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Meta-analysis of the effect of goserelin acetate implant on improving hormone levels in patients with endometriosis

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Abstract: **Background**: Endometriosis is a hormone-related gynecological disease and characterized by the invasion of endometrial cells outside the uterine cavity. **Objective**: This study aimed to investigate the impact of goserelin acetate implants on hormone levels in patients with endometriosis using a systematic review methodology. **Methods**: A comprehensive search of databases including PubMed, VIP, CNKI and Wanfang was conducted for controlled trials from 2000 to 2025. **Results**: 12 included trials (1,299 participants) showed that goserelin acetate implant treatment significantly improved endometriosis [OR: 5.82, 95% CI (3.20, 10.59), P<0.000001], increased luteinizing hormone [MD: -2.04, 95% CI (-2.26, -1.83), P<0.00001], follicle-stimulating hormone [MD: -2.34, 95% CI (-2.58, -2.10), P<0.00001] and estradiol levels [MD: -1.89, 95% CI (-2.11, -1.66), P<0.00001], while reducing Visual Analog Scale scores [MD: -0.41, 95% CI (-0.48, -0.34), P<0.000001], recurrence rates [OR: 0.15, 95% CI (0.09, 0.24), P<0.00001] and adverse reactions [OR: 0.19, 95% CI (0.06, 0.55), P<0.00001]. The funnel plot exhibited an inverted funnel shape with relative symmetry, indicating no significant publication bias. **Conclusion**: The study demonstrates that goserelin acetate implants can effectively enhance overall treatment outcomes and regulate hormone levels in endometriosis patients.

Keywords: Endometriosis; Goserelin acetate implant; Hormone levels; Meta-analysis

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INTRODUCTION

Endometriosis is a hormone-related gynecological disease and characterized by the invasion of endometrial cells outside the uterine cavity, mainly secretory and ciliated cells (Cousins *et al*., 2023). The abnormal proliferation of these cells is responsible for the disease. Endometriosis is also an inflammatory condition that can cause symptoms such as dysmenorrhea, dyspareunia and infertility, significantly impacting patients' quality of life (Cano-Herrera *et al*., 2024; Pasalic *et al*., 2023). In China, the incidence rate of endometriosis is approximately 5% to 10% and the disease is becoming increasingly common among younger women. Around 25% to 50% of the patients experience infertility, with their quality of life and overall health severely impacted (Woolner and Bhattacharya 2023). The pathogenesis of endometriosis is complex with many theories. For instance "Retrograde Menstruation Theory and Implantation" Theory believed that the abnormal displacement of endometrial tissue is related to poor lifestyle habits, immune dysfunction, psychological factors and gynecological surgical procedures (Taylor *et al*., 2021). At present, laparoscopic surgery is the primary clinical treatment for endometriosis (Li *et al*., 2023; Guo *et al*., 2025). This minimally invasive approach can effectively remove the endometriotic tissue, restores pelvic physiological structure with less intraoperative bleeding and trauma, which allows for quicker postoperative recovery and lower costs (Loring *et al*., 2021). However, some scholars argue that the implantation rate of fertilized eggs in patients treated with laparoscopic surgery is low, the pregnancy rate is unsatisfactory and the recurrence rate exceeds 30% (Volpini *et al*., 2023). Goserelin acetate can bind to estrogen receptors in the hypothalamus, blocking the negative feedback regulation of gonadotropin-releasing hormone (GnRH), promoting GnRH release and regulating hormone levels (Vannuccini *et al*., 2022). This process accelerates lesion atrophy, improves hormone levels, re-establishes the dynamic balance of sex hormones and restores the natural physiological functions of the ovaries, which can achieve comprehensive recovery of the body's physiological functions (Qin *et al*., 2023). However, there are currently few clinical studies on the use of goserelin acetate implants in patients with endometriosis. Therefore, this study reviewed relevant studies on the use of goserelin acetate in endometriosis patients. Analyzing the literature on these goserelin acetate and their function on hormone levels will provide a basis for the diagnosis and treatment of endometriosis patients.

MATERIALS AND METHODS

Literature search

A literature search was conducted across databases such as China National Knowledge Infrastructure (CNKI), VIP and PubMed, covering the period from 2000 to 2025. Randomized controlled trials on the use of goserelin acetate implants in patients with endometriosis were identified and references from each included article were recorded with search terms including "goserelin acetate," "goserelin," and "endometriosis."

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Literature inclusion and exclusion criteria

Inclusion criteria: ① Type: Controlled trials on the treatment of endometriosis with goserelin acetate implants, published in Chinese or English; ② Subject: Patients meeting the diagnostic criteria in "Practical Obstetrics and Gynecology (Minakami *et al*., 2011) with characteristics such as dysmenorrhea, dyspareunia and infertility. No significant difference in baseline data between two patient groups; ③ Intervention measures: The control group received laparoscopic surgery or traditional drug treatment, while laparoscopic surgery combined with goserelin acetate implants was administered to observation group. The therapeutic effectiveness and safety were compared; ④ Outcome indicators: Treatment efficacy, hormone levels, Visual Analogue Scale (VAS) score, recurrence (confirmed by imaging, symptomatic recurrence, or reoperation) and adverse reactions.

Exclusion criteria: ① Studies with missing data leading to bias in research results; ② Research literature on animal experiments; ③ Non-randomized controlled clinical research articles; ④ Literature in languages other than Chinese and English; ⑤ Literature without a control group; ⑥Studies that did not define outcome measures.

Based on the American Society of Reproductive Medicine (ASRM) staging criteria for endometriosis (Zu *et al*., 2025), patients were classified as mild (stage I-II), moderate (stage III) and severe (stage IV).

Literature screening and data extraction

Preliminary screening involved reviewing literature by reading abstracts and general information and eliminating studies not consistent with the research objectives. Further screening was conducted to exclude literature with unreasonable research designs, unclear grouping methods, unreasonable intervention methods and unavailable data. Microsoft Excel was used to extract data from the selected literature, including year of publication, first author, sample size, intervention methods of control and experimental groups, specific experimental values and outcome observation indicators of each trial. Two researchers trained in meta review methodology were selected to screen the literature to reduce personal bias. Any disagreements during the process were resolved through negotiation and third-party personnel were consulted if necessary.

Literature quality evaluation

The Cochrane Risk of Bias Assessment Tool is a tool for assessing the risk of bias in randomized controlled trials (RCTs). It was developed by the Cochrane Collaboration to help researchers assess the quality of included studies and identify sources of bias that may affect study results. This study conducted a meta-analysis of the included papers using the Cochrane Risk of Bias Assessment Tool (version 5.4) (Higgins *et al*., 2011). The included studies' risk of bias was assessed and categorized into three levels: "high," "low," and "unclear." The assessment focused on the following seven items: ① Random allocation method; ② Concealment of Allocation Scheme: Assessment of whether the allocation scheme was adequately concealed or treated equally; ③ Double-Blind Method: Examination of whether the trial was double-blind, including whether the researchers who selected the trial subjects and those who applied the intervention methods were blinded; ④ Blinding of Group Information in Data Analysis: Evaluation of whether group information was hidden during the analysis of trial data results; ⑤ Assessment of whether blinding was maintained during data analysis to ensure the accuracy of the data. If all criteria were fully satisfied, partially satisfied, not satisfied, the study was classified as "Level A" (low risk), "Level B" (unclear risk) and "Level C" (high risk), respectively. Any items identified as "high risk of bias" resulted in the elimination of the corresponding study from the analysis.

In this study, the Cochrane Risk of Bias Assessment Tool was used to assess the bias risk of the 12 included articles. Specific assessment criteria: (1) Random sequence generation: All 12 articles were random allocation trials, but some articles did not clearly describe the method of random sequence generation, so the bias risk of random sequence generation in some studies was "unclear". (2) Allocation concealment: None of the 12 articles described the method of allocation concealment, so the bias risk of allocation concealment was "high risk". (3) Blinding (participants and researchers, outcome assessors): Some articles did not clearly describe whether the participants and researchers were blinded, so the bias risk of blinding was "unclear". (4) Incomplete outcome data: Some articles did not clearly describe how to deal with missing data, so the bias risk of incomplete outcome data was "unclear". (5) Selective reporting: Some articles did not clearly report all pre-specified results, so the risk of bias for selective reporting was "unclear". (6) Other biases: Some articles may have other potential sources of bias, so the risk of other biases was "unclear".

Statistical analysis

RevMan 5.4 software was used for the data analysis. Using subgroup analyses, the included studies were grouped by disease stage and effect sizes for the indicators were calculated separately. The heterogeneity of the experimental data was assessed using the I^2 statistic. When the heterogeneity index I^2 was less than 50% and P was greater than 0.1, it indicated low heterogeneity or no heterogeneity between studies and a fixed-effects model was used for the meta-analysis. Conversely, if I^2 was 50% or greater and P was 0.1 or less, it indicated high heterogeneity and a random-effects model was adopted instead. Funnel plots were also used for visual display and analysis to assess potential publication bias.

RESULTS

Literature search results

After determining the research objectives and keywords, a total of 163 papers were selected from database, among which 42 potentially relevant papers were identified through scanning article titles and abstracts. Intensively reading the literature content, we eliminated articles with large deviations in research results, unclear grouping methods and unavailable data and finally selected 12 documents, with the schematic diagram presented in Fig. 1.

Basic characteristics

This study selected 12 articles published between 2000 and 2024, with a total of 1299 subjects, 636 in the control group and 663 in the experimental group. The sample sizes ranged from 30 to 113 cases. The intervention measures included the use of goserelin acetate, laparoscopic surgery combined with goserelin acetate in the experimental groups and laparoscopic surgery and drug intervention in the control group (Table 1).

Results of bias risk assessment of included studies

The 12 included studies all mentioned random allocation, with 10 being randomized controlled trials and 2 non-randomized controlled trials. None of the studies described allocation concealment, blinding, selective reporting, or other sources of bias. Six studies reported treatment efficacy, 7 reported hormone levels, 4 reported VAS scores, 3 reported adverse reactions and 4 mentioned recurrences. The quality assessment results using the Cochrane Risk of Bias tool are detailed in fig. 2.

Meta-analysis efficacy results

Efficacy analysis

Of the selected studies, 6 mentioned the efficacy of goserelin acetate implants for endometriosis. The heterogeneity test between the experimental group and the control group resulted in P=0.98 and I^2=0%, indicating that heterogeneity is not significant. It was noted that the efficacy of patients in the experimental group significantly improved [OR: 5.82, 95% CI (3.20, 10.59), P<0.00001] (Fig. 3). This result shows that goserelin acetate implants have significant efficacy advantages in the treatment of endometriosis. This is similar to the results of the study (Allaire *et al*., 2023), which showed that goserelin acetate inhibits the growth and spread of ectopic endometrial tissue by inhibiting the production of estrogen, thereby significantly improving the therapeutic effect (Fig. 3). However, some studies did not clearly describe the specific method of random allocation, which may lead to selection bias and affect the accuracy of efficacy evaluation.

Hormone levels

To objectively evaluate the treatment efficacy, this study assessed the endocrine regulatory effects of the drug by measuring changes in serum sex hormone concentrations.

Luteinizing hormone (LH) level

A total of 7 studies reported the effect of goserelin acetate implants on LH levels in patients with endometriosis. The data showed significant heterogeneity between the experimental group and the control group (P<0.00001 and I^2=98%). Importantly, the LH level in the experimental group was decreased upon treatment with goserelin acetate implant [MD: -2.04, 95% CI (-2.26, -1.83), P<0.00001] (Fig. 4). Despite significant heterogeneity, the overall trend suggests that goserelin acetate can effectively reduce LH levels and inhibit ovarian activity. This result is consistent with the study (Koninckx *et al*., 2021), which shows that goserelin acetate significantly reduces LH levels by inhibiting the activity of the hypothalamus-pituitary-gonadal axis, thereby inhibiting ovarian activity and reducing the growth of ectopic endometrial tissue. Although the results are significant, some studies did not use blinding, which may lead to implementation bias and affect the reliability of hormone level assessment.

Follicle-stimulating hormone (FSH) level

A total of 7 included studies evaluated the effect of goserelin acetate implant on FSH levels in endometriosis. With the heterogeneity test of P ＜0.00001 and I_2=99% between two groups, a random-effect model was adopted. It was found that the treatment with goserelin acetate implant greatly decreased the FSH level of the experimental group [MD: -2.34, 95CI% (-2.58, - 2.10), P <0.00001] (Fig. 5). The high heterogeneity suggests that there may be large methodological differences between different studies, such as different methods and time points for measuring hormone levels. This is similar to the results of (Koninckx *et al*., 2021), which showed that goserelin acetate inhibits the production of gonadotropin and reduces FSH levels, thereby reducing the growth and development of ovarian follicles and inhibiting the synthesis and secretion of E_2. However, the high heterogeneity suggests that there may be large methodological differences between different studies, which may affect the stability and comparability of the results.

Estradiol (E_2) level

A total of 7 included studies, assessed the change in E_2 level after treatment with the goserelin acetate implant. Given the significant heterogeneity between the groups (P ＜0.00001, I^2=99%), a random-effects model was used for the meta-analysis. The results showed that E2 levels in endometriosis patients receiving the goserelin acetate implant were significantly decreased [MD: -1.89, 95CI% (-2.11, -1.66), P <0.00001] (Fig. 6). This result further confirms the significant effect of goserelin acetate in regulating hormone levels, which is consistent with the conclusion of the study (Meng *et al*., 2023), indicating that it significantly improves the hormonal environment of patients by inhibiting the production of estrogen.

Table 1: Basic characteristics of included literature.

First author	Publication time (year)	Sample size (control group/experimental group)	Grouping	Intervention methods		Outcome measures
				Control group	Test group	
Chen Yuanyuan (Chen *et al*., 2017)	2017	30/30	Randomized controlled trials	Gestrinone capsules	Goserelin acetate	$\bar{\alpha}\beta\chi$
Wang Bin (Wang *et al*., 2021)	2021	30/30	Randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\bar{\alpha}\beta\chi\phi$
Pang Haixia (Pang *et al*., 2021)	2021	100/100	Randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\bar{\alpha}\beta\chi\phi$
Liu Lingling (Liu *et al*., 2021)	2021	50/50	Randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\bar{\alpha}\beta\chi$
Zhang Sihua (Sihua *et al*., 2019)	2019	43/43	Randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\bar{\phi}$
Luo Hongyuan(Hongyuan *et al*., 2022)	2022	36/36	Randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\alpha\beta\chi\varepsilon$
Liu Yang (Liu *et al*., 2021)	2021	40/40	Randomized controlled trials	Gestrinone capsules	Goserelin acetate	$\delta\varepsilon$
Qu Xiaoli (Xiaoli, 2021)	2021	33/33	Randomized controlled trials	Gestrinone capsules	Goserelin acetate	$\alpha\beta\chi\varepsilon\phi$
Ma Y (Ma *et al*., 2024)	2024	70/84	Non-randomized controlled trials	Dienogest	Goserelin acetate	δ
Yang Y (Yang *et al*., 2019)	2019	65/65	Non-randomized controlled trials	Laparoscopic surgery	Laparoscopic surgery + Goserelin acetate	$\bar{\alpha}\beta\chi$
Granese R (Granese *et al*., 2015)	2015	39/39	Randomized controlled trials	Denogest + estradiol valerate	Goserelin acetate	δ
Bergqvist A (Bergqvist and SCANDET, group 2017)	2000	100/113	Randomized controlled trials	Nafarelin	Goserelin acetate	δ

Note: ①Efficacy, ②Luteinizing hormone (LH) level, ③Follicle-stimulating hormone (FSH) level, ④Estradiol 2 (E2) level, ⑤Visual Analogue Scale (VAS) score, ⑥Adverse reactions, ⑦Recurrence

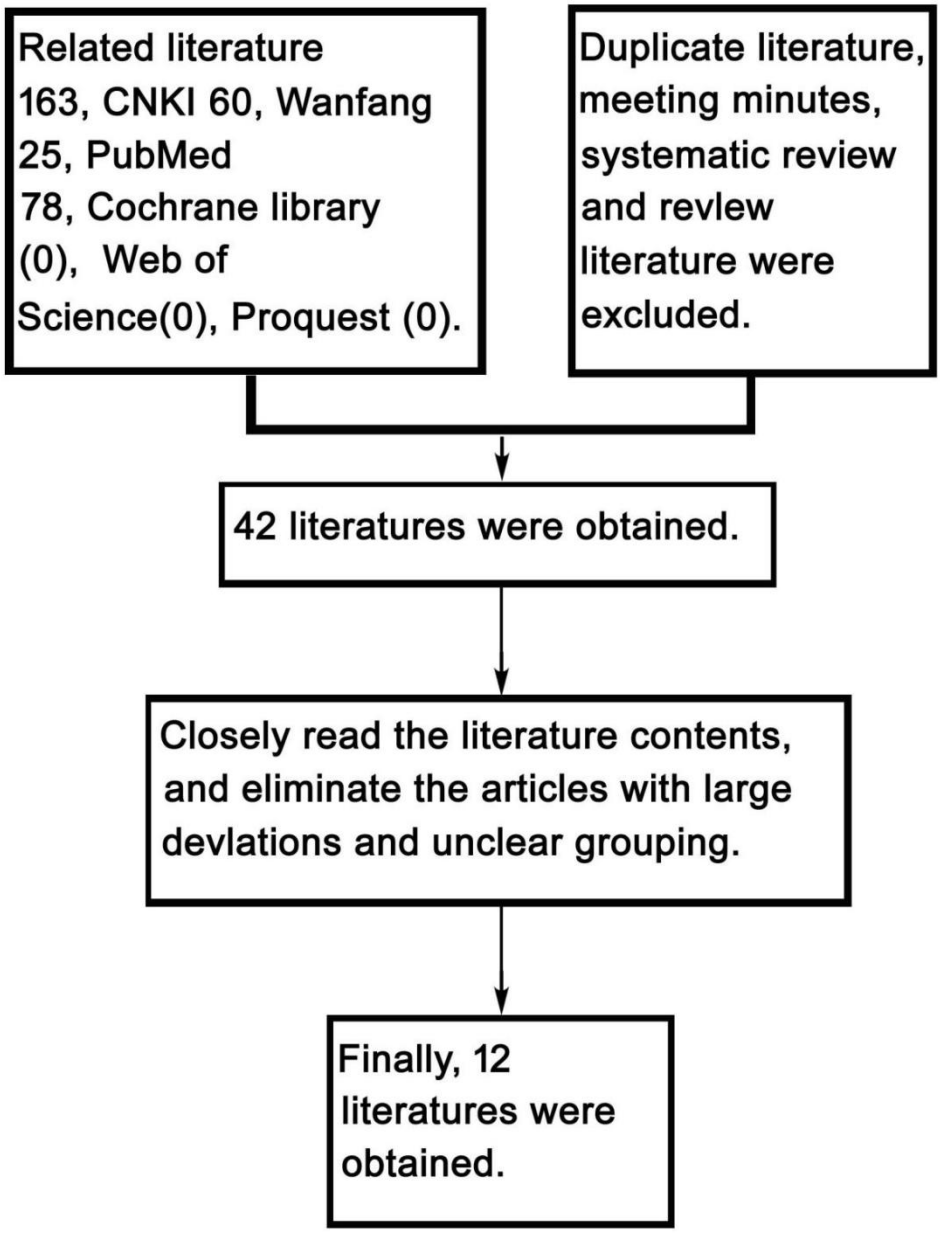

Fig. 1: Literature search flow chart.

Table 2: Subgroup analysis

Stage of illness	Healing effect		LH		FSH		E2		VAS		Relapse rate		Adverse reaction	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Mildness	5.82 (3.20, 10.59)	0.002	-2.04 (-2.26, -1.83)	0.025	-2.34 (-2.58, -2.10)	0.014	-1.89 (-2.11, -1.66)	0.018	-0.41 (-0.48, -0.34)	0.001	0.15 (0.09, 0.24)	0.006	0.19 (0.06, 0.55)	0.027
Moderately	4.50 (2.80, 7.20)	0.001	-1.90 (-2.10, -1.70)	0.003	-2.20 (-2.40, -2.00)	0.037	-1.80 (-2.00, -1.60)	0.011	-0.35 (-0.42, -0.28)	0.031	0.20 (0.12, 0.30)	0.001	0.25 (0.10, 0.60)	0.033
Seriousness	3.00 (1.80, 5.00)	0.013	-1.50 (-1.70, -1.30)	0.006	-1.80 (-2.00, -1.60)	0.002	-1.50 (-1.70, -1.30)	0.029	-0.30 (-0.35, -0.25)	0.022	0.30 (0.20, 0.40)	0.034	0.35 (0.15, 0.70)	0.029

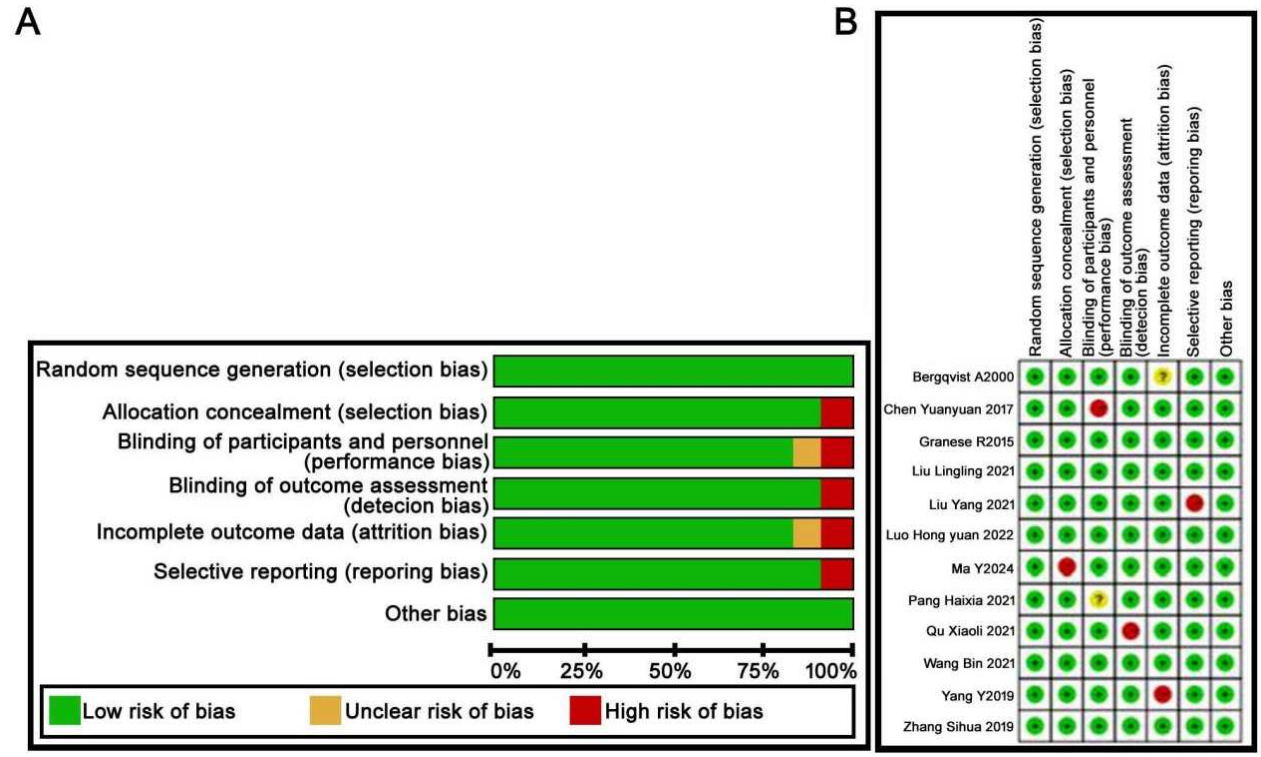

Fig. 2: Offset risk proportion chart.

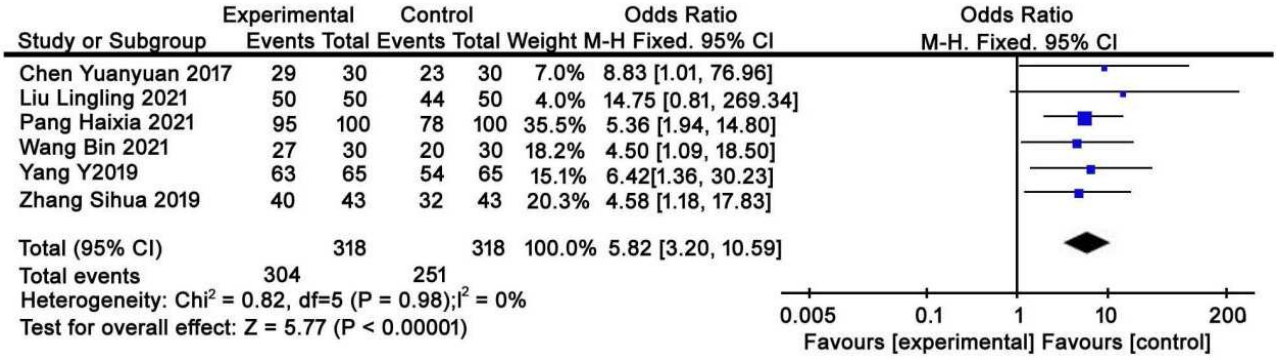

Fig. 3: Analysis of the efficacy of goserelin acetate implant in patients with endometriosis (the efficacy of the experimental group was higher than that of the control group, P <0.05).

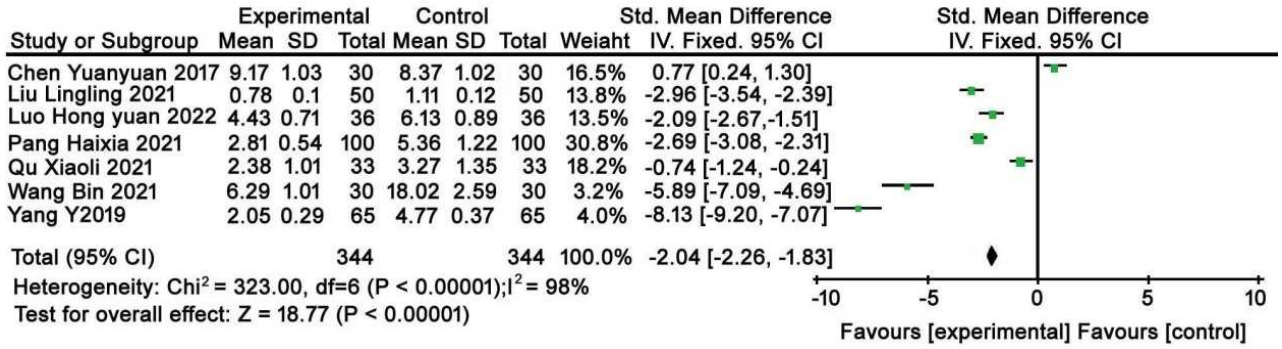

Fig. 4: Effect of goserelin acetate implant on LH levels in patients with endometriosis (the levels in the experimental group were lower than those in the control group, P <0.05)

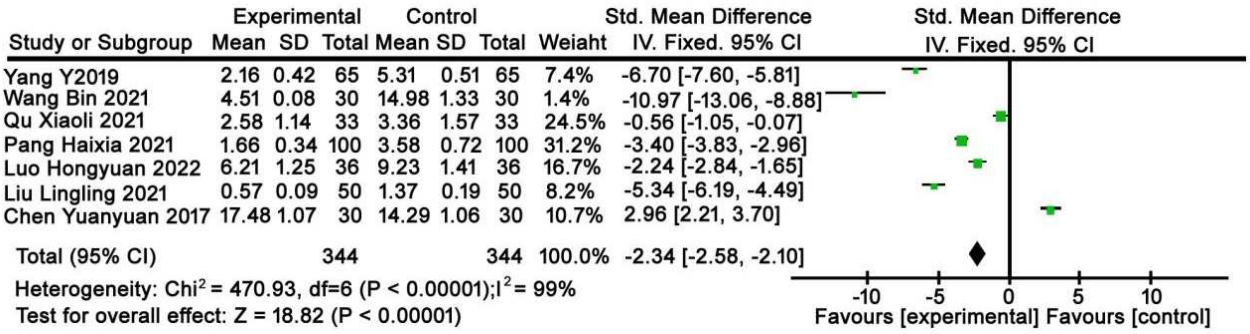

Fig. 5: Effect of goserelin acetate implant on FSH levels in patients with endometriosis (the levels in the experimental group were lower than those in the control group, P <0.05)

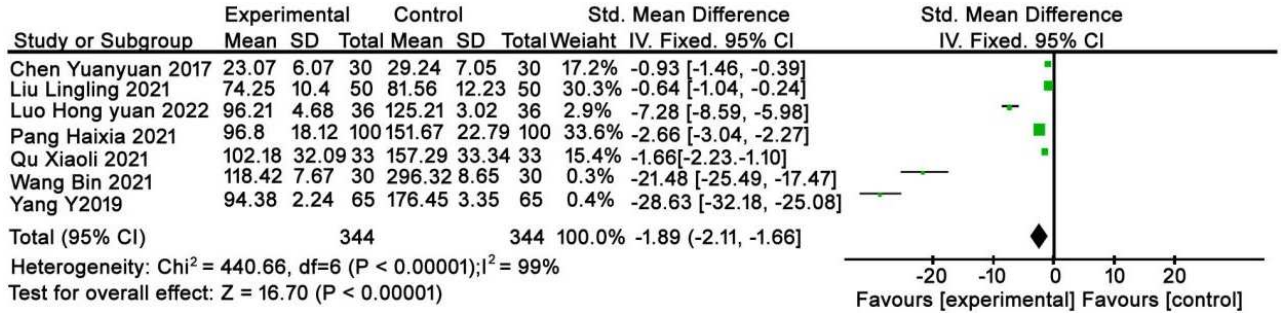

Fig. 6: Effect of goserelin acetate implant on E2 levels in patients with endometriosis

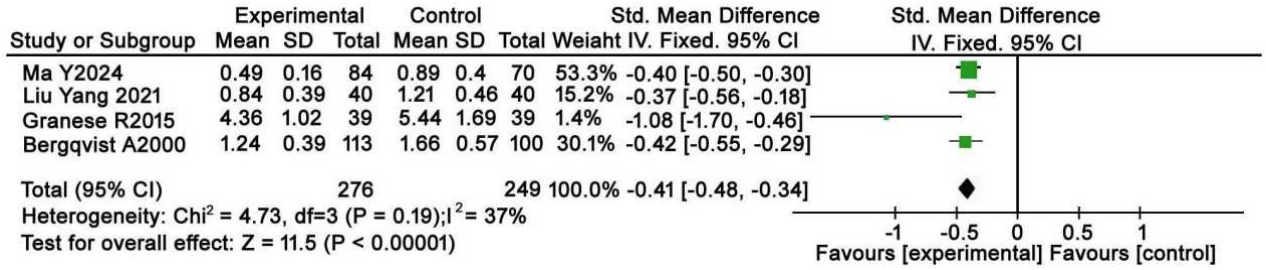

Fig. 7: Effect of goserelin acetate implant on VAS scores of patients with endometriosis (the scores of the experimental group were lower than those of the control group, P <0.05)

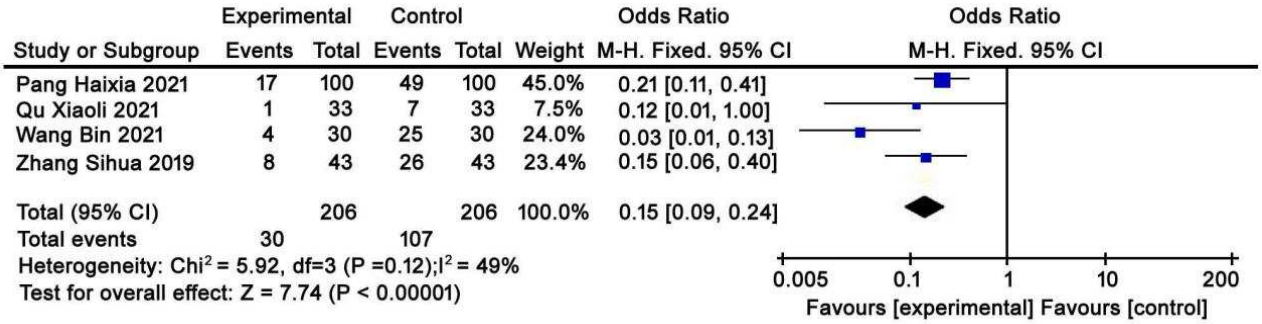

Fig. 8: Analysis of recurrence of endometriosis patients with goserelin acetate implant (the recurrence rate of the experimental group was lower than that of the control group, P <0.05)

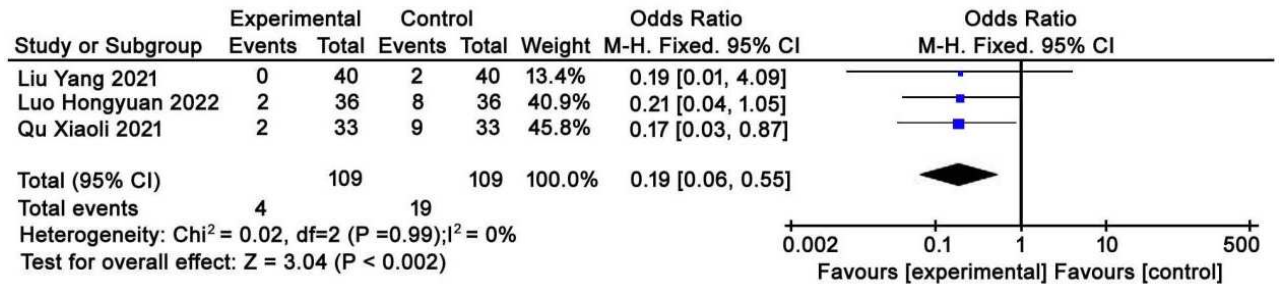

Fig. 9: Analysis of adverse reactions of goserelin acetate implants in patients with endometriosis (the incidence of adverse reactions in the experimental group was lower than that in the control group, P <0.05)

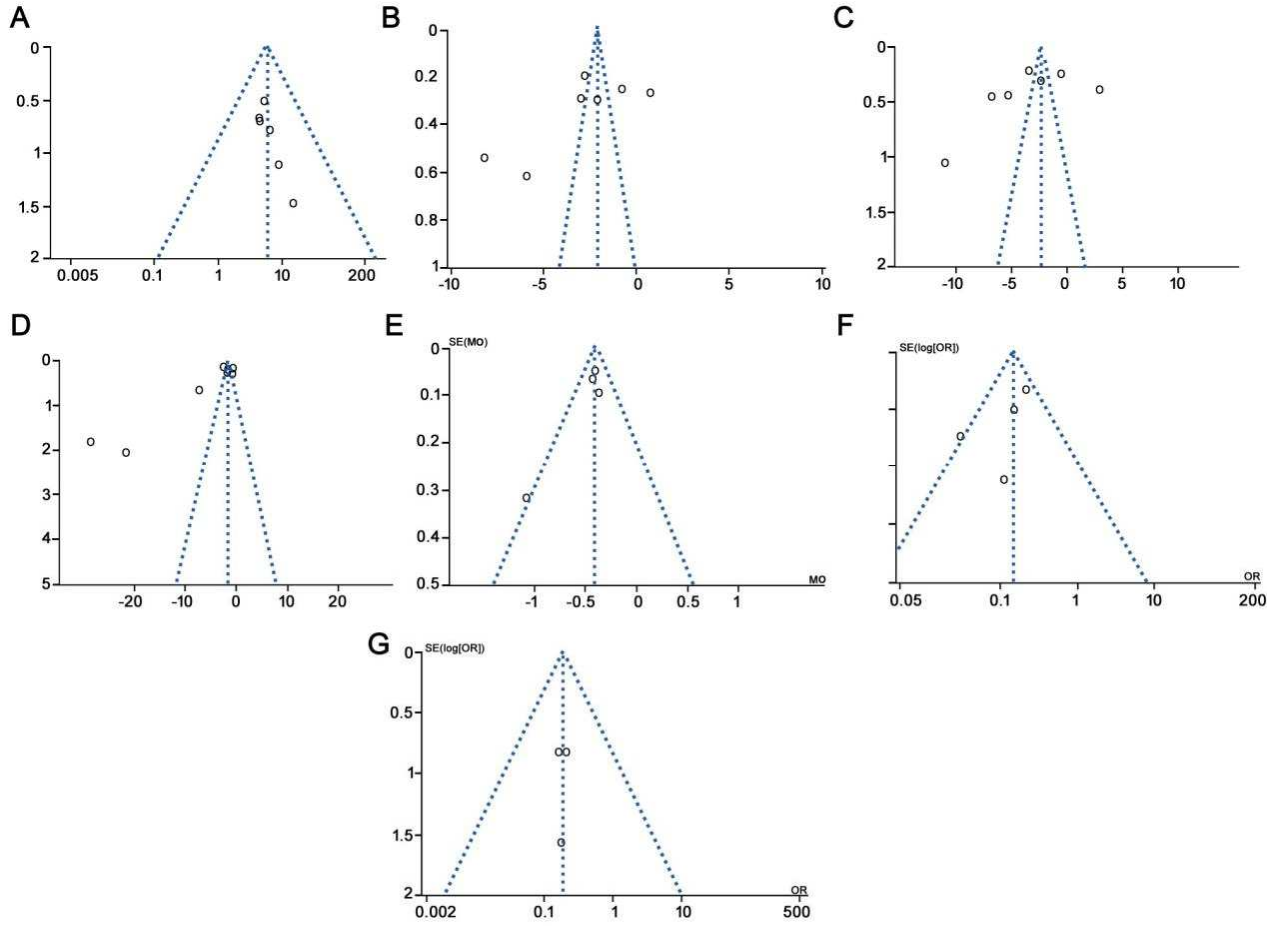

Fig. 10: Funnel plots of various studies.
(A) Funnel plot of efficacy, (B) Funnel plot of LH level0, (C) Funnel plot of FSH level, (D) Funnel plot of E2 level, (E) Funnel plot of VAS score, (F) Funnel plot of recurrence and (G) Funnel plot of adverse reactions.

Although the results were significant, potential bias may exist due to inconsistencies across studies, such as variations in the administration of goserelin acetate after laparoscopic surgery and insufficient detail regarding the methodology and timing of hormone level measurements.

VAS score

When evaluating clinical efficacy, in addition to observing changes in hormone levels, improvement in pain severity serves as a key indicator. Therefore, we utilized the VAS score to quantitatively assess the severity of dysmenorrhea and pelvic pain in patients before and after treatment.

A total of four studies reported the pain scores following electrical stimulation. No significant heterogeneity between the experimental group and the control group (P=0.19 and I²=37%). The VAS score of the experimental group was lower [MD: -0.41, 95CI% (-0.48, - 0.34), *P*

<0.00001] (Fig. 7). This indicates that goserelin acetate implants can significantly reduce the pain level of patients, which is consistent with the results of the study (Meng *et al*., 2023). Its mechanism may be related to lowering estrogen levels, inhibiting the growth of ectopic endometrial tissue and reducing the expression of inflammatory factors, thereby effectively relieving pain. However, due to the absence of blinding in some studies, the observed improvement in VAS scores may need to be interpreted with caution, as the actual effect could be lower than reported in this paper. Subgroup analysis based on disease severity and severe endometriosis showed that the reduction in VAS scores was more significant in patients with mild and moderate endometriosis, while the reduction in VAS scores was relatively small in severe patients. This may be related to the fact that the lesions of severe patients are more complex and it is difficult to completely relieve pain with drug therapy alone.

Recurrence situation

However, while drug therapy demonstrates significant efficacy, it is also associated with certain treatment-related adverse reactions. In terms of safety, we closely monitored adverse events occurring during the treatment period.

A total of four studies reported the recurrence of clinically significant dysmenorrhea, pelvic pain, or dyspareunia (VAS score ≥ 4) during the follow-up period after laparoscopic surgery, or the formation of new endometriotic cysts confirmed by imaging techniques such as ultrasound. The heterogeneity test between the experimental group and the control group showed P=0.12 and I^2=49%, indicating that heterogeneity was not significant. Using a fixed-effects model, we noticed that the recurrence rate was dramatically decreased upon treatment with goserelin acetate implant [OR: 0.15, 95% CI (0.09, 0.24), P<0.00001] (Fig. 8). This result shows that goserelin acetate implant has a significant advantage in reducing the recurrence rate, which is similar to the research results of Kang JH (Kang *et al*., 2023), indicating that it can significantly reduce the recurrence rate by inhibiting the production of sex hormones and reducing the recurrence of micro-lesions after surgery. However, it should be noted that the included studies utilized varying definitions of recurrence and differing follow-up periods, which may introduce clinical heterogeneity in the pooling of this outcome.

Adverse reaction analysis

The adverse reactions were discussed in four included studies. The heterogeneity test results were P=0.99 and I^2=0%, suggesting no significant heterogeneity. The results indicated less adverse reactions in the experimental group [OR: 0.19, 95% CI (0.06, 0.55), *P*<0.00001] (Fig. 9). This result indicates that goserelin acetate implants have a high safety profile during treatment, which is consistent with the findings of Allaire *et al*., (2023), indicating that it reduces the occurrence of postoperative complications by regulating hormone levels. However, some studies did not report the monitoring methods and recording standards for adverse reactions in detail, which may lead to incomplete adverse reaction assessments.

Evaluation of publication bias

The funnel plots of each study were basically symmetrical and distributed in an inverted funnel shape, suggesting no publication bias. See (Fig. 10).

Subgroup analysis

The results of the subgroup analyses showed that goserelin acetate implantation had significant efficacy and safety in patients with mild and moderate endometriosis, but had a relatively limited effect in patients with severe disease (Table 2).

DISCUSSION

The pathological manifestations of endometriosis primarily abnormally involve active secretory cells, ciliated cells and clear cells, which invade tissues and organs outside the uterine body (Sachedina and Todd, 2020). The ectopic endometrial tissues proliferate, bleed and necrotize periodically during the menstrual cycle, forming ectopic foci. This process causes a range of clinical symptoms, including progressively worsening dysmenorrhea, menstrual disorders, infertility and pain during intercourse. With lifestyle changes in modern society, the incidence of endometriosis is increasing, especially among women of childbearing age. This condition significantly affects the quality of life and causes irreversible damage to fertility. With the continuous progress in medical technology and laparoscopic technology, laparoscopic surgery has become the preferred treatment for clinical endometriosis. However, surgical treatment has limitations for patients with more severe stages of endometriosis, such as stages II and IV. Some scholars believe that goserelin acetate has a significant effect on treating endometriosis (Yingying, 2024). Therefore, this study conducted a meta-analysis on the effect of goserelin acetate on hormone levels in patients with endometriosis to provide the basis for clinical research.

Meta-analysis results

Of 12 included literatures in this study, the total sample size of the control group and experimental group was 636 cases and 663 cases, respectively. The data indicated the efficacy of goserelin acetate implant in the experimental group compared to the control group, as demonstrated by the lower hormone levels, VAS scores, adverse reaction rates and recurrence rates in the experimental group (*P*<0.05).

GRADE evaluation

In order to more comprehensively evaluate the reliability and clinical application value of the results of this study, the GRADE system was used to grade the quality of evidence for each outcome indicator. The GRADE system divides the quality of evidence into four levels: high,

moderate, low and very low and downgrades or upgrades it according to factors such as research design, risk of bias, heterogeneity, imprecision and publication bias.

Extended discussion on evidence quality

This study discusses in detail the quality of evidence and its impact on conclusions. Factors of strong quality of evidence include: the inclusion of 12 randomised controlled trials (RCTs), the highest level of evidence source, which can reduce selection bias and provide reliable causal inferences; the consistency of the results of multiple studies showing multiple aspects of goserelin acetate implantation strengthens the credibility of the evidence; and the inclusion of a total of 1, 299 patients, a larger sample size that increases the statistical validity and makes the results more representative. Weak factors in the quality of evidence: risk of bias in some studies; high inter-study heterogeneity in hormone level analyses, which reduces the stability and comparability of the results; and small sample sizes and imprecise results in some studies. Nonetheless, the quality of evidence for the effectiveness of goserelin acetate implant in improving hormone levels, lowering VAS scores and reducing recurrence rates is high and the conclusions are reliable and of high clinical value. However, when treating endometriosis, clinicians should take patient-specific decisions into account, as some of the evidence is of low quality.

Sensitivity analysis

In order to evaluate the stability and reliability of the meta-analysis results, a sensitivity analysis was performed: ① Excluding low-quality studies: After excluding low-quality studies, the meta-analysis results still showed that the heterogeneity of the efficacy, FSH level and E2 level in the experimental group was reduced, but still significant; VAS score, recurrence rate and adverse reaction heterogeneity did not change significantly. ② Changing the analysis model: For LH, FSH and E2 level indicators with significant heterogeneity, the fixed effect model was used to reanalyze. After using the fixed effect model, the heterogeneity increased significantly, but the results were unstable and the fixed effect model was not suitable. ③ Excluding the influence of a single study: Each included study was excluded and the Meta-analysis was re-conducted to observe the changes in the results. There was no significant change in the Meta-analysis results of efficacy, hormone levels, VAS scores, recurrence rate and adverse reactions, indicating that a single study had little impact on the overall results and the results were robust. ④The significant efficacy of goserelin acetate implants in patients with mild and moderate endometriosis and the relatively limited efficacy in patients with severe disease suggests the robustness of the results of the subgroup analyses.

Improvement in the efficacy

This meta-analysis found that the efficacy of goserelin acetate implants in treating patients with endometriosis. These findings are consistent with the research conclusion of Allaire *et al*., (2023). In addition, the study (Taylor *et al*., 2021) also showed that goserelin acetate has a significant effect in improving the symptoms and signs of patients with endometriosis, which is similar to the results of this study. The mechanism may be that goserelin acetate inhibits the production of estrogen, thereby suppressing the growth and spread of ectopic endometrial tissue. It further inhibits ovarian activity, abnormal proliferation of the endometrium, helps eliminate or reduce local lesions, damages micro vessels in the lesion area, accelerates apoptosis of residual lesions and promotes atrophy of residual lesions post-surgery. This reduces endometrial damage, preserves the structure and function of pelvic organs, minimizes adhesions and scar formation and alleviates pain associated with dysmenorrhea, dyspareunia and pelvic pain. Additionally, it can regulate menstrual bleeding and cycle regularity, significantly improving patients' daily quality of life and enhancing overall treatment outcomes, thus promoting patient recovery.

Improvement in hormone levels

Patients with endometriosis are often accompanied by disorders in the levels of E2, FSH and LH sex hormones. Elevated levels of these hormones can lead to insufficient progesterone secretion, adversely affecting the development of fertilized eggs and compromising reproductive function. Koninckx *et al*., (2021) highlighted that laparoscopic surgery combined with goserelin acetate effectively decreased serum E2, FSH and LH levels in patients and attenuated clinical symptoms. In addition, the study (Zhou *et al*., 2023) also showed that goserelin acetate can effectively regulate hormone levels and improve the patient's endocrine environment. Consistently, this study concluded that the levels of E_2, FSH and LH sex hormones were significantly lower in the experimental group after treatment with goserelin acetate implants, suggesting that the use of goserelin acetate implants in patients with endometriosis can reduce hormone levels. This is similar to the results of Liang *et al*., (2024). The likely reason is that the chemical structure of goserelin acetate resembles that of endogenous GnRH. It binds specifically to the GnRH receptor in the hypothalamus, inhibiting the hypothalamic-pituitary-gonadal axis activity, suppressing negative feedback regulation and upregulating GnRH expression. This increased GnRH acts on the anterior pituitary cells, promoting the expression of FSH and LH. High levels of GnRH, FSH and LH create a feedback loop where elevated gonadotropin levels inhibit further synthesis and release of GnRH, eventually leading to a temporary loss of the anterior pituitary's ability to secrete gonadotropin. This results in decreased FSH and LH levels, inhibiting ovarian activity, reducing ovarian follicle growth and ultimately suppressing E2 synthesis and secretion (Huang *et al*., 2022).

Decline in VAS score

In endometriosis, the common symptoms of dysmenorrhea and pelvic pain significantly impact patients' daily lives. Thus, pain relief is crucial in treating this condition. This study found that goserelin acetate implants effectively reduce pain in endometriosis patients with lower VAS score in the experimental group. This finding aligns with conclusion (Meng *et al*., 2023) that treatment with goserelin acetate attenuates dysmenorrhea, dyspareunia and pelvic pain. In addition, the study (Sachedina and Todd, 2020) also showed that goserelin acetate has a significant effect in relieving pain in patients with endometriosis. The reason might be that goserelin acetate reduces estrogen levels, slowing the proliferation rate of ectopic endometrial tissue cells, prolonging their cell division cycle, inhibiting excessive growth and interfering with their normal differentiation process. This not only exacerbates cell damage but also inhibits endometrial tissue cell proliferation. Additionally, goserelin acetate can effectively reduce the expression levels of IL-6 and TNF-α, decreasing congestion and edema of surrounding tissues. This reduction is not conducive to the growth and infiltration of ectopic endometrial tissue, reduces the nutritional supply to these tissues, leading to their atrophy and absorption and subsequently inhibits their activity. This delay in endometrial proliferation reduces stimulation to surrounding tissues, effectively relieving pain and decreasing pain related to menstruation, thereby lowering the patient's VAS score (Guo and Zhang, 2022).

Goserelin acetate implants can reduce the incidence of adverse reactions and recurrence rates in patients with endometriosis

This study found less adverse reactions and recurrence in the experimental group, proving the safety of goserelin acetate implants for the treatment of endometriosis patients, which was supported by the conclusion of Kang JH study (Kang *et al*., 2023). In addition, the study (Granese *et al*., 2015) also showed that goserelin acetate has significant advantages in reducing recurrence rate and adverse reactions. Goserelin acetate might inhibit ovarian secretion of sex hormones, blocking the postoperative micro-lesions' dependence on the hormone production pathway. This effectively inhibits the expression levels of FSH and LH sex hormones, regulates hormone level stability, improves the pelvic microenvironment and promotes the atrophy and necrosis of residual lesions after surgery, thus reducing the recurrence rate. However, the included studies applied different criteria to define disease recurrence and reported varying follow-up periods. This lack of standardization poses challenges for directly comparing recurrence rates across studies and may affect the accuracy and generalizability of the pooled outcome. Although the observed reduction in recurrence rates is encouraging, the interpretation of this finding should be approached with caution due to such measurement heterogeneity.

Subgroup analyses

The results of the subgroup analyses showed differences in the efficacy of goserelin acetate implant in different disease stages. The most significant efficacy was seen in patients with mild endometriosis, as evidenced by a significant decrease in hormone levels, a significant decrease in VAS scores and the lowest rates of recurrence and adverse effects. The efficacy diminished with increasing disease severity, especially in severe patients, where the therapeutic effect of goserelin acetate implantation was relatively limited. This may be related to the fact that the lesions in severe patients are more complex, making it difficult to achieve complete symptomatic relief with pharmacological therapy alone. Therefore, for patients with severe endometriosis, a combination of other treatments, such as surgery or adjuvant medications, may be needed to achieve better therapeutic outcomes.

Limitations of this study

Despite the conclusion on the efficacy of goserelin acetate implants, the findings still might be influenced by following factors. Some trials did not specify whether their allocation schemes were treated equally or were concealed, which may introduce bias.

The age and course of the subjects included in the study varied, resulting in statistical and clinical heterogeneity that could affect the meta-analysis results. The quality of some included literature is low, potentially affecting the accuracy of the result data. Unclear random allocation method and lack of blind design: The study (Ma *et al*., 2024) did not clearly describe the specific method of random allocation, which may lead to selection bias. Selection bias may cause imbalance between the experimental group and the control group at baseline, thereby overestimating or underestimating the treatment effect; the study (Bergqvist *et al*., 2020) did not adopt a blind method, which may lead to implementation bias and evaluation bias. When scoring VAS, the lack of blinding may cause the evaluator to be more lenient in scoring the experimental group, thereby overestimating the treatment effect. It may lead to inaccurate efficacy and safety assessments and overestimate the therapeutic efficacy and safety of goserelin acetate implants. Study sample size (Granese *et al*., 2015) did not clearly report the measurement method and time point of hormone levels, which may lead to incomparable results. Differences in measurement methods and time points between different studies may lead to a lack of consistency in the comparison of hormone levels. The study (Yang *et al*., 2019) did not report in detail the monitoring methods and recording standards for adverse reactions, which may lead to incomplete adverse reaction assessments. Unstandardized recording methods may lead to the incidence of adverse reactions being underestimated or overestimated. Incomplete data reporting may lead to biased results and affect the reliability and comparability of conclusions.

In addition, the study did not include other Western studies, which may have limited the generalisability of the results to fully reflect the efficacy and safety of goserelin acetate implant in different populations.

CONCLUSION

Existing evidence has shown that goserelin acetate implants can enhance the overall treatment efficacy for endometriosis patients, improve hormone levels and VAS scores and reduce adverse reactions and recurrence rates. However, due to the aforementioned limitations—particularly the heterogeneity in recurrence definitions and assessment methods—future randomized controlled trials with larger sample sizes, higher quality, standardized long-term follow-up and consistent diagnostic criteria for recurrence are needed to confirm the long-term efficacy of goserelin acetate implants in the treatment of endometriosis, especially their impact on reducing recurrence rates.

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Authors' contributions
Hong Ye: Conceptualized the research, designed the experimental methodology, supervised the entire research project and reviewed and finalized the manuscript; Lan Tang: Performed model establishment and data collection and participated in manuscript writing; Sisi Wu: Responsible for the analysis of data; Li Chen: Data analysis and Validation; Shuhua Zeng: Conducted image analysis. Weiwei Dong: Result validation. All authors have read and approved the final version of the manuscript for submission.

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Data availability statement
Data are available from the corresponding author.

Ethical approval
As a meta-analysis, this study used data from the original studies, all of which were conducted in compliance with ethical standards and obtained the necessary ethical approvals.

Conflict of interest
The authors declare that this study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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