uterine scar defect rate Height of uterine incision defect Uterine incision length Operation time RMT	Transvaginal sonography/ Siemens Acuson Antares, 5–6 MHz.	The study found statistically significant differences in the uterine scar defect rate, uterine incision length, and RMT. However, there was no statistically significant difference observed in the height of the uterine incision defect or the operation time.
Halouani et al. 2023	Tunisia	RCT	PSUS group *N* = 42 Control group *N* = 37	PSUS 30.4 ± 6 Control 30.5 ± 5.7	Double-layered PSUS	Double-layered uterine closure (Double-Layer Continuous Unlocked Suture: First layer for deep myometrium, second layer for upper myometrium, both continuous and unlocked.)	Uterine scar defects Length of uterine incision defect RMT Amount of blood loss during operation	Transvaginal sonohysterography/ Samsung Medison UGEO HS40, 5–6 MHz.	The study found a statistically significant difference in uterine scar defects. However, there was no statistically significant difference observed in the length of the uterine incision defect, the RMT, or the amount of blood loss during the operation.
Radwan et al. 2019	Egypt	RCT	PSUS group *N* = 44 Control group *N* = 44	The mean age of women was not reported separately for different study groups, but included women above the age of 16.	Double-layered PSUS	Double-layered uterine closure (Classical double-layered closure: specific details not provided.)	Uterine scar defects Operation time	Transvaginal sonography/ SonoACE R3, 5–6 MHz.	The study found no statistically significant difference in uterine scar defects or operation time.
Mohamed et al. 2022	Egypt	RCT	PSUS group *N* = 68 Control group *N* = 68	PSUS 25.94 ± 3.23Control 26.94 ± 3.43	Double-layered PSUS	Double-layered uterine closure (Double-layer continuous non-locking suture: Holding sutures at each corner; uterine incision closed including decidua.)	Uterine scar defects Height of uterine incision defect Uterine incision length Operation time	Transvaginal sonography/ Samsung Medison, Sonoace R3, 5–6 MHz.	The study found statistically significant differences in the uterine scar defects, the height of the uterine incision defect, and the uterine incision length. However, the study did not find any statistically significant difference in the operation time between the groups studied.
Yıldız et al. 2023	Turkey	RCT	PSUS group *N* = 58 Control group *N* = 53	PSUS 27.3 ± 5.9 Control 29 ± 6.2	Double-layered PSUS	Single-layered uterine closure. (Classic single-layer unlocked uterus closure.)	Uterine scar defects Length of uterine incision defect Height of uterine incision defect RMT Uterine incision length	Transvaginal sonography/ Mindray DC 8 Expert, 5–9 MHz.	The study found statistically significant differences in the length of the uterine incision defect, the RMT, and the uterine incision length. There was no statistically significant difference observed in the uterine scar defects or the height of the uterine incision defect.

Table 1 (continued)

First Author and date of publication	Country	Type of clinical trial	Sample size	Age of participants (years)	Intervention	Comparison	Outcomes	Ultrasound method for scar assessment/ Ultrasound device	Results
Shenishan et al. 2023	Egypt	RCT	PSUS group *N* = 37 Control group *N* = 38	28.59 ± 4.71	Double-layered PSUS	Double-layered uterine closure (Classic double-layer technique: Continuous double-layer sutures decidua and uterine incision sewn together.)	Uterine scar defects Height of uterine incision defect RMT Uterine incision length Operation time	Transvaginal sonography /NR	The study found statistically significant differences in the RMT, uterine incision length, and operation time. There was no statistically significant difference observed in the uterine scar defects or the height of the uterine incision defect.
Heraiz et al. 2022	Egypt	RCT	PSUS group *N* = 48 Control group *N* = 44	PSUS 29 ± 3 Control 28 ± 4	Double-layered PSUS	Double-layered uterine closure (Conventional double-layered closure: Multifilament continuous running sutures for both layers; first layer includes decidua, second layer uses inverted Lambert method.)	Uterine scar defects Length of uterine incision defect RMT Operation time Amount of blood loss during operation	Transvaginal sonohysterography/ Mindray DC 70 Expert, 7.5 MHz.	The study found statistically significant differences in the uterine scar defects, length of the uterine incision defect, RMT, and operation time. However, there was no statistically significant difference observed in the amount of blood loss during the operation.
Dimassi et al. 2022	Tunisia	RCT	PSUS group *N* = 43 Control group *N* = 41	PSUS 32.80 ± 0.77 Control 33.86 ± 0.75	Double-layered PSUS	Single-layered uterine closure. (Single-layer continuous uterine suture: Holding Vicryl suture in the left corner; continuous non-locking stitch from the right corner, closing the entire uterine wall (including decidua) in a cranial/caudal direction.)	Uterine scar defects Length of uterine incision defect RMT	Transvaginal sonography/ Samsung Medison UGEO H609, 5–6 MHz.	The study found statistically significant differences in the uterine scar defects, length of the uterine incision defect, and RMT.

RMT: residual myometrium thickness; RCT: randomized controlled trial; PSUS: purse-string uterine suture; NR: not reported

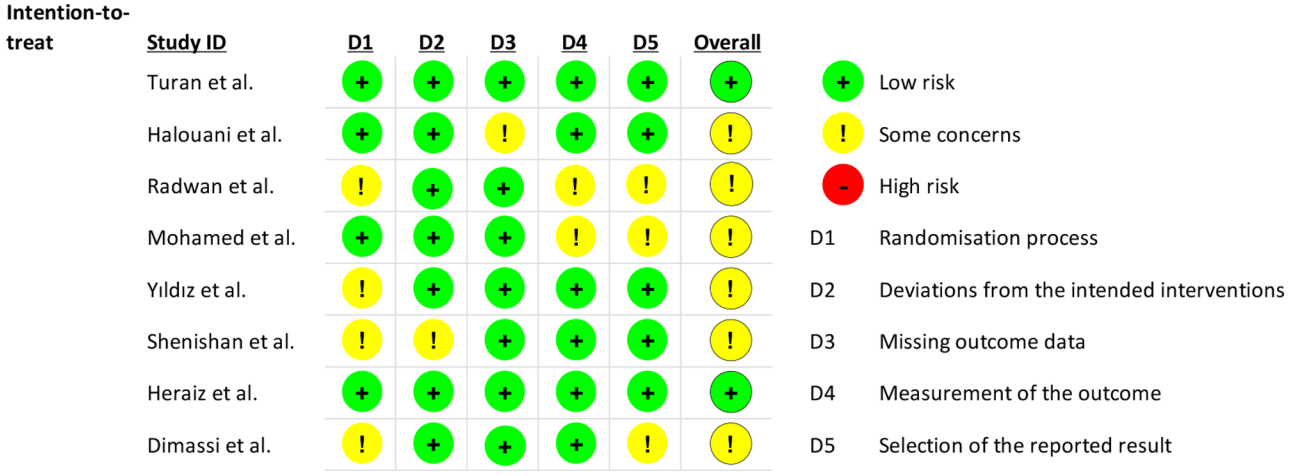

Fig. 3 Risk of bias summary: Review authors' judgments about each risk of bias item for each included study

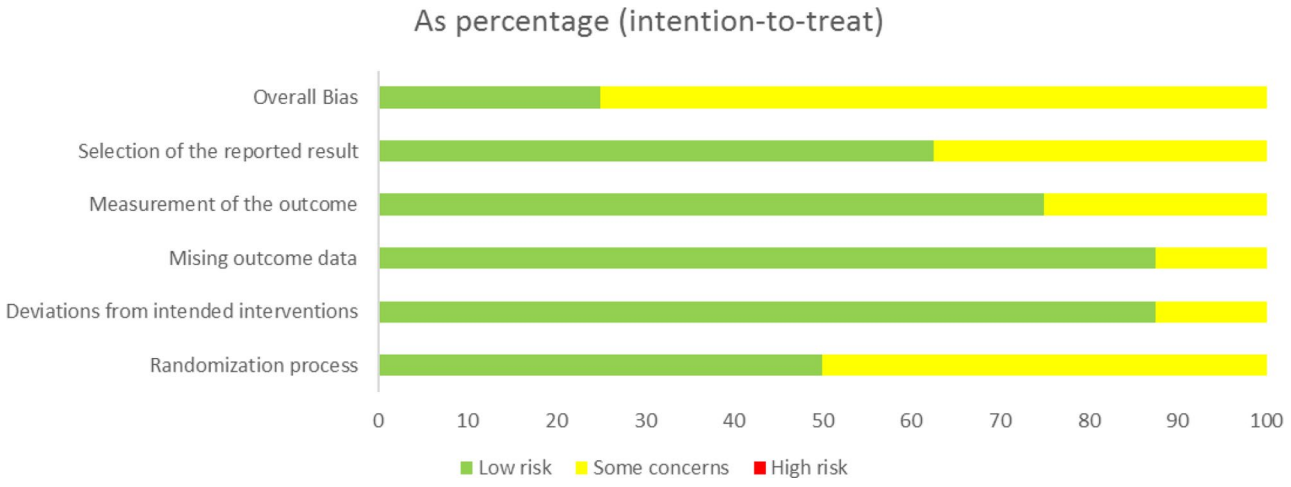

Fig. 4 Risk of bias graph. Review authors' judgments about each risk of bias item presented as percentages across all included studies

Meta-analysis

The results of the study's outcomes are summarized in Table 2.

Uterine scar defects (primary outcome)

Compared to the control group, the use of PSUS likely reduced the incidence of uterine scar defects after cesarean delivery (RR 0.45, 95% CI 0.36 to 0.58; 8 trials, 751 participants; I^2 = 0%, Fig. 5). We assessed the certainty of the evidence as moderate, downgrading it for risk of bias (-1) (Table S1).

Subgroup analysis: timing of postoperative imaging evaluations (24 Weeks/6 Weeks/12 weeks)

The analysis of subgroups based on the timing of postoperative imaging evaluations did not reveal any significant differences or interactions among the subgroups. The test for subgroup differences supports this, showing Chi^2 = 1.52, degrees of freedom (df) = 2 (p = 0.47), and I^2 = 0%. These results suggest a consistent treatment effect across the different time points for postoperative imaging evaluations (Fig. 5).

Subgroup analysis: variation in control groups (Single-layered/double-layered uterine closure)

The analysis based on the type of uterine closure in the control groups did not reveal any significant differences or interactions. The results of the test for subgroup differences are as follows: Chi^2 = 0.84, df = 1 (p = 0.36), and I^2 = 0%. These findings indicate a consistent treatment effect across the different closure types in the control groups (Fig. 6).

Subgroup analysis: variation in postoperative imaging modalities (Transvaginal sonography vs. Transvaginal sonohysterography)

The analysis of subgroups based on the type of imaging modality evaluated did not reveal any significant differences or interactions. The results of the test for subgroup differences are as follows: Chi^2 = 0.30, df = 1 (p = 0.58),

Table 2 Summary of findings on the effects of PSUS on ultrasound evaluation outcomes and surgical parameters
Patient or population: pregnant women with indications for cesarean section, gestational age over 34 weeks, and a singleton pregnancy
Setting: Tunisia; Egypt and Turkey
Intervention: PSUS
Comparison: double-layered uterine closure; single-layered uterine closure

Outcomes		Anticipated absolute effects [95% CI]		Relative effect [95% CI]	No of Participants [studies]	Quality of the evidence
		Risk with control	Risk with PSUS			
Postsurgical ultrasound measurements	Uterine scar defects	400 per 1000	180 per 1000 (144 to 232)	RR 0.45 (0.36 to 0.58)	751 [8 RCT]	⊕⊕⊕⊖ Moderate
	Length of the uterine incision (in millimeters)	The mean of length of the uterine incision in the control groups was 20.5	The mean of length of the uterine incision in the intervention group was − 3.84 lower (-4.97 to -2.71)	MD -3.84 (-4.97 to -2.71)	438 [4 RCT]	low ⊕⊕OO
	Length of the incision defect (in millimeters)	The mean of length of the incision defect in the control groups was 6.35	The mean of length of the incision defect in the intervention group was − 1.91 lower (-4.42, 0.60)	MD -1.91 (-4.42 to 0.60)	432 [4 RCT]	⊕⊖⊖⊖ Very Low
	Height of the incision defect (in millimeters)	The mean of height of uterine incision defect in the control groups was 3.04	The mean of height of the incision defect in the intervention group was − 0.27 lower (-0.59 to 0.05)	MD -0.27 (-0.59 to 0.05)	438 [4 RCT]	⊕⊖⊖⊖ Very Low
	RMT (in millimeters)	The mean of RMT in ultrasound evaluation in the control groups was 6.18	The mean of postpartum perineal pain in the intervention group was 1.33 higher (0.72 to 1.94)	MD 1.33 (0.72 to 1.94)	417 [5 RCT]	⊕⊕⊖⊖ Low
Surgical parameters	Duration of the operation (in minutes)	The mean of duration of the operation in the control groups was 32.9	The mean of operation time in the intervention group was 1.30 higher (-0.24 to 2.83)	MD 1.30 (-0.24 to 2.83)	491 [5 RCT]	⊕⊖⊖⊖ Very Low
	Amount of blood loss during the surgery (in milliliters)	The mean of postpartum perineal pain in the control groups was 498.1	The mean of postpartum perineal pain in the intervention group was 1.12 higher (-28.5 to 30.7)	MD 1.12 (-28.55 to 30.79)	171	⊕⊖⊖⊖ Very Low

Note: CI: confidence interval; MD: mean difference; RMT: residual myometrium thickness; RR: relative risk; PSUS: purse-string uterine suture

GRADE Working Group grades of evidence

Moderate quality: We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect

Very low quality: We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

The risk in the intervention group [and its 95% confidence interval] is based on the assumed risk in the comparison group and the relative effect of the intervention [and its 95% CI]

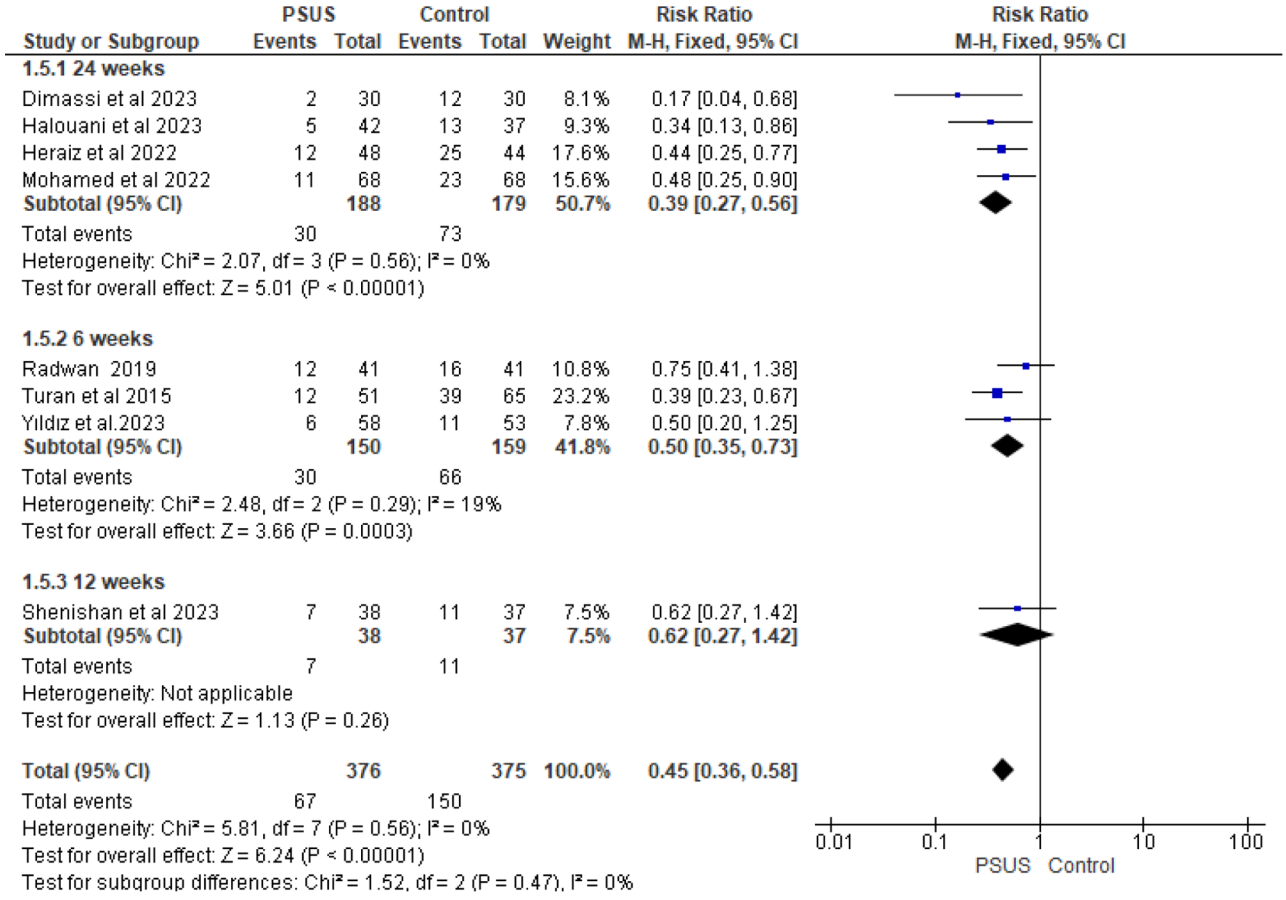

Fig. 5 Forest plot of the effect of purse-string uterine suturing on uterine scar defects, categorized by the timing of postoperative transvaginal ultrasound evaluations

and I^2 = 0%. These findings indicate a consistent treatment effect across the different imaging modalities (Fig. 7).

Meta-regression

The results of the random effects meta-regression analyses revealed no significant correlations between uterine scar defects and the following factors: mean maternal age ($p = 0.159$), preoperative hemoglobin level ($p = 0.130$), percentage of additional hemostatic sutures required ($p = 0.422$), BMI ($p = 0.770$), number of cesarean deliveries ($p = 0.171$), or mean gestational age ($p = 0.897$) (Table S2).

Trial sequential analysis

TSA was performed for uterine scar defects following cesarean delivery, revealing an incidence of 40%, a relative risk reduction (RRR) of 55%, a two-sided alpha (α) of 1%, a beta (β) of 10%, an I^2 of 0%, and a RIS of 254.

The blue Z-curve remained below the upper monitoring boundary, indicating that although the double-layer PSUS technique may reduce the incidence of uterine scar defects after cesarean delivery, the results did not reach statistical significance. Consequently, the evidence does not support a definitive conclusion regarding its efficacy. However, the Z-curve did reflect the RIS of 254 patients, suggesting that the analysis was adequately powered to evaluate the intervention's effectiveness (Fig. S1).

Secondary outcomes (Postoperative imaging modality evaluation)

Length of the uterine incision (in mm)

Compared with the control group, the use of the PSUS technique may reduce the length of the uterine incision observed in postoperative ultrasound evaluations (MD -3.84, 95% CI -4.97 to -2.71; 4 trials, 438 participants; I^2 = 80%, Table 3). However, the certainty of this evidence was assessed as low due to concerns regarding the risk of bias (-1) and inconsistency (-1) (Table S1). To investigate the possible reasons for the substantial heterogeneity observed, we conducted subgroup and sensitivity analyses for the length of the uterine incision.

Subgroup: variations in the timing of postoperative imaging evaluations (24 weeks/6 weeks/12 weeks)

The analysis of subgroups based on the timing of postoperative imaging evaluations revealed significant

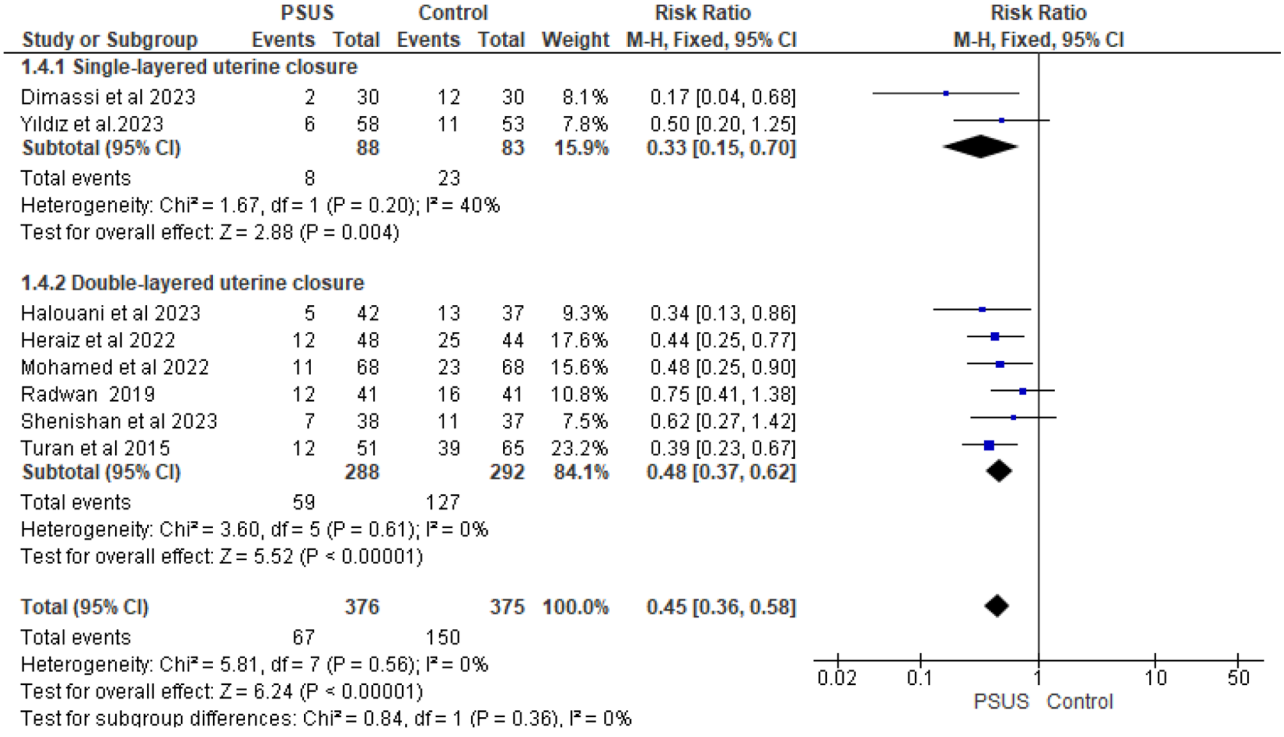

Fig. 6 Forest plot of the effect of purse-string uterine suturing on uterine scar defects, categorized by the types of control groups used in the studies

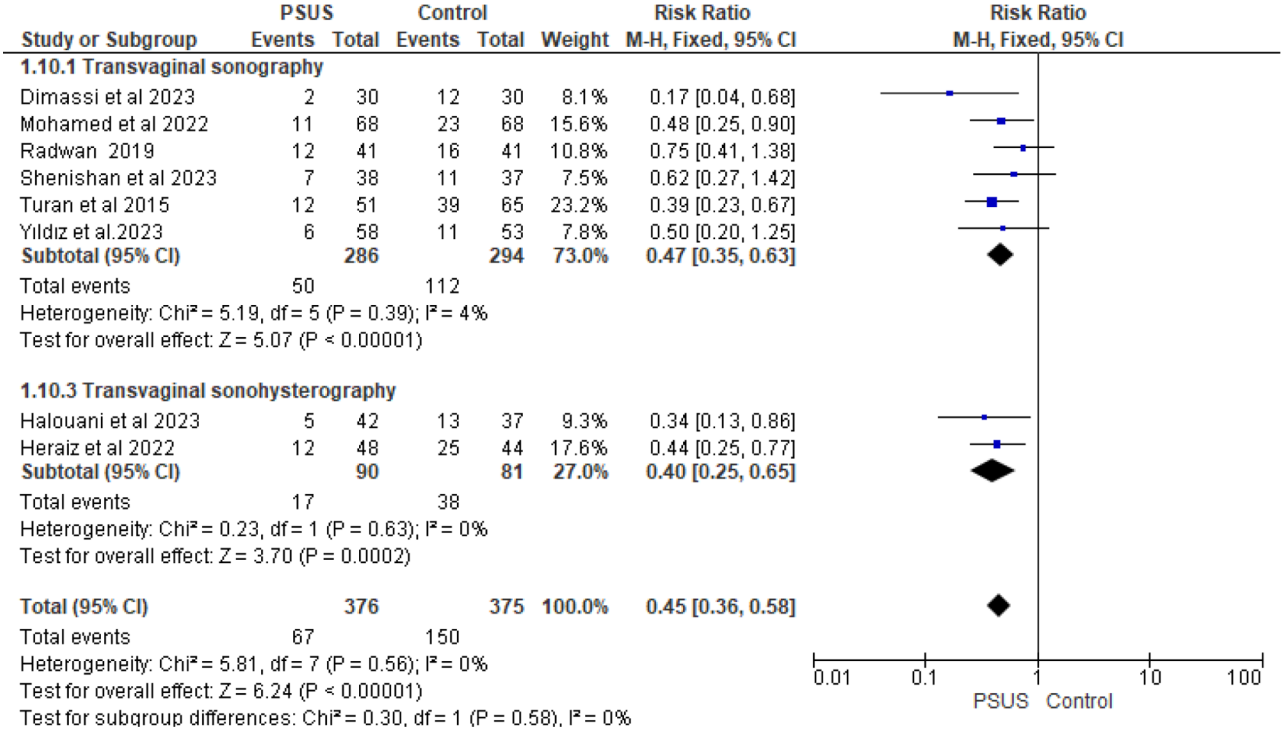

Fig. 7 Forest plot of the effects of purse-string uterine suturing on uterine scar defects categorized by the postoperative imaging modalities used for evaluation

Table 3 Results of the effects of PSUS on secondary outcomes

Outcomes	Turan et al. 2015	Halouani et al. 2023	Radwan 2019	Mohamed et al. 2022	Yıldız et al. 2023	Shenishan et al. 2023	Heraiz et al. 2022	Dimassi et al. 2023	Overall and subgroup analysis results			
									variables	Effect Size MD [95% CI]	I^2	Test for Subgroup difference *p* value, and I^2
Postsurgical ultrasound evaluation outcomes (Subgroup analysis based on the timing of postoperative imaging modality evaluations [24 weeks/6 weeks/12 weeks])												
Length of the incision defect (in millimeters)	NR	0.28 ± 0.66 vs. 0.76 ± 1.77	NR	NR	7.8 ± 0.90 vs. 6.90 ± 1.70	NR	9.0 ± 2.10 vs. 16.0 ± 3.80	0.45 ± 1.76 vs. 1.75 ± 2.20	Overall	-1.91 [-4.42, 0.60] $p = 0.14$	98%	**$P = 0.03$, $I^2 = 77.7\%$**
									24 weeks	-2.89 [-6.36, 0.58] $p = 0.10$	98%	
									6 weeks	0.90 [0.39, 1.41] $p < 0.0001$	N/A	
Height of the incision defect (in millimeters)	3.62 ± 1.19 vs. 4.06 ± 1.43	NR	NR	3.36 ± 0.69 vs. 3.90 ± 0.62	3.70 ± 0.70 vs. 3.70 ± 0.50	0.42 ± 0.98 vs. 0.51 ± 1.04	NR	NR	Overall	-0.27 [-0.59, 0.05] $p = 0.10$	76%	$P = 0.11$, $I^2 = 55.5\%$
									24 weeks	-0.54 [-0.76, -0.32] $p < 0.0001$	N/A	
									6 weeks	-0.17 [-0.59, 0.25] $p = 0.43$	63%	
									12 weeks	-0.09 [-0.55, 0.37] $p = 0.70$	N/A	
RMT (in millimeters)	NR	9.38 ± 2.30 vs. 8.40 ± 3.90	NR	NR	6.00 ± 0.50 vs. 5.4 ± 0.60	7.64 ± 0.58 vs. 6.70 ± 0.57	7.80 ± 1.10 vs. 5.90 ± 0.60	6.96 ± 2.55 vs. 4.53 ± 0.09	Overall	1.33 [0.72, 1.94] $p < 0.0001$	92%	$p < 0.0001$
									24 weeks	1.92 [1.40, 2.44] $p < 0.0001$	30%	
									6 weeks	0.60 [0.39, 0.81] $p < 0.0001$	N/A	
									12 weeks	0.94 [0.68, 1.20] $p < 0.0001$	N/A	
Length of the uterine incision (in millimeters)	21.4 ± 4.38 vs. 26.2 ± 6.11	NR	NR	21.2 ± 2.28 vs. 23.8 ± 3.35	3.20 ± 0.7 vs. 6.40 ± 1.10	19.9 ± 2.23 vs. 25.5 ± 3.82	NR	NR	Overall	-3.84 [-4.97, -2.71] $p < 0.0001$	80%	**$P = 0.003$, $I^2 = 83.3\%$**
									24 weeks	-2.55 [-3.51, -1.59] $p < 0.0001$	N/A	
									6 weeks	-3.76 [-5.30, -2.21] $p < 0.0001$	30%	
									12 weeks	-5.57 [-6.99, -4.15] $p < 0.0001$	N/A	
Surgical parameters (Subgroups based on the type of uterine closure in the control groups [single-layered/double-layered uterine closures])												

Table 3 (continued)

Outcomes	Turan et al. 2015	Halouani et al. 2023	Radwan 2019	Mohamed et al. 2022	Yıldız et al. 2023	Shenishan et al. 2023	Heraiz et al. 2022	Dimassi et al. 2023	Overall and subgroup analysis results			
									variables	Effect Size MD [95% CI]	I^2	Test for Subgroup difference *p* value, and I^2
Duration of the operation (in minutes)	28.5 ± 10.6 vs. 27.9 ± 4.8	NR	36.81 ± 4.95 vs. 35.9 ± 5.42	26.50 ± 1.86 vs. 26.41 ± 1.89	NR	39.74 ± 2.88 vs. 37.16 ± 3.91	44.33 ± 20.8 vs. 37.33 ± 6.13	NR	Overall*	1.30 [-0.24, 2.83] $p = 0.10$	67%	N/A
Amount of blood loss during the surgery (in milliliters)	NR	556 ± 641.7 vs. 546.3 ± 510.5	NR	NR	NR	NR	451.0 ± 52.0 vs. 450.0 ± 88.0	NR	Overall*	1.12 [-28.55, 30.79] $p = 0.94$	0%	N/A

NR: not reported; N/A: not applicable; CI: confidence interval; MD: mean difference; RMT: residual myometrium thickness; PSUS: purse-string uterine suture

*All studies utilized double-layered uterine closure in the control group

differences among the groups. This finding is supported by the subgroup difference test, which yielded a p-value of 0.003 and an I^2 of 83.3%. The length of the uterine incision was significantly lower in the PSUS group compared to the control group at all assessment points, with the highest values at 12 weeks, followed by 6 weeks and 24 weeks (details are shown in Table 3).

Subgroup: variations in postoperative imaging modality evaluations (Transvaginal sonography vs. Transvaginal sonohysterography)

The subgroup analysis based on the type of imaging modality did not reveal any significant differences or interactions between the two methods. Specifically, transvaginal sonohysterography demonstrated an MD of -3.72 (95% CI -10.10 to 2.67; 2 trials, 171 participants; I^2 = 99%), whereas transvaginal sonography showed an MD of -0.16 (95% CI -2.31 to 2.00; 2 trials, 171 participants; I^2 = 93%). The results of the test for subgroup differences are as follows: Chi^2 = 0.30, df = 1 ($p = 0.30$), and I^2 = 6.6%. These findings indicate a consistent treatment effect across the different imaging modalities.

Length of the incision defect (in mm)

Compared with the control group, the effects of PSUS on the length of the incision defect, as evaluated by postoperative ultrasound, were highly uncertain (MD -1.91, 95% CI -4.42 to -0.60; 4 trials, 432 participants; I^2 = 98%, see Table 3). The certainty of the evidence was assessed as very low, downgraded due to concerns about risk of bias (-1), inconsistency (-1), and imprecision (-1) (refer to Table S1). To investigate the possible reasons for the considerable heterogeneity observed, we conducted subgroup and sensitivity analyses for the length of the incision defect.

Subgroup analysis: variation in the timing of postoperative imaging evaluations (24 Weeks/6 Weeks/12 weeks)

The analysis of subgroups based on the timing of postoperative imaging evaluations revealed significant differences among them. This was supported by the subgroup difference test, which yielded a p-value of 0.03 and an I^2 of 77.7%. While no significant differences were observed between the groups at the 24-week assessment, the ultrasound evaluation at 6 weeks revealed that the length of the incision defect was significantly greater in the PSUS group compared to the control group (details are shown in Table 3). All studies assessed postoperative outcomes via transvaginal sonography; therefore, a subgroup analysis based on the type of postoperative imaging modality evaluated (transvaginal sonography vs. transvaginal sonohysterography) was not performed.

Height of the incision defect (in mm)

Compared with the control group, the effects of PSUS on the height of the incision defect in postoperative ultrasound evaluations were highly uncertain (MD -0.27, 95% CI -0.59 to -0.05; 4 trials, 438 participants; I^2 = 76%, Table 3). The certainty of the evidence was assessed as very low, downgraded due to concerns regarding risk of bias (-1), inconsistency (-1), and imprecision (-1) (Table S1). To investigate the possible reasons for the substantial heterogeneity observed, we conducted subgroup and sensitivity analyses for the height of the incision defect.

Subgroup analysis: timing of postoperative imaging evaluations (24 weeks/6 weeks/12 weeks)

The subgroup analysis based on the timing of postoperative imaging evaluations did not reveal any significant differences or interactions among the subgroups. The test for subgroup differences confirmed this, yielding a p-value of 0.11 and an I^2 of 55.5%. These results indicate a consistent treatment effect across the different time points for postoperative imaging evaluation (details are shown in Table 3). All studies assessed postoperative outcomes via transvaginal sonography; therefore, a subgroup analysis based on the type of postoperative imaging modality evaluated (transvaginal sonography vs. transvaginal sonohysterography) was not conducted.

RMT (in mm)

Compared with the control group, the use of PSUS may increase the RMT in postsurgical ultrasound evaluations (MD 1.33, 95% CI 0.72 to 1.94; 5 trials, 417 participants; I^2 = 92%, Table 3). However, the certainty of this evidence was considered low due to concerns about the risk of bias (-1) and inconsistency (considerable heterogeneity) (-1) (Table S1). To investigate the possible reasons for the considerable heterogeneity observed, we conducted subgroup and sensitivity analyses for RMT.

Subgroup: variation in the timing of postoperative imaging evaluations (24 Weeks/6 Weeks/12 weeks)

The analysis of subgroups stratified by the timing of postoperative imaging revealed significant differences among them. This is supported by the subgroup difference test, which produced a p value of < 0.0001 and an I^2 of 91.5%. RMT was significantly higher in the PSUS group compared to the control group at all assessment points, with the highest values at 24 weeks, followed by 12 weeks and 6 weeks (details are shown in Table 3).

Subgroup: variation in postoperative imaging modality evaluations (Transvaginal sonography vs. Transvaginal sonohysterography)

The analysis of subgroups based on the type of imaging modality did not reveal any significant differences or interactions. Specifically, transvaginal sonohysterography showed an MD of 1.70 (95% CI 0.99 to 2.44; 2 trials, 171 participants; I^2 = 33%), while transvaginal sonography demonstrated an MD of 1.10 (95% CI 0.54 to 1.67; 3 trials, 246 participants; I^2 = 88%). The results of the test for subgroup differences are as follows: Chi^2 = 0.30, df = 1 (p = 0.19), and I^2 = 40.7%. These findings indicate a consistent treatment effect across both imaging modalities.

Surgical parameters

Duration of the operation (in Minutes)

Compared with the control group, the effects of PSUS on the duration of the operation were highly uncertain (MD 1.30, 95% CI -0.24 to 2.83; 5 trials, 491 participants; I^2 = 67%, Table 3). The certainty of the evidence was assessed as very low, downgraded due to concerns about risk of bias (-1), inconsistency (moderate heterogeneity) (-1), and imprecision (-1) (Table S1). All studies in the control group employed double-layered uterine closure; therefore, a subgroup analysis based on the type of uterine closure (single-layered vs. double-layered) was not performed.

Amount of blood loss during surgery (in Milliliters)

Compared with the control group, the effects of PSUS on blood loss during surgery were highly uncertain (MD 1.12, 95% CI -28.5 to 30.7; 2 trials, 171 participants; I^2 = 0%, Table 3). The certainty of the evidence was evaluated as very low and was downgraded due to concerns about the risk of bias (-1) and imprecision (-2) (Table S1). Like the previous parameter, all studies utilized double-layered uterine closure in the control group, which precluded subgroup analysis based on the type of uterine closure.

Sensitivity analysis

The sensitivity analysis, which excluded studies utilizing single-layer uterine closures, indicated that the type of control group did not significantly impact cesarean scar defects, uterine incision lengths, RMT, or lengths of uterine incision defects. However, the height of the uterine incision defect was sensitive to the type of control group. Initially, before excluding studies with single-layer closures, the difference was not significant (MD = -0.27, p = 0.10). After focusing on studies with double-layer closures, the difference became significant (MD = -0.41, p = 0.02).

Discussion

The results of the current investigation indicate that, compared to the control group, the PSUS group experienced a statistically significant reduction in the rate of cesarean scar defects. While this finding is statistically significant, its clinical relevance warrants further

exploration, particularly in light of the low certainty of evidence. Additionally, the PSUS group demonstrated a shorter uterine incision length, as evaluated by all included studies using postoperative transvaginal sonography. However, the clinical significance of this finding remains uncertain due to the limited evidence and variability in outcomes. Similarly, the PSUS group exhibited greater RMT than the control group, but the clinical implications of this difference are not yet fully understood. It is important to note that while PSUS appears promising, the evidence for secondary outcomes such as incision length, defect height, and blood loss is less robust, and these findings should be interpreted with caution.

The increasing rate of cesarean sections presents a public health challenge, particularly due to the associated risk of uterine scar defects, which can complicate future pregnancies and adversely affect maternal health [24]. This concern is especially pertinent for infertile women post-cesarean delivery, who face lower pregnancy and live birth rates compared to those with vaginal deliveries, along with higher risks of preterm birth and secondary infertility [45, 46].

While the incidence of cesarean scar defects is variably estimated [47, 48], these defects can lead to significant clinical symptoms such as bleeding and pelvic pain [7, 8]. Our findings suggest that the PSUS technique may help reduce the occurrence of these defects; however, the included studies did not assess its effects on associated symptoms, indicating a research gap. Future studies are needed to explore the impact of PSUS on symptomatology.

The closure technique used during cesarean delivery is crucial in determining the quality of repair and subsequent complications [49]. Research has shown that double-layer hysterotomy closure can reduce the incidence of cesarean scar defects and is associated with greater RMT when compared to single-layer closure [14, 50]. Systematic reviews have reinforced these results, suggesting that double-layer techniques generally lead to improved outcomes without notable differences in the formation of isthmocele [51]. This double-layer approach, which involves separately suturing the myometrial and serosal layers, is expected to leave a thicker layer of residual myometrium than a single-layer method. This occurs because the two-layer technique retains more intact myometrial tissue after closure [43, 44].

Our analysis indicated that uterine closure techniques significantly influence the height of cesarean incision defects. When excluding studies using single-layer closures, we observed a notable reduction in the impact of PSUS on this outcome, underscoring the importance of study selection in systematic reviews. The analysis of subgroups stratified by the timing of postoperative imaging revealed significant differences in several outcomes, including the length of the uterine incision, the length of the incision defect, and RMT. These differences underscore the complexity of factors influencing surgical outcomes. Additionally, the healing process and biological response to surgical trauma can vary significantly among individuals, potentially impacting the size of the defect [52]. Understanding these sources of heterogeneity is crucial for interpreting our findings and may guide future research aimed at standardizing imaging techniques and improving surgical practices.

Another subgroup analysis revealed that the PSUS technique significantly reduces cesarean scar defects compared to both single-layer and double-layer methods. This suggests that PSUS may foster a more conducive healing environment by enhancing blood perfusion and reducing tissue tension, both vital for effective wound healing [19, 53]. Additionally, the PSUS technique results in shorter incisions, which may mitigate complications related to larger incisions post-delivery [54, 55]. However, the clinical relevance of these findings remains uncertain due to the low certainty of evidence, and further research is needed to confirm these potential benefits.

Although two-layer suturing is associated with longer surgical durations [50], the PSUS technique did not significantly prolong operation time compared to controls, indicating potential advantages without the associated time costs. However, confidence in this finding is low (Table 2), suggesting variability in actual surgical duration.

Our meta-regression analysis revealed that maternal age did not emerge as a significant risk factor for cesarean scar defects ($p = 0.159$). This indicates that while maternal age has been considered a potential influencer of surgical outcomes [56, 57], our findings suggest it does not significantly correlate with the incidence of scar defects. However, the literature identifies maternal age as a predictive factor for large cesarean scar defects [58, 59]. Similarly, no significant correlations were found for BMI ($p = 0.770$) or the number of prior cesarean deliveries ($p = 0.171$). Nevertheless, existing literature recognizes that a higher maternal BMI is an independent risk factor for cesarean scar defects, with each additional unit of BMI potentially increasing the risk by 6% [60]. Furthermore, obesity is associated with impaired wound healing and a higher likelihood of complete wound failure following surgical procedures [61]. Thus, although our analysis did not identify significant correlations, the potential impact of these factors cannot be entirely ruled out, warranting further investigation, particularly in the context of the PSUS technique.

Additionally, a well-documented relationship exists between multiple cesarean deliveries and the formation of isthmocele. A previous cesarean scar can adversely

affect the healing of a new incision, with the risk of developing isthmocele increasing with each subsequent cesarean delivery. Repeated trauma to the uterine wall and reduced blood flow in the scar tissue can hinder proper healing [62, 63]. This suggests that factors such as the number of prior cesarean deliveries may play a significant role in surgical outcomes and should be explored in future research focused on the PSUS technique.

Furthermore, while a shorter distance between the cesarean scar and the external os may correlate with higher defect rates, this was only evaluated in two studies, which did not find it significant [64]. Future research should further investigate these relationships, especially in the context of the PSUS technique. The included studies utilized different imaging modalities for postoperative evaluation, including transvaginal ultrasound and saline contrast sonohysterography. While saline contrast sonohysterography is generally considered more sensitive for detecting scar defects and assessing their dimensions, with a diagnostic accuracy of 96% compared to 89.21% for transvaginal ultrasound [11, 65], the subgroup analysis did not reveal significant variations in outcomes. This may be attributed to the relatively small number of studies using saline contrast sonohysterography in our meta-analysis. However, we acknowledge that the higher diagnostic accuracy of saline contrast sonohysterography could influence the outcomes, particularly in detecting smaller or less obvious scar defects. To address this, we ensured that all imaging evaluations were performed by trained professionals using standardized protocols within each study.

Strengths and limitations

This study's strengths include its exclusive focus on RCTs, which minimizes bias and provides robust evidence. Additionally, the use of the GRADE framework for systematic quality assessment enhances the credibility of the findings. The incorporation of TSA further increases the reliability of the results, while a comprehensive literature search ensured that relevant studies were included. Notably, this research is the first to evaluate the impact of the PSUS technique on ultrasound assessments of uterine scars and operational outcomes.

Several limitations warrant consideration. First, the lack of long-term and clinical follow-up raises concerns regarding the durability of the findings over time. Second, the generalizability of the results is limited, as the studies were conducted solely in Northern Africa and Turkey, restricting their applicability to other geographical regions. Moreover, the study population predominantly consisted of low-risk and singleton pregnancies, which may not accurately reflect the circumstances surrounding emergency cesarean sections or higher-risk groups, including multiple pregnancies. This selective inclusion further narrows the relevance of the findings to broader populations.

Additionally, there is considerable heterogeneity among the included studies, which may affect the reliability and generalizability of the results. Variations in postoperative imaging techniques, control groups, and the timing of postoperative assessments contribute to these inconsistencies. Furthermore, differences in patient characteristics, uncertainty regarding blinding in several trials, biases in the randomization process, and biases in the selection of reported results may lead to biased outcomes, as researchers could have preconceived notions about the effectiveness of certain imaging techniques. This may influence the reported effectiveness of imaging methods in assessing scar defects. These factors resulted in a one-level downgrade in the confidence of the evidence for all study outcomes.

Although the meta-analysis includes fewer than 10 studies, which precludes formal publication bias testing, it is important to acknowledge the potential for publication bias due to the limited number of studies included. A small number of studies increases the likelihood that positive or statistically significant results may be overrepresented in the literature, while negative or null findings may remain unpublished. This could lead to an overestimation of the true effect size of the PSUS technique. Therefore, while our findings suggest promising outcomes, they should be interpreted with caution, and future research with a larger number of studies is needed to confirm these results and reduce the risk of publication bias.

Implications for research and practice

Despite a moderate level of confidence in the evidence and the absence of heterogeneity, a 55% reduction in the rate of cesarean scar defects was observed in the PSUS group compared to the control group among low-risk women undergoing elective cesarean delivery. Therefore, we recommend the use of this technique within this specific population. However, clinicians and policymakers should exercise caution when interpreting these findings due to limitations in the certainty and generalizability of the evidence.

The current study primarily focuses on short-term postoperative outcomes (within 6–24 weeks). Future research should consider expanding the follow-up period to assess longer-term outcomes, including subsequent pregnancies, maternal health, and complications such as cesarean scar pregnancy, placenta accreta spectrum, and uterine rupture [66–68]. Additionally, evaluating outcomes such as scar tissue formation, fertility, and postoperative recovery would provide a more comprehensive understanding of the technique's impacts. Investigating the cost-effectiveness and practical implications of the

PSUS approach could also significantly influence clinical guidelines and healthcare policies.

Conclusions

The use of PSUS during cesarean sections offers moderate-quality evidence for reducing cesarean scar defects, suggesting potential benefits for surgical outcomes and maternal health. However, the evidence regarding other ultrasound evaluation outcomes and surgical parameters is of low to very low certainty, necessitating caution in interpretation. Thus, further research is urgently needed to confirm these findings and to investigate the long-term clinical implications of PSUS in cesarean procedures.

Abbreviations

BMI	Body mass index
CI	Confidence interval
MD	Mean difference
MRI	Magnetic resonance imaging
N/A	Not applicable
NR	Not reported
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
PSUS	Purse-string uterine suture
RCTs	Randomized controlled trials
RIS	Required information size
RMT	Residual myometrium thickness
ROB2	Risk of bias 2
RR	Relative risk
TSA	Trial sequential analysis
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

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Author contributions

The study was conceptualized and designed by M.M.I. and M.V. M.N., M.Ma., and M.Mi. were responsible for screening the studies and extracting the data. The initial draft of the manuscript was written by M.N., M.Ma., M.Mi., and M.V. M.N., M.Ma., and M.Mi. Then, the manuscript was revised and finalized for submission. All the authors provided feedback on earlier versions of the manuscript and approved the final version.

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Data availability

The data and materials used in the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent of participants

The current study received ethical approval from the committee at Tabriz University of Medical Sciences with reference number IR.TBZMED.REC.1403.109.

Human ethics and consent to participate

This study did not involve human participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Student Research Committee, Medical School, Ardabil University of Medical Sciences, Ardabil, Iran
[2]Fellowship Gynecology-Oncology, Women's Reproductive Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
[3]Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran
[4]Department of Midwifery, Faculty of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, Iran
[5]Social Determinants of Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran

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