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Original Article

Efficacy of transvaginal erbium laser treatment for vaginal relaxation and its impact on vaginal microenvironment indicators

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Abstract: Objective: To evaluate the efficacy of transvaginal erbium laser therapy in the treatment of Vaginal Relaxation Syndrome (VRS) and its effects on key indicators of vaginal health. Methods: This retrospective study analyzed clinical data from women treated for VRS at the China-Japan Friendship Hospital. Participants were divided into two groups: laser therapy (n = 130) and estrogen treatment (n = 112). Demographic characteristics, clinical outcomes, vaginal microenvironment parameters, and sexual function were assessed. Primary outcomes included changes in pelvic floor muscle strength, vaginal atrophy scores, vaginal pH, lactobacilli grades, and sexual satisfaction. Results: At the three-month follow-up, the laser group showed significant improvement in pelvic floor muscle strength ($P = 0.046$) and reductions in vaginal atrophy scores ($P = 0.035$) compared to the estrogen group. Additionally, patients in the laser group reported greater sexual satisfaction, including increased orgasm frequency ($P = 0.007$). While improvements in lactobacilli grades and vaginal pH were observed in the laser group, these changes were not statistically significant (both $P > 0.05$). Adverse reactions were mild and occurred less frequently in the erbium laser group ($P < 0.05$). Conclusion: Transvaginal erbium laser therapy is an effective intervention for alleviating VRS symptoms and enhancing pelvic floor muscle function. It also contributes to improved sexual satisfaction and supports the maintenance of a healthy vaginal microenvironment.

Keywords: Vaginal relaxation syndrome, erbium laser therapy, non-invasive treatment, vaginal microenvironment, sexual function improvement

Introduction

Vaginal relaxation syndrome (VRS) is a prevalent condition affecting a significant proportion of women worldwide. It is characterized by vaginal tissue laxity, commonly resulting from childbirth, aging, hormonal changes, or genetic predisposition [1]. VRS can diminish sexual satisfaction and negatively impact quality of life and self-image. Traditional treatment options include pelvic floor muscle training and surgical interventions, which, although effective, may not always be preferred or feasible due to patient-specific factors such as prolonged recovery time and potential surgical risks. In recent years, non-invasive therapies have garnered increasing attention as viable alternatives for managing VRS, with laser therapy emerging as a leading modality [2].

Among these, transvaginal erbium laser therapy represents an innovative and promising approach. Erbium lasers are recognized for their ability to stimulate collagen remodeling and enhance tissue elasticity without causing significant thermal damage, making them suitable for a variety of dermatological and gynecological applications. The underlying mechanism involves precise photothermal effects that induce neocollagenesis, thereby strengthening the vaginal wall and improving functional outcomes. Compared to surgical options, erbium laser therapy is non-invasive, requires minimal downtime, and has a favorable safety profile, enhancing its appeal among patients seeking alternatives to conventional procedures [3-5].

Despite growing clinical interest, comprehensive evaluations of laser therapy's effective-

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ness-particularly beyond symptom relief-remain limited. A critical but often overlooked aspect of vaginal health is the vaginal microenvironment. Key factors such as pH and the composition of the vaginal microbiota are essential for maintaining mucosal homeostasis and preventing infections [6, 7]. Lactobacilli, the dominant beneficial bacteria in the vaginal ecosystem, produce lactic acid that maintains an acidic environment, which is crucial for inhibiting pathogenic bacterial growth. Disruption of this delicate balance may predispose women to infections and inflammation, exacerbating symptoms of atrophy and relaxation [8-10]. This study aims to address this gap by comprehensively evaluating the efficacy of transvaginal erbium laser therapy for VRS and its impact on key indicators of the vaginal microenvironment.

Materials and methods

Study design

This retrospective analysis was conducted at China-Japan Friendship Hospital between January 2020 and June 2024. The target population included women presenting with symptoms of vaginal relaxation, such as dryness, dyspareunia, irritation, and pain. The inclusion criteria were as follows: (1) Women aged 25-65 years; (2) Diagnosed with vaginal laxity [11]; (3) Experiencing reduced sexual sensation, either self-reported or reported by partners, due to vaginal looseness impacting sexual satisfaction, or experiencing vaginal noise during physical activity caused by air trapping [12]; (4) Completion of a three-month follow-up; (5) Normal mental and cognitive function; and (6) Availability of complete medical records.

Exclusion criteria were as follows: (1) Pregnancy or lactation; (2) History of unexplained vaginal bleeding; (3) Abnormal Pap smear findings; (4) Presence of pelvic inflammatory disease or other infections; (5) Active or recent genitourinary tract infections; (6) Use of hormonal therapy, vaginal lubricants, moisturizers, or spermicides; (7) History of vaginal surgery [13]; and (8) History of photosensitivity or use of photosensitizing medications [3].

A total of 242 patients were included. Based on treatment modality, patients were categorized into a laser group and an estrogen group. The sample size was calculated using G * Power 3.1 software under the assumptions of a moderate effect size (d = 0.5), two-tailed significance level (α = 0.05), and statistical power of 95%. A minimum of 105 participants per group was required to reject the null hypothesis of equal means using a two-sample, equal-variance t-test.

Strict inclusion criteria were applied to ensure that both groups received only the designated interventions during critical time windows. Patients with non-compliant or heterogeneous treatment exposures were excluded. This methodological rigor minimized intergroup variability, balanced baseline characteristics, and ensured comparability between cohorts.

Data were extracted from the hospital's medical record system and included demographic and clinical variables such as age, body mass index (BMI), smoking and alcohol use history, comorbidities, education level, marital status, number of children, mode of delivery, menopausal status, and primary presenting symptoms.

Ethics statement

Ethical approval for this study was obtained from the Institutional Review Board (IRB) and Ethics Committee of China-Japan Friendship Hospital. As the study was based solely on de-identified patient data and posed no risk to patient care, the requirement for informed consent was waived. This exemption was granted in accordance with relevant regulations and ethical guidelines governing retrospective research.

Treatment approach

Patients in the estrogen group applied 0.5-1 gram of 17β-estradiol ointment (Ovestin, Bayer Healthcare Co., Ltd., National Drug Approval Number: H20173221) containing 0.01% estradiol, once daily at bedtime for approximately two weeks. Thereafter, the frequency was reduced to several times per week to maintain the therapeutic effect.

Patients in the laser group received treatment using an Erbium-doped Yttrium Aluminium Garnet (Er:YAG) laser system (IntimaLase, XS Dynamis, Fotona d.o.o., Ljubljana, Slovenia). A full-beam handpiece (R11) delivering 8-10 J/cm^2 was used for the vaginal canal, and a fractional handpiece (PS03) delivering 10 J/cm^2 was used for the vestibule and introitus. A 7-mm spot-size handpiece with a pulse dura-

tion of 250 ms and a repetition rate of 1.6 Hz was used for both regions. Follow-up assessments were conducted for both groups three months after treatment.

Pelvic floor muscle contraction pressure

Pelvic floor muscle strength (PFMS) was measured using the Apimedis Perinometer1 (EXTT-101, Korea). Four consecutive contractions were recorded, and the following parameters were documented: maximum contraction pressure (mm Hg), average contraction pressure (mm Hg), and contraction duration (seconds) [14]. Measurements were taken before treatment and again at the three-month follow-up.

Vaginal atrophy symptoms and vaginal atrophy score

During each follow-up, a physician-administered questionnaire was used to evaluate patients' primary symptoms, including dryness, pain, itching, and dyspareunia. Each symptom was rated on a five-point scale, with higher scores indicating greater severity and impact on daily life. The scores were summed to generate a total vaginal atrophy symptom score, with a maximum of 20 points [15, 16].

In addition, vaginal atrophy was assessed using a Visual Analog Scale (VAS) [17]. The VAS score was based on the physician's evaluation of vaginal wall appearance, color, elasticity, and secretions. Scores ranged from 1 to 10: 1-3 indicated normal vaginal health, 4-6 indicated mild atrophy, and 7-10 indicated severe atrophy [18].

Female sexuality questionnaire

At the three-month follow-up, all patients completed the McCoy Female Sexuality Questionnaire (MFSQ) [19, 20], designed to assess aspects of female sexuality influenced by hormonal changes or biological fluctuations. The MFSQ includes 15 items, each rated on a 7-point Likert scale [21]: 1 (Strongly Disagree) to 7 (Strongly Agree). Responses were dichotomized, with scores of 5-7 indicating agreement and scores of 1-4 indicating disagreement or neutrality.

Adverse reactions and vaginal tightness satisfaction

Patients evaluated changes in vaginal tightness based on three criteria: their own satisfaction, overall satisfaction, and their partner's satisfaction [2]. Results were categorized into five levels [20]: Worst: decreased satisfaction in more than one criterion; No change: no improvement in any criterion; Slightly improved: improvement in one criterion; Moderately improved: improvement in two criteria; Significantly improved: improvement in all three criteria. Adverse reactions were also recorded and analyzed.

Lactobacilli grades and vaginal pH

Vaginal swabs were collected from the posterior fornix, and vaginal pH was measured using pH indicator strips applied to the lateral vaginal wall. Samples were evaluated by a microbiologist to assess lactobacilli levels, categorized into four grades based on the number of bacteria per high-power field (HPF): Grade 1: < 6/HPF; Grade 2: 6-20/HPF; Grade 3: 21-50/HPF; Grade 4: > 50/HPF [4].

Statistical analysis

All statistical analyses were conducted using SPSS 24.0 (IBM Corp., Armonk, NY, USA). Categorical variables are presented as counts and percentages [n (%)]. For categorical data, the chi-square test (χ^2) was applied when the sample size was ≥ 40 and the expected frequency (T) was ≥ 5. When T was between 1 and < 5, the chi-square test was adjusted using a continuity correction. Fisher's exact test was used when the sample size was < 40 or T < 1. Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed data are expressed as mean ± standard deviation (X ± s). Non-normally distributed data were reported as median and interquartile range [median (25th percentile, 75th percentile)]. The Wilcoxon rank-sum test was used for comparisons of non-normally distributed variables. A *p*-value < 0.05 was considered statistically significant.

Results

Comparison of baseline characteristics

The mean age was 45.36 ± 4.98 years in the laser group and 44.32 ± 3.43 years in the estrogen group (P = 0.056) (**Table 1**). BMI was comparable between the two groups: 23.56 ± 2.98 kg/m^2 in the laser group and 23.67 ± 2.54 kg/m^2 in the estrogen group (P = 0.743). There were no significant differences in smok-

Table 1. Comparison of demographic characteristics between the two groups

	Laser group (n = 130)	Estrogen group (n = 112)	t/χ^2	P
Age	45.36 ± 4.98	44.32 ± 3.43	1.919	0.056
Body Mass Index (kg/m^2)	23.56 ± 2.98	23.67 ± 2.54	0.329	0.743
Smoking history (Yes/No)	5 (3.85%)/125 (96.15%)	3 (2.68%)/109 (97.32%)	0.021	0.884
Drinking history (Yes/No)	16 (12.31%)/114 (87.69%)	14 (12.5%)/98 (87.5%)	0.002	0.964
Hypertension (Yes/No)	5 (3.85%)/125 (96.15%)	4 (3.57%)/108 (96.43%)	0	1
Diabetes (Yes/No)	4 (3.08%)/126 (96.92%)	4 (3.57%)/108 (96.43%)	0	1
Educational level (Junior college graduate/College graduate or higher)	76 (58.46%)/54 (41.54%)	68 (60.71%)/44 (39.29%)	1.919	0.056
Marital Status (Married/Unmarried)	114 (87.69%)/16 (12.31%)	102 (91.07%)/10 (8.93%)	0.329	0.743
Number of children			0.143	0.998
0	8 (6.15%)	6 (5.36%)		
1	26 (20%)	22 (19.64%)		
2	69 (53.08%)	60 (53.57%)		
3	23 (17.69%)	21 (18.75%)		
4	4 (3.08%)	3 (2.68%)		
Type of childbirth			0.225	0.973
No children	8 (6.15%)	6 (5.36%)		
Vaginal delivery	64 (49.23%)	58 (51.79%)		
Caesarean section	45 (34.62%)	38 (33.93%)		
Vaginal delivery and Caesarean section	13 (10%)	10 (8.93%)		
Menopausal Status (Yes/No)	15 (11.54%)/115 (88.46%)	13 (11.61%)/99 (88.39%)	0	0.987
Most symptoms				
Dryness	42 (32.31%)	26 (23.21%)	2.462	0.117
Dyspareunia	64 (49.23%)	60 (53.57%)	0.454	0.501
Irritation	5 (3.85%)	6 (5.36%)	0.317	0.574
Pain	5 (3.85%)	6 (5.36%)	0.317	0.574

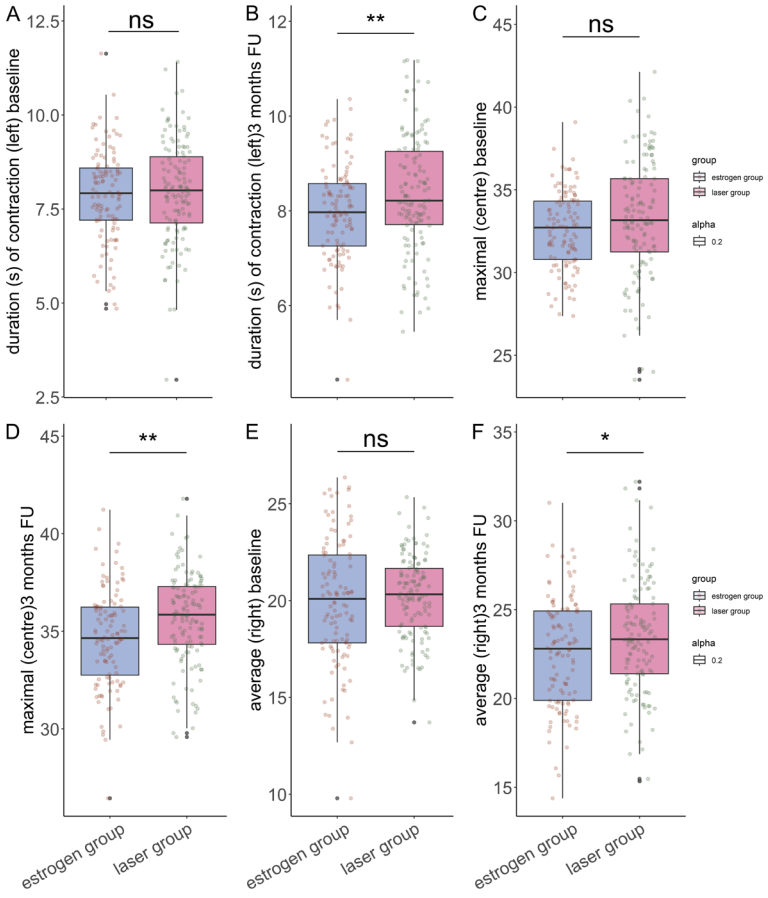

Figure 1. Comparison of pelvic floor muscle contraction pressure between two groups. A. Duration (s) of contraction (left) Baseline; B. Duration (s) of contraction (left) 3 months FU; C. Maximal (center) Baseline; D. Maximal (center) 3 months FU; E. Average (right) Baseline; F. Average (right) 3 months FU. ns: no statistically significant difference; *: P < 0.05; **: P < 0.01.

ing and alcohol consumption history, hypertension, or diabetes (all P > 0.05).

Similarly, educational level, marital status, number of children, mode of childbirth, and menopausal status were evenly distributed between the groups (all P > 0.05). Baseline symptoms, including vaginal dryness, dyspareunia, irritation, and pain, also showed no significant differences (all P > 0.05). Overall, the two groups were comparable in demographic and clinical characteristics at baseline.

Comparison of pelvic floor muscle contraction pressure

At baseline, there were no significant differences in pelvic floor muscle contraction parameters between the two groups, including contraction duration, maximal pressure, and average pressure (all P > 0.05) (**Figure 1**). At the 3-month follow-up, the laser group showed significantly better outcomes. Contraction duration increased to 8.35 ± 1.24 seconds in the laser group compared to 7.97 ± 1.02 seconds in the estrogen group (P = 0.009). Maximal contraction pressure was also higher in the laser group (35.65 ± 2.35 mmHg) than in the estrogen group (34.65 ± 2.51 mmHg) (P = 0.002). Similarly, the average contraction pressure was significantly greater in the laser group (23.43 ± 3.21 mmHg) than in the estrogen group (22.61 ± 3.12 mmHg) (P = 0.046).

Comparison of vaginal atrophy symptoms and scores

At baseline, no significant differences were observed between groups in the mean vaginal atrophy symptom scores (laser: 17.25 ± 2.86 vs. estrogen: 16.96 ± 2.23, P = 0.378) or in the corresponding vaginal atrophy scores (6.85 ± 1.29 vs. 7.05 ± 1.35, P = 0.245) (**Figure 2**). However, at the 3-month follow-up, the laser group demonstrated greater improvement. The mean vaginal atrophy symptom score decreased to 8.53 ± 2.74 in the laser group versus 9.16 ± 2.02 in the estrogen group (P = 0.043). The corresponding vaginal atrophy score also declined more in the laser group (4.95 ± 0.85) compared to the estrogen group (5.14 ± 0.51) (P = 0.035) (**Figure 2**).

Comparison of sexual function based on the female sexuality questionnaire

At the 3-month follow-up, the laser group showed significantly higher levels of sexual satisfaction. More participants in the laser group reported enjoyment of sexual activity (58.46% vs. 44.64%, P = 0.032) and satisfaction with sexual frequency (56.92% vs. 43.75%, P = 0.041, **Table 2**). Additionally, dissatisfaction related to the partner's lack of interest was lower

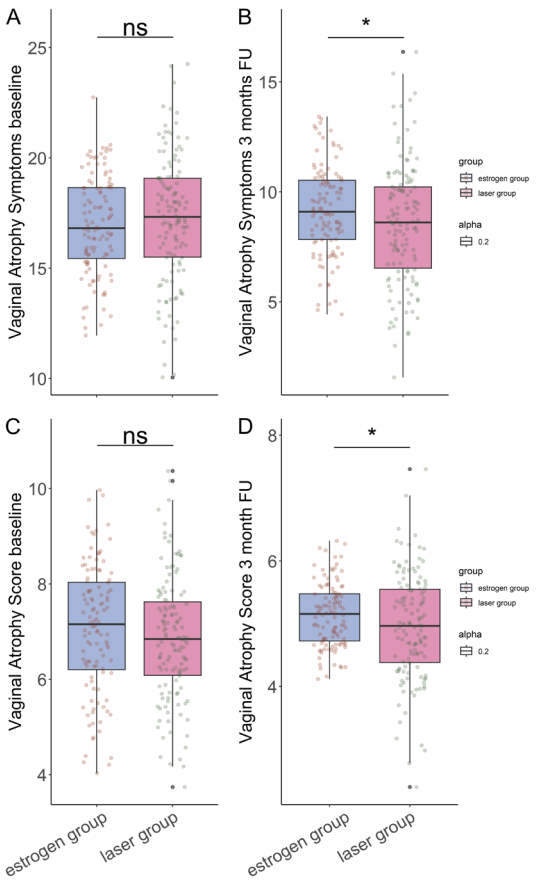

Figure 2. Comparison of vaginal atrophy symptoms and vaginal atrophy score between two groups. A. Vaginal Atrophy Symptoms Baseline; B. Vaginal Atrophy Symptoms 3 months FU; C. Vaginal Atrophy Score Baseline; D. Vaginal Atrophy Score 3 months FU. ns: no statistically significant difference; *: P < 0.05.

in the laser group (32.31%) than in the estrogen group (47.32%) (P = 0.017), while satisfaction with the partner as a lover was higher (64.62% vs. 50.89%, P = 0.031). The frequency of orgasm was also significantly greater in the laser group (58.46%) compared to the estrogen group (41.07%) (P = 0.007, **Table 2**). Other aspects of sexual function - including frequency of sexual thoughts, arousal, interest, vaginal lubrication, and self-perceived sexual attractiveness - did not differ significantly between the two groups (all P > 0.05, **Table 2**).

Comparison of adverse reactions

In the laser group, leukorrhea was reported in 10% of participants compared to 12.5% in the estrogen group (P = 0.538). Vaginal dryness occurred in 1.54% of the laser group and 0.89% of the estrogen group (P = 1.000) (**Table 3**). Dysuria, itching, and spot bleeding were each reported in one participant in the estrogen group, but none in the laser group. The overall incidence of adverse reactions was 11.54% in the laser group versus 16.7% in the estrogen group (P = 0.306).

Comparison of patient satisfaction with vaginal tightness

Patient-reported satisfaction with vaginal tightness showed a statistically significant difference between the two groups (P = 0.001) (**Table 4**). No participants in either group reported a worsening of symptoms. In the laser group, 5.38% reported no change after treatment, compared to 13.39% in the estrogen group. Slight improvement was noted by 33.08% of patients in the laser group and 43.75% in the estrogen group. Moderate improvement was reported by 43.08% in the laser group and 38.39% in the estrogen group. Notably, 18.46% of patients in the laser group experienced significant improvement, compared to only 4.46% in the estrogen group.

Comparison of lactobacilli grades

At baseline, no significant difference in lactobacilli grade distribution was observed between the two groups (P = 0.079) (**Table 5**). However, at the 3-month follow-up, a significant difference emerged (P = 0.012). Grade 1 lactobacilli were present in 66.92% of the laser group and 69.64% of the estrogen group. The proportion of Grade 4 lactobacilli was higher in the laser group (19.23%) than in the estrogen group (8.93%).

Comparison of vaginal pH

Baseline vaginal pH was similar between groups: 6.30 ± 1.40 in the laser group and 6.40 ± 1.20 in the estrogen group (P = 0.563) (**Figure 3**). At the 3-month follow-up, the mean vaginal pH slightly decreased to 6.10 ± 1.20 in the laser group and 6.20 ± 1.10 in the estrogen group, with no significant difference (P = 0.498).

Discussion

This study compared the efficacy of transvaginal erbium laser therapy and estrogen treatment for vaginal relaxation and their respective impacts on indicators of the vaginal microenvi-

Table 2. Comparison of result of McCoy female sexuality questionnaire (MFSQ) between the two groups

	Laser group (n = 130)	Estrogen group (n = 112)	χ^2	P
Enjoyment of sexual activity (5-7/1-4)	76 (58.46%)/54 (41.54%)	50 (44.64%)/62 (55.36%)	4.603	0.032
Satisfaction with frequency of sexual activity (5-7/1-4)	74 (56.92%)/56 (43.08%)	49 (43.75%)/63 (56.25%)	4.177	0.041
Frequency of sexual thoughts and fantasies (5-7/1-4)	63 (48.46%)/67 (51.54%)	51 (45.54%)/61 (54.46%)	0.207	0.649
Excitement/arousal during sexual activity (5-7/1-4)	69 (53.08%)/61 (46.92%)	56 (50%)/56 (50%)	0.228	0.633
Level of sexual interest (5-7/1-4)	61 (46.92%)/69 (53.08%)	53 (47.32%)/59 (52.68%)	0.004	0.951
Vaginal lubrication (5-7/1-4)	71 (54.62%)/59 (45.38%)	55 (49.11%)/57 (50.89%)	0.731	0.392
Sexually attractive, generally (5-7/1-4)	64 (49.23%)/66 (50.77%)	49 (43.75%)/63 (56.25%)	0.726	0.394
Sexually attractive, to partner (5-7/1-4)	68 (52.31%)/62 (47.69%)	56 (50%)/56 (50%)	0.128	0.72
Decreased satisfaction due to partner's disinterest (5-7/1-4)	42 (32.31%)/88 (67.69%)	53 (47.32%)/59 (52.68%)	5.687	0.017
Satisfaction with partner as lover (5-7/1-4)	84 (64.62%)/46 (35.38%)	57 (50.89%)/55 (49.11%)	4.659	0.031
Satisfaction with partner as friend (5-7/1-4)	72 (55.38%)/58 (44.62%)	49 (43.75%)/63 (56.25%)	3.258	0.071
Enjoyment of sexual intercourse (5-7/1-4)	73 (56.15%)/57 (43.85%)	51 (45.54%)/61 (54.46%)	2.715	0.099
Frequency of orgasm (5-7/1-4)	76 (58.46%)/54 (41.54%)	46 (41.07%)/66 (58.93%)	7.278	0.007
Pleasure of orgasm (5-7/1-4)	74 (56.92%)/56 (43.08%)	59 (52.68%)/53 (47.32%)	0.438	0.508
Additional stimulation needed to reach orgasm (5-7/1-4)	78 (60%)/52 (40%)	57 (50.89%)/55 (49.11%)	2.023	0.155

Table 3. Adverse reactions from Er:YAG laser treatments on both groups

	Laser group (n = 130)	Estrogen group (n = 112)	χ^2	P
Leukorrhea	13 (10%)	14 (12.5%)	0.379	0.538
Dryness	2 (1.54%)	1 (0.89%)	0	1
Dysuria	0 (0%)	1 (0.89%)		0.463
Itching	0 (0%)	1 (0.89%)		0.463
Spot bleeding	0 (0%)	1 (0.89%)		0.463
All adverse reactions	15 (11.54%)	18 (16.7%)	1.05	0.306

Table 4. Comparison of patient's vaginal tightness satisfaction between the two groups

	Laser group (n = 130)	Estrogen group (n = 112)	χ^2	P
Worst	0 (0%)	0 (0%)	16.207	0.001
No change	7 (5.38%)	15 (13.39%)		
Slightly improved	43 (33.08%)	49 (43.75%)		
Moderately improved	56 (43.08%)	43 (38.39%)		
Significantly improved	24 (18.46%)	5 (4.46%)		

Table 5. Comparison of lactobacilli grade between the two groups

		Laser group (n = 130)	Estrogen group (n = 112)	χ^2	P
Baseline	Grade 1	89 (68.46%)	76 (67.86%)	6.774	0.079
	Grade 2	9 (6.92%)	18 (16.07%)		
	Grade 3	16 (12.31%)	10 (8.93%)		
	Grade 4	16 (12.31%)	8 (7.14%)		
3 months FU	Grade 1	87 (66.92%)	78 (69.64%)	10.987	0.012
	Grade 2	6 (4.62%)	16 (14.29%)		
	Grade 3	12 (9.23%)	8 (7.14%)		
	Grade 4	25 (19.23%)	10 (8.93%)		

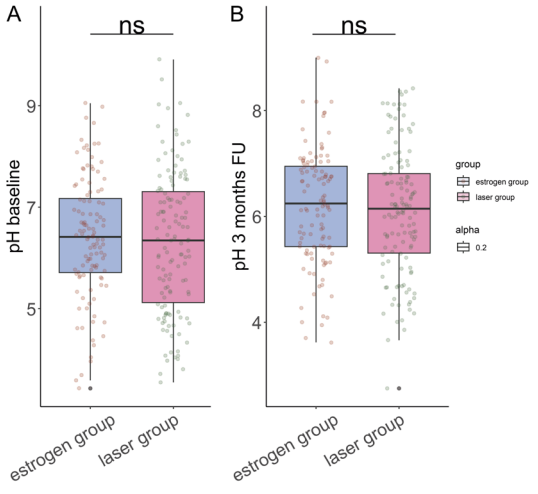

Figure 3. Comparison of vaginal pH between two groups. A. Baseline; B. 3 months FU. ns: no statistically significant difference.

ronment. The findings revealed distinct outcomes related to vaginal tightness, atrophy, sexual function, adverse events, lactobacilli grades, and vaginal pH, offering valuable clinical and mechanistic insights into this emerging therapeutic modality.

Transvaginal erbium laser therapy demonstrated superiority over estrogen treatment in improving patient-reported vaginal tightness. The significant enhancement in pelvic floor muscle contraction parameters observed in the laser group at the three-month follow-up suggests a direct effect of laser-induced collagen remodeling in vaginal tissues. Erbium lasers are characterized by their precision and minimal thermal damage, which promotes collagen synthesis and neocollagenesis. This remodeling likely reinforces the connective tissue matrix, improving both structural support and functional elasticity of the vaginal walls [22]. Laser-generated heat (40-70°C) activates transient receptor potential vanilloid 1 (TRPV1) channels, leading to the release of cytokines (IL-1β, IL-8). These,

in turn, recruit neutrophils and macrophages (CD68+ cells), initiating a controlled inflammatory response crucial for tissue repair [23, 24]. By contrast, estrogen therapy primarily promotes epithelial proliferation and mucosal hydration, mechanisms that improve surface-level comfort but do not contribute substantially to the biomechanical integrity achieved through laser-induced collagen restructuring [25-27].

The observed reduction in vaginal atrophy symptoms and scores in the laser group further underscores the therapeutic potential of erbium laser treatment. While estrogen mitigates symptoms by restoring hormonal balance and improving tissue pliability, erbium laser therapy appears to exert broader regenerative effects by addressing both structural deficits and clinical manifestations. The mechanical stimulation provided by laser pulses likely enhances blood flow, tissue oxygenation, and nutrient delivery, all of which contribute to improved mucosal health and function [3, 4, 27].

Improvements in specific domains of sexual function and satisfaction among women receiving laser treatment are also notable. Increased enjoyment and frequency of sexual activity, along with reduced dissatisfaction attributed to partner-related factors, may be linked to enhanced vaginal tone and reduced atrophy. Mechanistically, these outcomes could stem from improved nerve regeneration and heightened sensitivity facilitated by the reparative effects of laser therapy, potentially enhancing sexual arousal and satisfaction [28-30]. However, it is important to acknowledge the potential influence of patient expectations and psychosocial factors on self-reported sexual outcomes, which may confound purely physiological interpretations.

In terms of adverse reactions, the comparable safety profile of erbium laser therapy relative to estrogen treatment underscores its minimally invasive nature and high tolerability. The low incidence of dysuria, itching, and bleeding in the laser group is likely attributable to the laser's selective photothermolytic properties, which minimize collateral damage to surrounding tissues. Combined with its non-systemic mode of action, laser therapy offers a safer alternative, particularly for patients contraindicated for hormonal treatments [31, 32].

Changes in the vaginal microenvironment-specifically lactobacilli grades and pH levels-warrant further investigation into how laser therapy may influence microbial ecology. Lactobacilli play a central role in maintaining vaginal health by producing lactic acid, which helps preserve an acidic pH that inhibits pathogenic organisms [33-35]. The transient alterations in lactobacilli distribution and the slight pH reduction observed post-laser treatment may reflect temporary disturbances due to early tissue remodeling. As epithelial regeneration and collagen restructuring progress, the microbial environment may stabilize. These dynamics could be better understood through longitudinal microbiome studies, providing a clearer picture of how laser therapy interacts with vaginal microbial communities [4].

The preservation of lactobacilli populations and stable pH further support the microbiological safety of erbium laser therapy, suggesting a non-disruptive effect on the native microbiota. Previous research has primarily focused on clinical efficacy and subjective symptom improvement [36, 37], without establishing a link between erbium laser therapy and its effects on the vaginal microenvironment. In this study, we addressed this gap by elucidating how non-ablative erbium laser therapy influences tissue remodeling, immune activation, and microbial stability. This broader mechanistic understanding advances the therapeutic rationale for its use in treating vaginal relaxation and genitourinary syndrome of menopause (GSM). Future studies should further examine the potential of laser therapy to preserve or enhance a protective vaginal microbiome.

Despite its strengths, this study has several limitations. First, the lack of randomization and blinding introduces potential bias and limits the generalizability of the results. Second, reliance on self-reported outcomes, such as sexual satisfaction and symptom relief, may be affected by subjective perception and social desirability bias. Third, the exclusion of pregnant and lactating women restricts the applicability of the findings to these populations. Additionally, the three-month follow-up may be insufficient to capture long-term efficacy and safety. Lastly, although biological parameters such as vaginal pH and lactobacilli grades were assessed, broader microbiome profiles and underlying

molecular pathways were not fully explored. These aspects warrant further investigation.

In conclusion, transvaginal erbium laser therapy is a promising intervention for managing vaginal relaxation and associated atrophic symptoms. It offers superior structural and functional improvements compared to estrogen therapy, including enhanced vaginal tightness, reduced atrophy, and improved sexual satisfaction. With a favorable safety profile and non-hormonal mechanism of action, it represents an effective alternative for women unable or unwilling to undergo hormonal treatment. While the physiological mechanisms underlying its efficacy are increasingly understood, further research is essential to optimize treatment protocols, clarify microbial interactions, and extend its applicability to broader patient populations. Integrating laser-based approaches into clinical practice holds the potential to significantly improve gynecological health and quality of life for women.

Disclosure of conflict of interest

None.

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