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Original Article

Comparative evaluation of β-glucan functional dressing and interferon-α2a plug for vaginal microecology restoration and HPV clearance in women with bacterial vaginosis or aerobic vaginitis

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Abstract: Objective: To compare the effectiveness of β-glucan functional dressing and interferon-α2a (IFN-α2a) plug in promoting high-risk human papillomavirus (HR-HPV) clearance and restoring vaginal microecology in women with bacterial vaginosis (BV) or aerobic vaginitis (AV). Methods: This prospective-retrospective study enrolled 44 women diagnosed with BV or AV. Participants were evaluated for vaginal ecological indicators including pH, cleanliness, hydrogen peroxide (H_2O_2), sialidase, leukocyte esterase (LE), microbial diversity, lactobacilli proportion, and standard diagnostic scores (Nugent and AV). HPV status and squamous intraepithelial lesion (SIL) grade were assessed via cytology and colposcopy. Subjects were randomly divided into Group A (n=22), treated with β-glucan dressing, and Group B (n=22), treated with IFN-α2a plug for 14 days (excluding menstruation). Clinical and virological parameters were re-evaluated after three months. Results: Both groups were comparable at baseline. No adverse effects were reported. Post-treatment analysis showed that β-glucan dressing significantly improved markers of inflammation (LE, H_2O_2), increased lactobacilli abundance, and reduced pathogenic bacteria. IFN-α2a treatment improved vaginal pH and diagnostic scores but was less effective in microbiota restoration. The HPV-negative conversion rate was higher in the β-glucan group (87%) than that in the IFN-α2a group, and the difference was statistically significant ($P<0.05$). Conclusion: Both β-glucan and IFN-α2a dressings were safe and showed clinical benefits in women with BV or AV and HR-HPV infection. However, β-glucan demonstrated superior outcomes in restoring vaginal microecology and enhancing HPV clearance. These findings suggest that β-glucan may serve as a more effective intravaginal immunomodulatory therapy. Further multicenter studies with larger samples are needed to confirm these results.

Keywords: Bacterial vaginosis, aerobic vaginitis, human papillomavirus, β-glucan, interferon-α2a, LSIL, HR-HPV

Introduction

The vaginal microbiota of healthy women is typically dominated by lactic acid-producing *Lactobacillus* species (e.g., *L. crispatus, L. iners, L. jensenii, L. gasseri*), which help maintain an acidic vaginal pH (~3.5-4.5) and create a protective environment [1]. These lactobacilli produce lactic acid and hydrogen peroxide to inhibit pathogen growth, thereby preventing common vaginal infections [2, 3]. When this balanced microecological state is disrupted (dysbiosis), *Lactobacillus* dominance declines and anaerobic or aerobic bacteria (and sometimes yeasts) can overgrow, raising vaginal pH and compromising local immunity. Such dysbiosis underlies conditions like bacterial vaginosis (BV), aerobic vaginitis (AV), and candidiasis, and increases susceptibility to sexually transmitted infections (STIs), including HPV. Conversely, restoring a *Lactobacillus*-dominant, low-pH environment can enhance mucosal immunity and help re-establish a healthy vaginal ecosystem [4].

Lactobacilli populations in the vagina can fluctuate under various factors (e.g. hormones, antibiotics, sexual activity) [5]. A sudden loss of lactobacilli may trigger vaginal dysbiosis [3]. Bacterial vaginosis (BV) is a common dysbiotic

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condition resulting from the replacement of protective lactobacilli by anaerobic bacteria (such as *Gardnerella vaginalis, Atopobium vaginae, Ureaplasma urealyticum, Mycoplasma hominis,* among others) [6, 7]. BV is one of the most common causes of abnormal vaginal discharge in reproductive-age women (affecting roughly 30% of women at some point) [7, 8]. The etiology of BV is complex, but it is strongly associated with adverse reproductive outcomes (e.g., preterm birth) and a higher risk of acquiring STIs (including high-risk HPV). Diagnosis of BV is typically made using Amsel's clinical criteria or Nugent scoring of Gram-stained vaginal smears [4].

Aerobic vaginitis (AV) is another form of vaginal dysbiosis characterized by an abnormal overgrowth of aerobic or intestinal bacteria and marked vaginal inflammation. It affects an estimated 5-20% of women (higher among symptomatic patients) and is linked to poor obstetric outcomes (e.g., preterm labor). Common AV pathogens include *Enterococcus faecalis, Escherichia coli, group B Streptococcus, and Staphylococcus aureus,* with *E. faecalis* being one of the most frequently identified organisms (~30% of cases). AV can lead to symptoms from discharge to severe complications (e.g., urinary tract infections, abscesses, miscarriage). Recent evidence suggests that *E. faecalis* can harbor HPV genetic material: HPV16 DNA has been detected in *E. faecalis* isolates from cervical lesions, implying that untreated *E. faecalis*-associated AV in HPV-positive women might contribute to persistent HPV infection and progression to high-grade cervical disease. Because AV is often overlooked, failure to manage it may allow chronic infection and potentially facilitate cervical neoplasia.

Human papillomaviruses (HPVs) are small, double-stranded DNA viruses transmitted primarily through sexual contact [9]. They are classified as low-risk types (e.g., HPV-6, 11, causing benign warts) or high-risk types (e.g., HPV-16, 18, etc., associated with malignant lesions) [10]. Persistent infection with high-risk HPVs is the necessary cause of essentially all cervical cancers [11]. In particular, HPV-16 and HPV-18 together account for the majority of cases. Persistent infection of cervical epithelium with these high-risk types drives the progression from low-grade squamous intraepithelial lesions (LSIL) through high-grade lesions (HSIL) to invasive carcinoma [12]. Therefore, strategies that both restore normal vaginal microecology and target HPV infection could yield significant clinical benefits.

Standard treatment for BV or AV relies on broad-spectrum antibiotics (e.g., metronidazole, clindamycin) targeting anaerobic and aerobic bacteria. However, antibiotics alone often fail to fully eradicate dysbiotic flora or prevent recurrence, and they do not directly address latent HPV infection [13]. HPV often remains asymptomatic and undetected by routine care, so adjunctive intravaginal therapies with antiviral or immunostimulatory properties have been explored. For example, recombinant interferon-α2a (a type I interferon) has potent antiviral, antiproliferative, and immunomodulatory effects, and has been used to treat HPV-related lesions. Likewise, β-glucans (polysaccharides derived from yeast or fungal cell walls) are powerful immune stimulants (biological response modifiers) that enhance innate immunity [14-16]. Both interferon-α2a and β-glucan preparations have been investigated as topical treatments for HPV-related conditions, with some studies showing that β-glucan gel can promote regression of HPV-associated epithelial lesions. Nonetheless, the rationale and efficacy of these adjunctive treatments in improving vaginal microecology and HPV outcomes remain unclear.

To address this gap, we conducted a comparative study of two intravaginal dressings in women with BV or AV: Group A received a β-glucan functional dressing, which contains yeast-derived β-1,3/1,6-glucan intended to enhance local immune responses; Group B received an interferon-α2a vaginal plug (recombinant IFN-α2a) to deliver direct antiviral stimulation. We evaluated the effects of these treatments on vaginal microecology and on high-risk HPV clearance. Our aim was to determine whether these biologic dressings could restore a healthy lactobacilli-dominant vaginal environment and prevent persistent HPV infection.

Methodology

Materials

β-glucan: Pathogen-associated molecular patterns (PAMPs) include β-glucans, which are

Table 1. Demographic and clinical characteristics of the study subjects

S. No	Characteristics	Group A (test)	Group B (control)	*P* value (>0.05)
1	Age (yr)	32.59±1.045*	33.64±1.892*	0.5836
2	Vaginal pH	4.118±0.09091*	4.209±0.1200*	0.4529
3	Chemical Analysis of Microbial Enzymes			
	Hydrogen peroxidase	0.8636±0.04545*	0.8182±0.1127*	0.6886
	Leukocyte esterase	0.9545±0.04545*	1.000±0.04545*	0.3230
	Sialidase	0.3182±0.04545*	0.2727±0.1406*	0.7481
4	Microecology evaluation (Mean ± SD)			
	Density of microflora	2.864±0.04545*	2.818±0.1602*	0.7781
	Diversity of microbiota	2.500±0.1364*	2.364±0.1651*	0.4135
	Proportion of lactobacilli	15.45±12.27*	27.73±6.642*	0.0717
	Proportion of other miscellaneous bacteria	84.55±12.27*	72.27±6.642*	0.0717
5	Pathogen Profile			NA
	Gardnerella/Prevobacterium	27	25	
	Resembles Bacillus motobacterium	0	0	
	Gram positive cocci	8	9	
	Gram negative bacilli	1	1	
	Menzi	6	4	
	Pseudohyphae	5	5	
	Trichomonas	0	0	
	Intracellular G diplococcus	0	0	
6	Cellular condition			NA
	Cleanliness	21 (III degree); 1 (IV degree)	19 (III degree); 2 (IV degree)	
	WBCs	31	30	
	Pus Cells	-	-	
	Erythrocytes	-	-	
	Clue cells	7	7	
7	Nugent Score (NS)	4.364±0.1364*	4.227±0.6496*	0.8347
8	AV Score	2.455±0.2273*	2.682±0.3611*	0.5325

*Represents Mean ± SD statistically presented using unpaired t-test. Values in parentheses are numbers. P>0.05 is presented as not significant. NA - Not applicable.

polysaccharides found in the cell walls of yeast, fungi, and some bacteria. They consist of linear β-1,3-linked D-glucose units with β-1,6-linked side chains of variable lengths and branching patterns [17, 18]. β-Glucans have long been recognized for their immunomodulatory properties and are classified as biological response modifiers (BRMs), capable of enhancing host immune responses and promoting antitumor activity [16, 19]. In this study, we used a commercially available anti-HPV β-glucan functional dressing (Gaojixing, 3 g per piece), which was applied intravaginally in Group A participants.

Interferon-α2a: Interferons (IFNs) are cytokines with antiviral, immunoregulatory, and antiproliferative functions. Recombinant interferon-α2a (rIFN-α2a) has been shown to inhibit HPV replication and enhance local immune responses [20]. It has been studied as an adjunct therapy for both clinical and subclinical HPV infections [21]. In this study, participants in Group B received an intravaginal plug containing rIFN-α2a, administered according to the standard protocol.

Participants and eligibility criteria

The study was conducted following approval by the Ethics Committee of Shandong Provincial Maternal and Child Health Care Hospital Affiliated to Qingdao University: (Number SYDW-2023007), and all participants provided written informed consent. Inclusion criteria: (1) Women aged 22-45 years. (2) Diagnosed with bacterial vaginosis (BV) or aerobic vaginitis (AV) based on clinical criteria and laboratory tests. (3) Positive for high-risk HPV (HR-HPV), but without evidence of high-grade cervical lesions (i.e., CIN2+). (4) Agreed to abstain from vaginal prod-

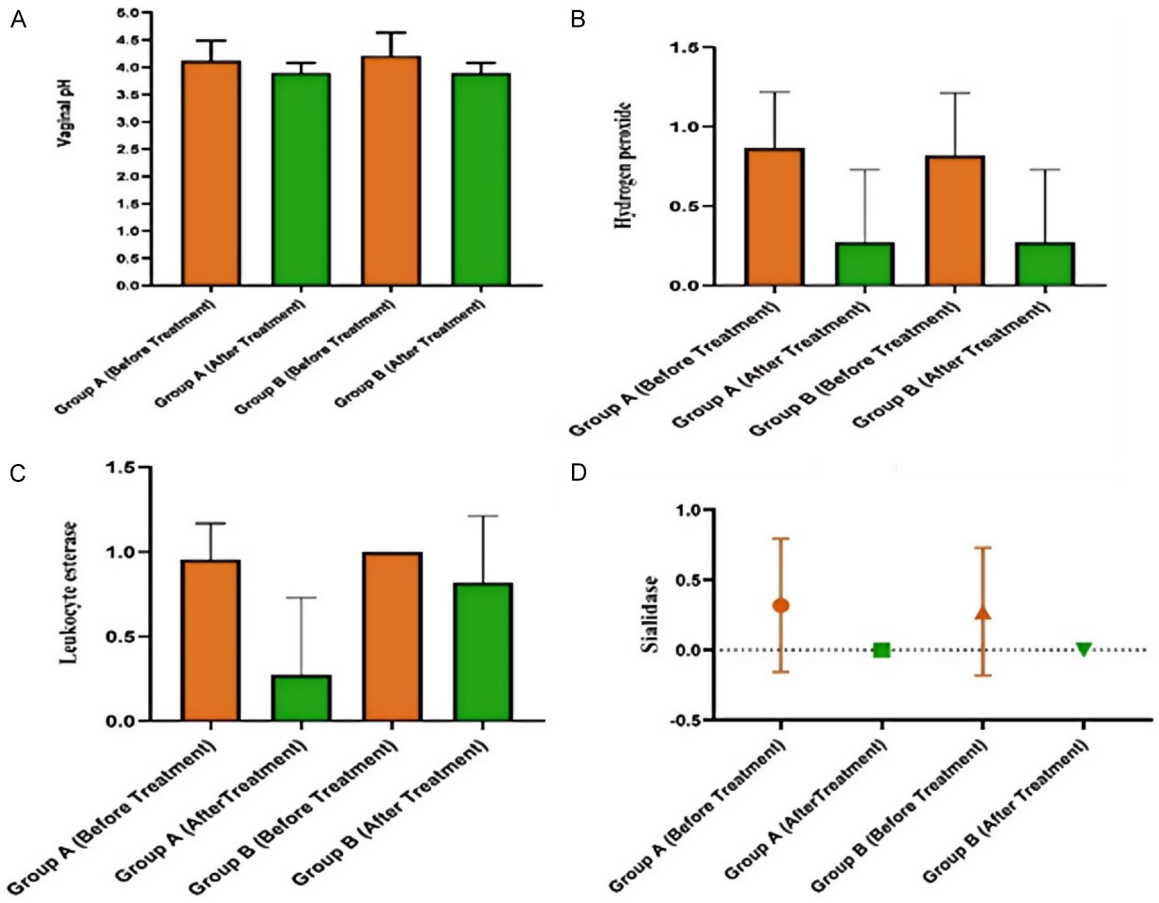

Figure 1. Vaginal chemical microecological markers before and after treatment. A. Vaginal pH values in Group A and Group B before and after treatment. B. Hydrogen peroxide levels, indicating the presence of hydrogen peroxide-producing Lactobacillus strains. C. Leukocyte esterase activity, reflecting inflammatory response levels. D. Sialidase levels, indicating anaerobic bacterial activity. Error bars represent standard deviation. β-glucan group = Group A (orange), IFN-α2a group = Group B (green).

ucts and sexual activity during the intervention. Exclusion criteria: (1) Known allergies to β-glucan or interferon products. (2) Active menstrual bleeding or bleeding during examination. (3) Use of antibiotics or vaginal medications within the last 3 weeks. (4) Sexual intercourse within 48 hours prior to enrollment. (5) Immunodeficiency, hepatic or renal dysfunction, malignancy, or other gynecologic cancers. (6) Current pregnancy or breastfeeding.

Study design and procedures

A total of 44 eligible women were enrolled and randomly assigned into two treatment arms using a simple randomization method: Group A (n=22) received the β-glucan functional dressing, and Group B (n=22) received the rIFN-α2a vaginal plug. All participants were clinically diagnosed with either BV or AV based on symptoms and laboratory testing. General and gynecological examinations were performed at baseline to assess reproductive health. Prior to treatment, cervicovaginal specimens were collected using sterile swabs for microbiological and cytological assessment. Colposcopic evaluation was also performed. Treatments were administered for 14 days (excluding the menstrual period). Assessment parameters before and after treatment included: Vaginal pH and cleanliness; Enzymatic indicators: hydrogen peroxide (H_2O_2), sialidase, and leukocyte esterase (LE); Density and diversity of vaginal microflora; Proportion of Lactobacillus and miscellaneous pathogenic bacteria; Cytological findings (including presence of clue cells, WBCs, erythrocytes); HPV status; Gold-standard diagnostic scores: Nugent and AV score.

The Nugent scoring system, based on Gram-stained vaginal smears, evaluates the relative abundance of lactobacilli, Gardnerella, and Mo-

Table 2. Correlation of vaginal micro-ecology between Group A and Group B

Clinical Characteristic	SS	DF	MS	F-value	*P* value
Vaginal pH	1.700	3	0.5668	5.908	0.0010
Hydrogen Peroxide	7.125	3	2.375	13.67	<0.0001
Leukocyte esterase	7.398	3	2.466	24.11	<0.0001
Sialidase	1.943	3	0.6477	5.955	0.0010
Density of microflora	0.5795	3	0.1932	1.368	0.2582 (NS)
Diversity of microbiota	0.4886	3	0.1629	0.6181	0.6052 (NS)
Proportion of Lactobacilli	14067	3	4689	8.516	<0.0001
Proportion of other miscellaneous bacteria	14305	3	4768	8.625	<0.0001
Nugent Score	-	-	-	-	0.9070** (NS)
AV Score	-	-	-	-	0.5576** (NS)

Significance level α=0.05. DF, degree of freedom; SS, sum of squares; MS, mean of squares; F-value, analyzed using one-way ANOVA. **represents data analyzed using unpaired t-test. NS indicates no significance.

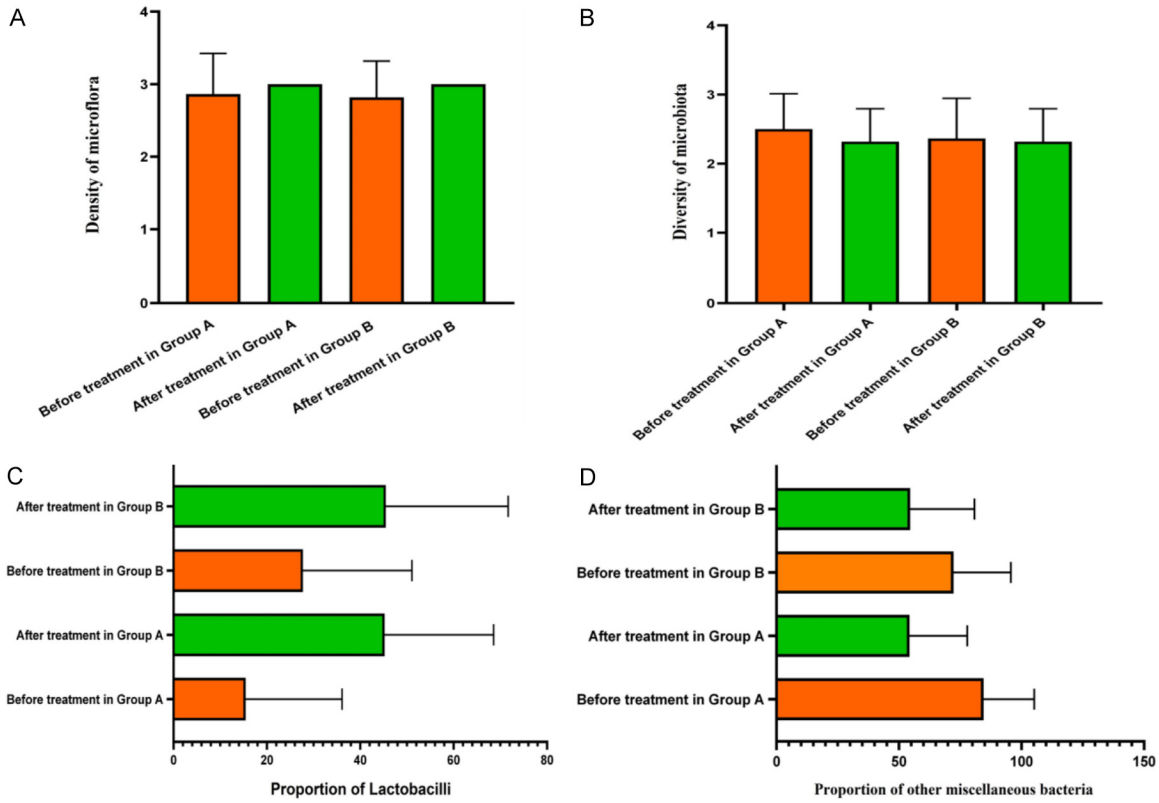

Figure 2. Vaginal microflora characteristics before and after treatment. A. Density of vaginal microflora in Groups A and B, pre- and post-treatment. B. Diversity index of vaginal microbiota, indicating ecological richness. C. Proportion of Lactobacillus observed microscopically, showing an increase after treatment in both groups, particularly in Group A. D. Proportion of other miscellaneous bacteria (e.g., Gardnerella, Gram-positive cocci, Gram-negative bacilli), showing a decrease after treatment, more prominently in Group A. Group A = β-glucan dressing (orange); Group B = IFN-α2a plug (green). Error bars represent standard deviation.

biluncus morphotypes. Scores range: 0-3 (normal flora), 4-6 (intermediate), and 7-10 (indicative of BV). The AV (aerobic vaginitis) score, adapted from Donders et al., combines four criteria observed on wet mount microscopy: (1) presence of toxic leukocytes, (2) decreased Lactobacillus count, (3) presence of background bacteria (e.g., E. coli), and (4) degree of inflammation. A total score of 0-2 is normal, 3-4 is mild, 5-6 is moderate, and ≥7 indicates severe AV. HPV detection was performed using ThinPrep PreservCyt medium and PCR-based

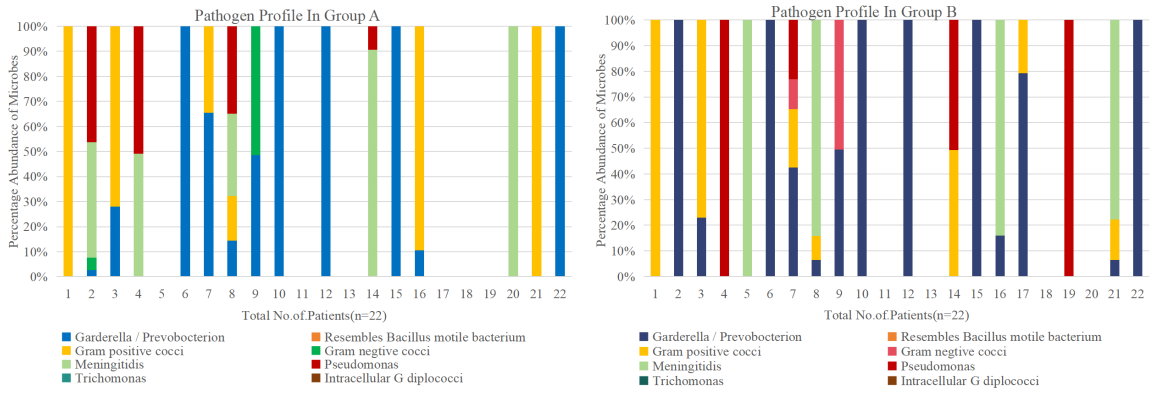

Figure 3. Pathogen profile in Group A and B. Stacked bar chart of pathogen abundance by sample collection method in Group A (Left) and Group B (Right). The top abundant species were *Gardnerella, Gram-Positive Cocci, Gram-negative bacilli*, and *Menzi* with no difference in species composition by sampling type in group A and addition of *Pseudohyphae* instead of Gram-negative bacilli in group B.

Table 3. Cytology pattern in Group A and Group B before and after treatment

Groups	Cleaning degree				White blood cells				Pus Cells		Erythrocytes		Clue cells			
	I	II	III	IV	+	++	+++	crumb	+	-	+	-	+	++	-	crumb
A (Before Treatment)	0	0	21	1	5	6	2	10	0	22	0	0	0	1	16	5
A (After Treatment)	0	11	11	0	2	1	0	19	0	22	0	0	0	0	22	0
B (Before Treatment)	0	0	19	2	7	7	1	8	0	22	0	0	3	1	14	4
B (After Treatment)	0	11	11	0	4	0	0	18	0	22	0	0	0	0	22	0
Total	0	22	62	3	18	14	3	55	0	88	0	0	3	2	74	9
χ^2	11.82				23.82				NA		NA		22.98			
P	0.0007				0.0046				NA		NA		0.0062			

Values in parentheses are numbers and statistically analyzed using Chi-square test. P<0.05 is presented as clinically significant.

genotyping at certified laboratories. Cytology results were categorized as NILM, ASCUS, LSIL, or HSIL according to the Bethesda classification system. Colposcopy images were recorded for lesion follow-up.

Statistical analysis

All data were analyzed using GraphPad Prism version 8.4.2. Continuous variables were compared using unpaired t-tests. Categorical variables were analyzed with Fisher's exact test or Chi-square test as appropriate. For multi-variable comparisons, one-way or two-way ANOVA was performed. A *p*-value <0.05 was considered statistically significant.

Results

Baseline data

A total of 50 participants were initially enrolled in the study, with 26 women allocated to the β-glucan functional dressing group and 24 to the recombinant interferon-α2a (IFN-α2a) plug group. Ultimately, 22 participants in each group (Group A and Group B) completed the study, with 6 subjects lost to follow-up. There was no significant difference in the mean age between the two groups (P>0.05). Prior to treatment, both groups were comparable in terms of vaginal pH, microflora density and diversity, lactobacilli abundance, and levels of pathogenic enzymes associated with bacterial vaginosis (BV) and aerobic vaginitis (AV), as shown in **Table 1**.

Significant reduction in bacterial enzymes

Biochemical analysis of the vaginal microecology revealed significant differences in the levels of hydrogen peroxide and leukocyte esterase (LE) following treatment in both groups. However, sialidase levels did not differ significantly between groups. These findings suggest

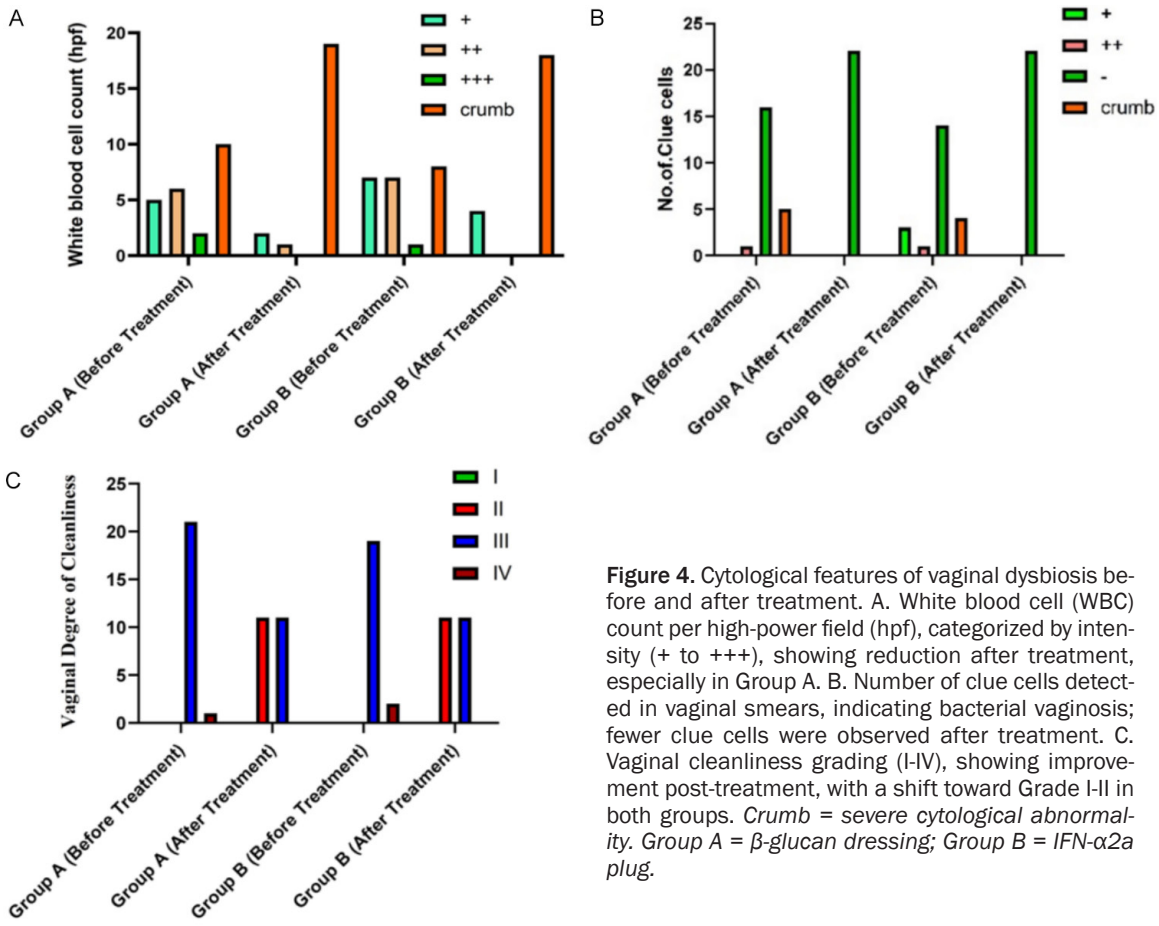

Figure 4. Cytological features of vaginal dysbiosis before and after treatment. A. White blood cell (WBC) count per high-power field (hpf), categorized by intensity (+ to +++), showing reduction after treatment, especially in Group A. B. Number of clue cells detected in vaginal smears, indicating bacterial vaginosis; fewer clue cells were observed after treatment. C. Vaginal cleanliness grading (I-IV), showing improvement post-treatment, with a shift toward Grade I-II in both groups. *Crumb = severe cytological abnormality. Group A = β-glucan dressing; Group B = IFN-α2a plug.*

a more pronounced reduction in inflammation in Group A (β-glucan) compared to Group B (IFN-α2a), particularly in cases involving aerobic pathogens (**Figure 1**; **Table 2**).

Significant reduction in miscellaneous bacteria and increased lactobacilli abundance

Culture analysis of the vaginal flora showed a notable reduction in the growth of organisms such as Gardnerella/Prevobacterium, Gram-positive cocci, Gram-negative bacilli, and Menzi in Group A. In Group B, Pseudohyphae were among the dominant organisms detected. Trichomonas and intracellular G diplococcus were rarely observed in either group. A marked increase in lactobacilli abundance was observed in Group A compared to Group B, although overall microflora density and diversity showed only marginal differences between the groups (**Figures 2**, **3**; **Table 2**).

Significant reduction in abnormal cell counts

Cytological analysis using Pap smears revealed reductions in key pathological indicators, including clue cells, white blood cells (WBCs), pus cells, and erythrocytes. The presence of clue cells was significantly decreased after treatment, and improvements in vaginal cleanliness and pH were noted in both groups. The degree of vaginal cleanliness ranged from Grade II to III, with no significant differences in pus cell and erythrocyte counts between the groups (**Table 3**; **Figure 4**).

Marginal reduction in Nugent and AV scores

Although Amsel's criteria were referenced during evaluation, the study primarily utilized the Nugent and AV scoring systems as gold-standard metrics for grading infection severity. Both scoring systems demonstrated only marginal differences between the groups after treatment (**Figure 5**; **Table 2**).

Marginal reduction in HPV recurrence

Based on Bethesda classification, cervical lesion recurrence occurred in 10 cases across both groups, indicating a 31% total variation.

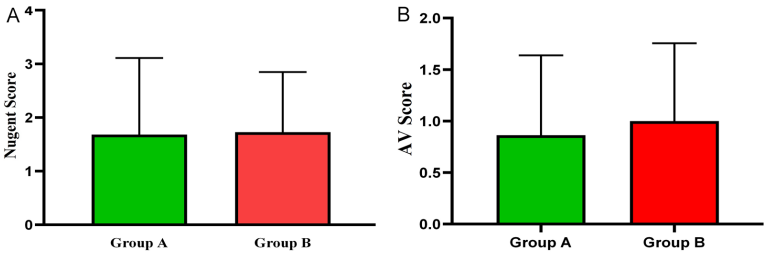

Figure 5. Gold standard diagnostic scores in Group A and B. A. Nugent scores based on Gram-stained vaginal smears, reflecting bacterial composition changes post-treatment. B. AV scores derived from cytological criteria, indicating the degree of aerobic vaginitis. Both scores showed mild reductions in Group A (β-glucan) and Group B (IFN-α2a), with no statistically significant difference between the groups. *Error bars represent standard deviation.*

Table 4. Colposcopy of Group A and Group B to identify HPV negative conversion rate

TCT (Total No. of. Patients)	Group A (n=22) HPV count		Group B (n=22) HPV count	
	Before treatment	After treatment	Before treatment	After treatment
Normal	2	0	1	0
Inflammation	4	0	2	0
NILM	12	0	11	2
ASCUS	12	0	8	0
LSIL	0	4	3	2
Total	30	4	25	4
Cervical lesion classification	LSIL			
P value	<0.0001			

Values in parentheses are numbers and statistically analyzed using 2-way ANOVA. P<0.05 is presented as clinically significant.

Prior to treatment, HPV subtypes 16 and 58 were more frequently observed in Group A, while HPV 18 and 58 were more prevalent in Group B. Following treatment, recurrence was observed in 6 of the 22 participants in Group B, suggesting a relatively high HPV-negative conversion rate. In Group A, only 4 participants remained HPV-positive, corresponding to an 87% HPV clearance rate. This difference was statistically significant (P<0.05), suggesting that β-glucan dressing was more effective in inhibiting persistent HPV infection (**Table 4**; **Figures 6** and **7**).

Discussion

Human papillomaviruses (HPVs) have evolved multiple mechanisms to evade both innate and adaptive immune surveillance, allowing them to persist in host tissues for extended periods. The viral oncoproteins E6 and E7 are known to inhibit the cGAS-STING DNA sensing pathway [22], suppress type I interferon (IFN) signaling [23-25], and impair immune recognition via toll-like receptor 9 and MHC class I downregulation [26]. These effects are mediated by direct interaction with cellular proteins, post-translational modifications, and epigenetic alterations such as promoter hypermethylation and histone modifications [11, 27]. These strategies contribute to HPV's ability to remain latent and increase its carcinogenic potential.

Beta-glucans are a diverse class of glucose-based polysaccharideswithimmunostimulatory properties. They differ in chain length, branching, solubility, and molecular configuration (e.g., β-1,3 and β-1,6 linkages) [28, 29]. Their biological effects depend on both molecular structure and solubility, with water-soluble β-glucans generally exhibiting greater immune activation [30]. Functionally, β-glucans interact with immune receptors (e.g., Dectin-1) to activate macrophages, dendritic cells, and natural killer cells, thereby enhancing antimicrobial and antitumor immunity [31-36]. These properties make β-glucans promising candidates for mucosal immune modulation, e.g., as adjuncts in HPV therapy.

Prior studies have demonstrated the efficacy of interferon-α (IFN-α) in managing genital warts, particularly via intralesional injection [36]. IFN-α has also been evaluated in clinical trials for cervical intraepithelial neoplasia (CIN) and cervical cancer, although the results have been inconsistent [37]. Some reports suggest that high-dose IFN-α can induce apoptosis and halt proliferation in HPV-positive squamous carcinoma cells, leading to viral clearance [38]. Moreover, IFN-inducible protein P56 has been shown to inhibit HPV DNA replication by binding to viral protein E1 [20]. However, IFN-α's role in

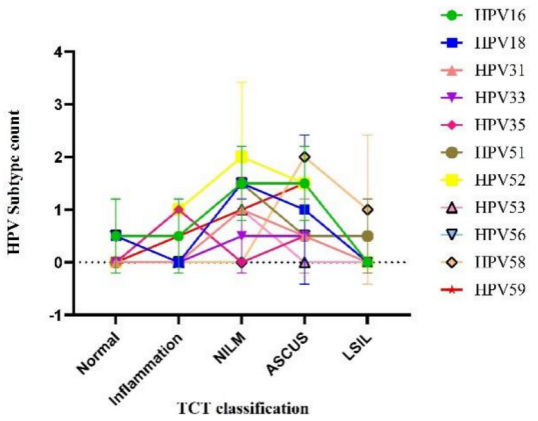

Figure 6. Prevalence of HPV subtype in both groups to determine HPV negative conversion rates. The graph illustrates the frequency of different high-risk HPV subtypes (e.g., HPV16, HPV18, HPV52, HPV58) across ThinPrep Cytology Test (TCT) classifications: normal, inflammation, NILM (negative for intraepithelial lesion or malignancy), ASCUS (atypical squamous cells of undetermined significance), and LSIL (low-grade squamous intraepithelial lesion). HPV58 and HPV16 were most commonly associated with abnormal cytological findings. Trends reflect the persistence or clearance patterns of HPV subtypes during the follow-up. *Each point represents the mean number of detected cases per subtype; error bars indicate standard deviation.*

eradicating latent or subclinical HPV infections remains inconclusive [39].

Our study provides evidence that intravaginal β-glucan dressings not only modulate the vaginal microecological environment but may also enhance local antiviral immunity, resulting in improved HPV clearance rates. Compared to the IFN-α2a group, the β-glucan group demonstrated greater reductions in inflammation-associated enzymes (e.g., leukocyte esterase and hydrogen peroxide), higher restoration of lactobacilli abundance, and a significantly higher HPV-negative conversion rate [40]. These findings support the hypothesis that restoring vaginal microbial balance may create an unfavorable environment for HPV persistence and reactivation.

In our interpretation, the observed therapeutic advantage of β-glucan over IFN-α2a could be attributed to its dual action: immune enhancement and microbial regulation [41]. While IFN-α2a acts directly on viral replication pathways, β-glucan may offer a broader benefit by modulating local immunity and facilitating microbiota recovery. This may explain its greater efficacy in reducing inflammation and promoting HPV clearance, especially in the context of aerobic vaginitis.

The study also highlighted several diagnostic parameters reflective of vaginal health. For instance, a vaginal pH between 3.8 and 4.5, pink H_2O_2 test, negative sialidase, and Nugent scores between 0 and 3 indicated normal microbiota composition. Conversely, pH>4.6, non-pink H_2O_2 results, positive sialidase, and high AV scores were associated with dysbiosis. These microecological indicators showed measurable improvements in both groups, though more prominently in the β-glucan cohort.

We believe that the inclusion of microecological biomarkers in future clinical monitoring protocols could enhance diagnostic accuracy and therapeutic targeting in HPV-related conditions.

Despite the growing recognition of the vaginal microbiome's role in HPV persistence, the exact mechanisms underlying the transition from dysbiosis to cervical carcinogenesis remain poorly understood. Our findings align with prior observations that altered vaginal flora - particularly loss of Lactobacillus dominance and increased inflammation - may facilitate viral persistence and integration. However, more mechanistic studies are required to validate these associations and to elucidate the pathways involved.

Currently, no specific antiviral agents are available for the eradication of HPV. Treatment of HPV-related diseases (e.g., genital warts, cervical lesions) remains focused on physical or ablative therapies such as surgery, cryotherapy, or chemical cauterization [36]. Although prophylactic HPV vaccines are available, they are most effective before sexual debut and are not therapeutic for existing infections. Moreover, access and affordability are significant barriers in many low- and middle-income countries [6, 42, 43]. These gaps underline the urgent need for effective, accessible, and low-toxicity antiviral strategies for HPV management [44].

Limitations

This study has certain limitations. The sample size was relatively small and derived from a single center, which may affect the generalizability of the findings. In addition, six partici-

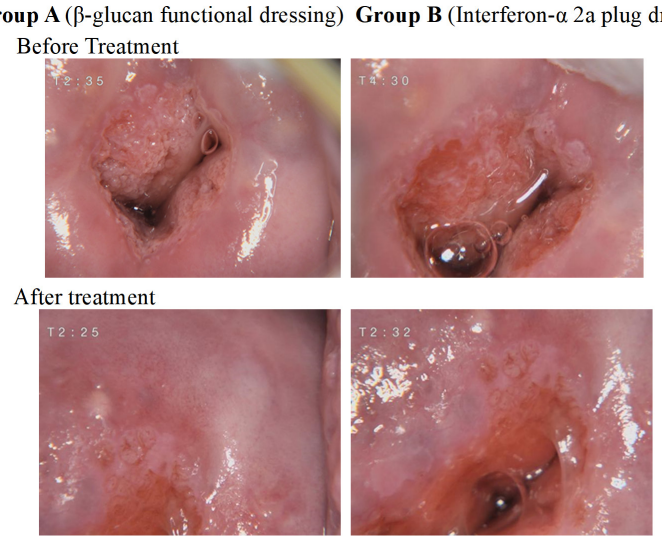

Figure 7. Colposcopy images showing the occurrence of low-grade squamous intra-epithelial lesion (LSIL) in Group A and Group B before and after treatment. Representative colposcopy images demonstrating the presence or regression of low-grade squamous intraepithelial lesions (LSIL) in Group A (β-glucan) and Group B (IFN-α2a) before and after treatment. Post-treatment images show notable lesion regression in Group A, suggesting improved HPV clearance and mucosal recovery.

pants withdrew from the study due to menstrual bleeding during the treatment cycle, which may have introduced some degree of bias. Future studies should aim for multicenter designs, larger sample sizes, and longer follow-up periods to validate and expand our findings.

Conclusion

Both β-glucan functional dressing and interferon-α2a plug were safe and well-tolerated, effectively improving vaginal microecology and reducing HPV infection. However, β-glucan dressing showed superior outcomes in enhancing Lactobacillus abundance, reducing pathogenic bacteria, and achieving a higher HPV-negative conversion rate. These findings suggest that β-glucan may be a more effective option for managing HPV-related gynecological infections.

Disclosure of conflict of interest

None.

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