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Potential Use of *Lactobacillus gasseri* G10 Isolated from Human Vagina along with Intrauterine Devices (IUD) to Prevent Pathogen Colonization

Büşra AKTAŞ *[1]

Abstract

Intrauterine devices (IUDs), well effective long-term contraception methods used around the world, are potential reservoir for pathogens and carry risk of reproductive-tract infections such as bacterial vaginosis and vulvovaginal candidiasis. A healthy vagina is dominated by *Lactobacillus* involved in protecting reproductive system against pathogens. This study aims to investigate the impact of *L. gasseri* G10 (G10), a vaginal isolate, and its Exopolysaccharide (EPS) on adherence of *Staphylococcus aureus* and *Candida albicans* to IUD-tail. Three conditions were simulated to examine if G10 with/without EPS is capable of displacing, excluding, and competing pathogen adhesion to IUD. Inhibitory impact of EPS at various concentrations on pathogen adherence was also evaluated with co-incubation. G10 blocked by co-incubation (97%) and displacement (46%) of S. aureus adherence to IUD tail and displaced *C. albicans* attached to IUD with about 99%. Compared with *S. aureus*, the biofilm formation by *C. albicans* was highly susceptible to EPS. All concentrations of EPS inhibited the adherence of *C. albicans* (81-97%); however, no significant reductions were observed in *S. aureus* adherence. Moreover, G10 and EPS together reduced the adherence of both *S. aureus* (>99%) and *C. albicans* (94-98%) through all three mechanisms. This study indicates that G10 and its EPS have the ability to inhibit adhesion of *S. aureus* and *C. albicans* to IUD and potential use in intravaginal products to prevent/manage IUD associated infections in women. The results suggest development of a new way of applying IUD along with probiotic agents alone or as synbiont.

Keywords: *Lactobacillus gasseri*, intrauterine devices (IUD), *Staphylococcus aureus*, *Candida albicans*, vaginal probiotics

1. INTRODUCTION

The intrauterine device (IUD) is one of the long term reversible contraception methods, which found to have the lowest failure rate of among other contraception methods which is less than 1% [1]. IUD has been used commonly around the world especially in less developed regions and easy to access in most of the countries [2, 3]. Copper-releasing IUDs with T-shaped frame is one of the frequently used IUD choice for women which last more than 10 years [4]. Since it is a long term contraception method, IUD use has

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raised concern for decades as a potential risk for infections in reproductive and urinary system [5], [6].

During IUD use, IUD has been colonized by anaerobic and aerobic bacteria and change the genital tract microbiota, which then may increase the prevalence of genital tract infection [7–9]. 9% of the bacterial species that human body hosts are associated with the urogenital tract [10]. A disruption in the well-balanced relationship between the genital microbiota and the host immune system maintaining homeostasis in healthy urogenital system can lead to health problems in genital tract such as persistent infection and cervical cancer [11]. Microbiota studies on women with IUD have been shown that IUD is associated with bacterial vaginosis and cervical infection [8, 12, 13]. Additionally, inflammatory infiltrates including leukocytes counting in cervical samples collected from women using copper IUD and control group of women not using contraception was found to be significantly more frequent in women with IUD compared to the control [12].

Bacterial vaginosis is a common dysbiosis in vagina of women at reproductive age [14]. It is characterized by replacement of lactobacilli with opportunistic bacteria and has found to be associated with adverse health problem including sexually transmitted diseases, preterm delivery, intrauterine infection and pelvic inflammatory disease. No matter when the genital tract infection occurs, either before IUD insertion or after the insertion, IUD is a potential reservoir for pathogen microorganisms including *Escherichia coli*, *Candida* spp., *Staphylococcus aureus* and *Pseudomonas aeruginosa*, which then could lead to antibiotic resistance and persistent infections in IUD users [8, 15–18]. Although toxic shock syndrome has been rarely seen due to IUD use, a few cases has been reported [19–21].

Vaginal dysbiosis may also lead to yeast infection such as vulvovaginal candidiasis which is considered the most common cause of vaginitis after bacterial vaginosis [22–24] . Most of the cases are originated by *Candida albicans* strains [22, 25]. IUD use as contraception method also has found to be associated with vulvovaginal candidiasis due to biofilm production by candida species [22, 26–30]. It has been reported that the presence of a foreign object such as cervical sutures or IUD seems to be the most crucial risk factor for the congenital systemic candidiasis and early preterm birth [31]. Studies reported that *C. albicans* are capable of adhering strongly to the different parts of IUD including copper head and the tail, which attached the most, and produce biofilm on IUD [26, 29, 32].

A healthy genital tract is usually dominated by *Lactobacillus* which one of the main genera commonly used as probiotics [33]. *Lactobacillus* lower the risk of infection and improve vaginal health. One of the species primarily found in the vaginal microbiota is *L. gasseri*, which are several health benefits attributed to its cells and cell fractions including protecting respiratory and reproductive system against pathogens and improving immune system [33–35]. In a double-blind, randomized, placebo-controlled study, 100 of women with bacterial vaginosis were received a vaginal cream containing clindamycin followed by a vaginal capsule containing 2 lactobacilli strains from *L. gasseri* and *L. rhamnosus* at $10^{8\text{-}9}$ CFU/capsules for 10 days during 3 menstrual cycles [36]. Probiotic treatment showed a 65% cure rate compared to the control with 46% and women treated with lactobacilli remained free of bacterial vaginosis at the end of the 6-month follow up. In a study including twenty women with candida vulvovaginitis, a probiotic gel with 3 selected lactobacilli strains was applied for 10 days [25]. Around 45% of the women with acute candida vulvovaginitis were treated successfully and they suggested that this lactobacilli mix can be used as an antimycotics adjuvant or as a preventive agent in patients with recurrent vulvovaginal candidosis. Parolin et al. explored the functionality of vaginal lactobacilli strains isolated from healthy premenopausal women against different *Candida* spp. adhered to HeLa cells [37]. The results of exclusion, competition, and displacement assays showed that *L. gasseri* strains were the most effective ones in reducing pathogen adhesion to the HeLa cells. In another study, vaginal lactobacilli have found to inhibit the attachment of *S. aureus*, which is an urogenital pathogen, to the vaginal epithelium cells [38].

Moreover, *S. aureus* infection and adherence to surgical implants have been inhibited by *L. fermentum* RC-14 in a rat model [39].

Previously our research group screened *L. gasseri* strains isolated from a healthy human vagina, and their EPSs for their impact on cervical cancer cell growth and immune response in addition to their adhesion capability to the HeLa cells [11]. *L. gasseri* G10 was the most adhesive strain and found to inhibit the cell proliferation of HeLa cells with the impact of EPS. In this study, we explored the potential use of *L. gasseri G10* and its EPS either alone or together as synbiont along with IUD and examined its inhibitory effect on both *S. aureus* and *C. albicans* with competition, exclusion, and displacement assays.

2. MATERIALS AND METHODS

2.1. Microbial strains and culture conditions

Previously described *L. gasseri* G10 (G10) isolated from a healthy human vagina was used in this study [40, 41]. Stock cultures were maintained at -30°C in de Man, Rogosa and Sharpe (MRS) broth (Merck, Germany), with 10% (v/v) glycerol. Working cultures were prepared from frozen stocks by 2 sequential transfers in MRS broth and incubations were carried out at 37°C for 24 h and 18 h, respectively. The culture was harvested by centrifugation at 3006 x g for 15 min at room temperature. The pellet was re-suspended in 0.9% NaCl (w/v) and the optical density at 600 nm (OD600) was determined. A volume of washed cells (based upon the OD600) sufficient to yield a 25 mL-cell suspension was harvested by centrifugation at 3006 x g for 15 min and washed with 0.9% NaCl. The resulting pellet was suspended in 25 mL of brain-heart infusion (BHI) (Neogen, UK) to obtain a final concentration of ~10^8 CFU/mL. Similarly, stock cultures of pathogen strains including *C. albicans* 10231 and *S. aureus* ATCC 6538, were maintained at -30°C in Malt Extract (Merck, Germany) and Tryptic Soy Broth (Merck, Germany), respectively, with 10% (v/v) glycerol. Working cultures were prepared from frozen stocks by 2 sequential transfers in broth medium and incubations were conducted at 37°C for 24 h and 18 h, respectively. The culture at early stationary phase was harvested by centrifugation at 3006 x g for 15 min at room temperature. The pellet was re-suspended in 0.9% NaCl (w/v) and the optical density at OD600 for *C. albicans* and at OD595 for *S. aureus* were determined. The pellets were washed twice with 0.9% NaCl and finally resuspended in BHI at a concentration of ~10^6 CFU/mL. The final culture solution of G10, *S. aureus* and *C. albicans* was enumerated on MRS, Mannitol Salt, and Malt extract agar, respectively, to confirm the concentration.

2.2. Isolation and lyophilization of exopolysaccharide

The method of Frengova et al. was followed to isolate G10 EPS [42]. The growth culture was heated at 100°C for 15 min. After cooling, the cell suspension was treated with 17% (v/v) of 85% trichloracetic acid solution and centrifuged at 16000 x g for 20 min to remove cells and proteins. The exopolysaccharide was precipitated using one volume of cold absolute ethanol followed by centrifugation at 16000 x g for 15 min. The exopolysaccharide was precipitated using 2 volume of cold absolute ethanol followed by centrifugation at 16000 x g for 15 min. The resulting pellet containing EPS was suspended in deionized water. The EPS isolated was lyophilized in Christ Alpha 2–4 freeze dryer (Marin Christ Co. FL, USA). The freeze-dried EPS powder was stored at 4°C.

2.3. Inhibition of *Staphylococcus aureus* and *Candida albicans* adherence to IUD tails by *Lactobacillus gasseri* G10

Tail of a commercially available IUD (T380A) was aseptically cut into 1 cm-pieces to use in adherence assays. Three different procedure was used to evaluate the ability of G10 to inhibit the adherence of *S. aureus* and *C. albicans* to IUD tail including exclusion, competition, and displacement assays. In the competition or co-incubation assay, G10 was added simultaneously with the pathogens to each well of a sterile 24-well plates (SPL life Science, Korea) containing 1 cm-piece of IUD tail and incubated in BHI at 37°C for 24h. In the displacement assay, *S. aureus* or *C. albicans* was initially incubated for 24 h at

37°C in BHI with 1 cm IUD tail sample. Then, non-adherent cells were removed from the tail by gently washing with 0.9% NaCl (w/v) 2 times. Precoated tails with pathogens were immediately inoculated with G10 and incubated at 37°C for another 24h. In the exclusion assay, G10 was initially incubated for 24 h at 37°C in BHI with 1 cm IUD tail sample. Then, non-adherent cells were removed from the tail by gently washing with 0.9% NaCl (w/v) 2 times. Precoated tails with G10 were immediately inoculated with *S. aureus* or *C. albicans* and incubated at 37°C for another 24h. The inhibitory activity of G10 was evaluated by enumerating the viable cells adhered on the IUD tail. After the plates were incubated at 37°C for 24 h, the samples were placed into a sterile 24-well plate and gently washed with 0.9% NaCl (w/v) 2 times to remove loosely adherent bacterial cells. The samples were then placed in 1 mL of 0.9% NaCl (w/v) and vortexed vigorously for 2 min to remove bacteria adhered to the IUD tail surface. Vortexed solution was enumerated by plate count on the MRS, Mannitol Salt, or Malt extract agar. Cultures of *S. aureus* and *C. albicans* incubated with the tail alone were used as control. Each enumeration was performed in triplicate and the assay experiments were carried out in 4 replicates.

2.4. Inhibition of *Staphylococcus aureus* and *Candida albicans* adherence to IUD tails by lactobacilli EPS or live cells + EPS

EPS isolated from G10 was dissolved in BHI and filter sterilized (0.2 μm). Inhibitory impact of EPS of G10 on *S. aureus* and *C. albicans* was evaluated with co-incubation assays. EPSs at various concentration (500, 750, and 1000 μg/mL) were added simultaneously with *S. aureus* and *C. albicans* to each well of a sterile 12-well plates containing 1 cm-piece of IUD tail and incubated at 37°C for 24h. Additionally, synbiotic effect of EPS at 750 μg/mL and live G10 cells was evaluated with exclusion, competition, and displacement assays as described above.

2.5. Statistical analysis

Statistical differences of the bacterial adhesion were assessed with the Each Pair Student's Test using JMP version 12 (SAS Institute Inc., Cary, NC) and were presented as the mean ± SEM. Statistical difference was determined at a P value of 0.05 or less.

3. RESULTS

3.1. *Lactobacillus gasseri* G10 mediated inhibition of *Staphylococcus aureus* and *Candida albicans adherence* to IUD tails

IUD acts as a microbial reservoir and induces microbial infection and biofilm formed by these microorganisms, it, therefore, has been thought to be one of the main reason of persistent infection in IUD users [17]. *S. aureus* and *C. albicans* are among the predominant pathogens found to be associated with IUD [15–17, 26, 43]. Since the tail of IUD serves as a bridge between external environment and vagina, we investigated the impact of *L. gasseri* G10 isolated from a healthy woman vagina, on adherence of *S. aureus* and *C. albicans* to IUD tail. The ability of *L. gasseri* G10 to inhibit *S. aureus* and *C. albicans* adhered to IUD was evaluated with exclusion, competition, and displacement assays by enumerating the number of bacteria on the tail surface. As shown in Fig. 1, the vaginal lactobacilli G10 was able to prevent the adherence of *S. aureus* and *C. albicans* at different extents via competing or displacing. G10 cells had no statistically significant inhibitory effect on any of the pathogen strains studied via exclusion. *S. aureus* is one of the organisms predominantly associated with biofilms formed on IUDs especially during long term use [15, 17, 18]. There was a significant reduction ($P<0.05$) in *S. aureus* cells adhered to IUD with the exposure of lactobacilli strain. G10 blocked by co-incubation and displacement 9% and 46% of *S. aureus* adherence to IUD tail, respectively. The greatest inhibition of *S. aureus* adhesion was produced when *S. aureus* was added together with G10 (competition). On the contrary, there was no significant reduction in the adhesion of *S. aureus* with G10 under the condition of exclusion. After bacterial vaginosis, vulvovaginal candidiasis is one of the most common microbial vaginitis and *C. albicans* is the most common cause [24]. *C. albicans* also have found to be associated with IUD infection [32]. The impact of vaginal lactobacilli G10 on *C. albicans* adherence

to IUD tail was evaluated and the results showed that G10 displaced the candida attached to IUD significantly ($P<0.05$) with more than 2 logs, corresponding to about 99% inhibition [44].

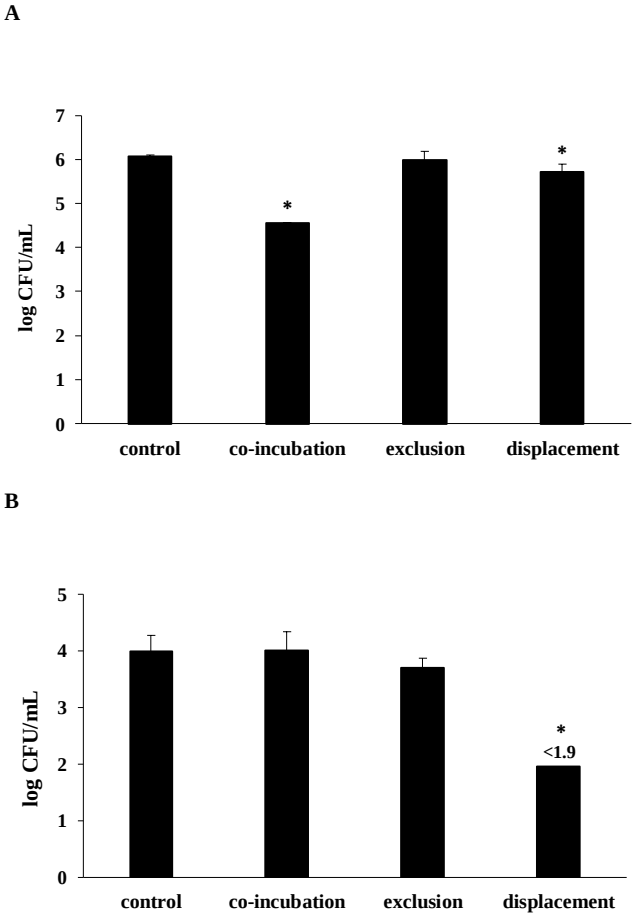

Figure 1 Inhibitory abilities of *Lactobacillus gasseri* G10 against *Staphylococcus aureus* 6538 (A) and *Candida albicans* 10231 (B). Log reduction in pathogenic cells adhered to IUD tail was calculated after competition, exclusion, and displacement with *L. gasseri* G10 and compared with *S. aureus* 6538 or *C. albicans* 10231 adherence alone. **P<0.05*: significant differences from the control

3.2. Lactobacilli EPS mediated inhibition of *Staphylococcus aureus* and *Candida albicans* adherence to IUD tails

Not only live cells but also polysaccharides produced by lactobacilli have found to be capable of inhibiting both biofilm production and growth of pathogens [45]. Moreover, combining live cells with polysaccharides as prebiotics may increase the probiotic effect [46]. To investigate the contribution of EPS on inhibition of urogenital pathogens, we co-incubated the pathogens together with the EPSs produced by G10 at various concentrations (500, 750, and 1000 µg/mL) and enumerated the number of bacteria on the tail surface. Additionally, we performed exclusion, competition, and displacement assays with the EPS at 750 µg/mL together with the live cells of G10 to evaluate the synbiotic effect on adherence. The results showed that G10 EPSs at all concentrations tested inhibited the adherence of *C. albicans* on IUD significantly ($P<0.05$) as seen in Fig. 2; however, no significant reductions were observed in the number of staphylococcal cells when co-incubated with G10 EPS (data not shown). Compared with *S. aureus*, the biofilm formation by *C. albicans* was highly susceptible to G10 EPS. Reduction of candida adherence by G10 EPS was significantly high with 97, 95, and 81% at the concentration of 500, 750, and 1000 µg/mL, respectively.

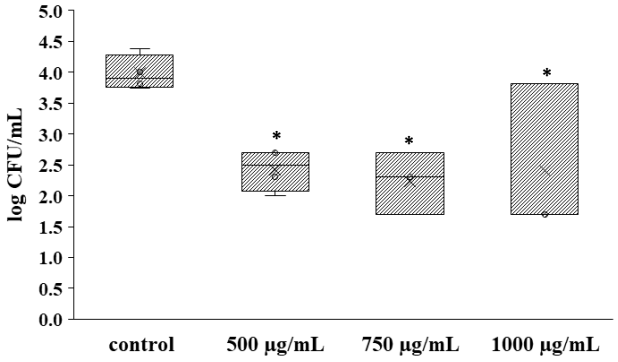

Figure 2 Inhibitory abilities of EPS isolated from *Lactobacillus gasseri* G10 against *Candida albicans* 10231. Log reduction in pathogenic cells adhered to IUD tail was calculated after co-incubation with EPSs at varying concentration which are 500 µg/mL, 750 µg/mL, and 1000 µg/mL and compared with *C. albicans 10231* adherence alone. **P< 0.05*: significant differences from the control

Moreover, a large reduction in adherence of both *S. aureus* and *C. albicans* through all 3

mechanisms were observed when G10 was added together with its EPS. The synbiotic impact of G10 and EPS on the adherence of *S. aureus* and *C. albicans* inhibition are shown in Fig. 3. G10 and EPS together caused about 3-log reduction and significantly ($P<0.05$) reduced the adhesion of *S. aureus* with more than 99% (Fig. 3). Co-incubation with G10 and EPS resulted in a 2-log reduction in the number of adhered *C. albicans* CFU ($P<0.05$). This was followed by about a log reduction in adherence with exclusion and displacement (Fig. 3). G10 and EPS together have a synbiotic inhibitory impact on candida adherence to IUD with 98, 90 and 94% reduction through co-incubation, exclusion, and displacement, respectively.

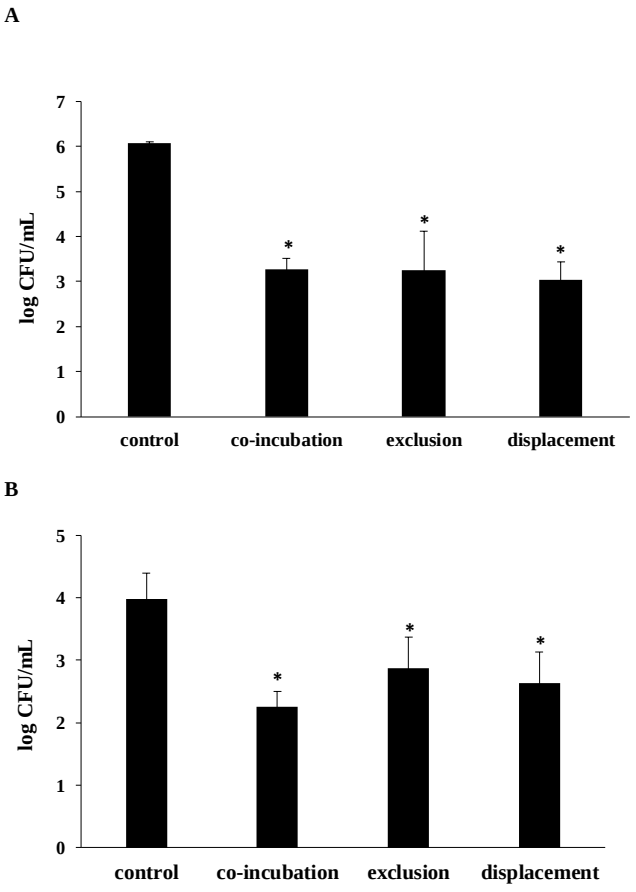

Figure 3. Synbiotic inhibitory effect of *Lactobacillus gasseri* G10 with EPS against *Staphylococcus aureus* 6538 (A) and *Candida albicans* 10231 (B). Log reduction in pathogenic cells adhered to IUD tail was calculated after competition, exclusion, and displacement with *L. gasseri* G10 together with EPS and compared with *S. aureus* 6538 or *C. albicans 10231* adherence alone. **P<0.05*: significant differences from the control

4. DISCUSSION

Various bacterial genera have been detected in vaginal microbiota and a healthy vaginal microbiota is dominated by *Lactobacillus* spp. including *L. crispatus*, *L. gasseri*, and *L. iners* [47]. Studies showed that replacement of *Lactobacillus* spp. in the vaginal microbiota with potential pathogens such as *Staphylococcus* spp., has been associated with vaginal dysbiosis resulting bacterial vaginosis and vaginitis [48]. The vaginal mucosa is populated by both bacteria and fungi, which normally exist together in a balance. When this balance breaks, the ecological state of vaginal microbiota may turn into a pathological state. Another common infection caused by vaginal dysbiosis is *Candida* spp. associated infections. Vulvovaginal candidiasis, a symptomatic vaginitis, affect around 75% of reproductive age women at least once in their lifespan [49].

Studies showed that *Lactobacillus* spp. have an antimicrobial impact on growth of *S. aureus*, which may cause toxic shock syndrome by colonizing and producing biofilm on intravaginal products, and *C. albicans* in addition to preventing their attachment to vaginal epithelium [21, 38, 50]. Ten different lactobacilli strains have been evaluated for development of vaginal tablets used to treat vaginal infections as replacement for antibiotics [51]. One of the best lactobacilli strains they chose for the preparation of vaginal tablets was belonging to *L. gasseri* which adhered to epithelial cells better and displaced the vaginal pathogens. In another study on biosurfactant produced by *L. brevis*, they showed that lactobacilli biosurfactant has the ability to slow down the adhesion of *C. albicans* to silicone surfaces and reported that lactobacilli metabolites are promising as antiadhesive coating products to prevent medical device associated fungal infection [52].

The presence of IUDs supplies a solid surface for microbial attachment and an ideal environment to grow and form biofilm. Although vaginal lactobacilli strains have been studied commonly for their probiotic effect, their application on intravaginal products are limited such as ability to adhere to the vaginal products and impact on

vaginal pathogens colonized on intravaginal devices [33–35]. Here we showed that a vaginal isolate *L. gasseri* G10 studied previously for their probiotic potential is capable of inhibiting adherence of vaginal pathogens including *S. aureus* and *C. albicans* on IUD and have a potential for alternative application with devices used in reproductive system. In an old study, IUDs in 2-year use were removed from 6 women with signs for neither uterine nor cervical infection to detect bacterial colonization and they revealed that microbial biofilms exist on prosthetic devices consisting of indigenous microorganisms with no symptom of an infection [53]. Moreover, they tested the attachment of *L. acidophilus*, *L. casei,* and *L. fermentum* strains to IUD and urinary catheters within 24h. They found that lactobacilli strains adhered to the surface of prosthetic devices in a strain-dependent manner and pointed out the clinical importance of lactobacilli having potential to prevent onset of infection. Similarly, in another study, the impact of *Lactobacillus* strains on the adhesion of *S. aureus* and *C. albicans* on urinary catheter were examined [54]. They showed that co-presence of lactobacilli significantly reduced the *S. aureus* adhesion and *C. albicans* adhesion was significantly reduced in presence of *S. aureus* and suggested that lactobacilli could be used as displacement agent in urinary catheters. Anti-biofilm effect of lactobacilli strains on *S. aureus* have been shown in different studies [55]. *L. brevis* strains recovered from milk tanks were tested for their inhibitory effect on biofilm formation by pathogenic microorganisms recovered from the milk tanks including the *S. aureus* on stainless steel surfaces [56]. They reported 5 *L. brevis* strains restricted the *S. aureus* adhesion on abiotic surfaces and suggested to use as natural barrier in the food processing sector.

Vaginal isolate G10 was able to displace the attached *S. aureus* on IUD tail and decreased the adherence with 46%. Moreover, the reduction in *S. aureus* adherence was 97% when they co-incubate together. The results suggest that the presence of G10 cells could not only inhibit the initial adherence of *S. aureus* but also suppress the development of a mature biofilm.

It has been reported that IUD use increases the risk of vulvovaginal candidiasis since candida species are capable of adhering to medical devices and promote reoccurrence over time [22], [23]. Candida cells have been shown to adhere strongly to the different parts of IUD including the tail [29]. Although different parts of the IUD promote yeast to stay in the genital tract, the tail is the part where *C. albicans* and non-albicans species adhered the most, indicating the tail is the key area for pathogen colonization [32]. Alternative strategies have been tried to prevent biofilm formation by *Candida* spp. on IUDs. Shanmughapriy et al. suggested a combination therapy of tyrosol with amphotericin to inhibit candida biofilm along with IUD use and pointed to need of a future work on such biomaterials to improve IUD devices [57]. While the combined inhibitory effect of tyrosol and amphotericin was 90%, individual inhibition was around 50%. Vaginal lactobacilli G10 showed a significant reduction in the *C. albicans* adherence with 99% by displacing the previously attached pathogen.

Studies showed that not only the live lactobacilli cells but also cell free supernatant or a specific metabolite could have inhibitory effect on growth of pathogens or biofilm production on a surface [37, 45, 55]. In another study, cell-free supernatant of *L. acidophilus* and *L. casei* strains have shown to inhibit the growth of *S. aureus* and remove the biofilm produced by *S. aureus* on polystyrene and glass surfaces in a species and concentration dependent manner [55]. EPS is one of the bacterial metabolites helping lactic acid bacteria to have a good adherence capability to host epithelial cells and to exhibit antimicrobial activity on pathogens [45, 58, 59]. Released EPSs produced by *L. acidophilus* strain have found to hamper biofilm production by a wide range of Gr (+) and Gr (-) pathogens [45].

Here in this study, although EPS from vaginal *L. gasseri* G10 alone had no inhibitory effect on *S. aureus* cell attachment to IUD, there was 97% reduction in *C. albicans* adherence to IUD when they were co-incubated with EPS. However, inhibitory impact on vaginal pathogens was much higher when EPS and live cells applied together. While synbiotic inhibitory effect of G10 with its

EPS on candida adherence to IUD ranged from 94% to 98%, G10 and EPS together reduced the *S. aureus* adherence with more than 99% showing that G10 has a high inhibitory impact on pathogen adherence to IUD with its EPS together. Combination of probiotics and prebiotics is called synbiotics and studies showed that synbiotics may confer better health benefit compared to the application of a probiotic alone and increase the adhesion capability of probiotics [46].

A few different mechanisms have been described for construction of multicellular clusters. Studies suggest that cells normally clusters mature and organize larger microcolonies to form biofilms; however, in the presence of a bacterial metabolites as antimicrobial agent, these organized microcolonies are reduced due to modified cell surface and decreased cell to cell surface interactions [45]. Cell surface hydrophobicity is one of the factors involving in cell adhesion and affecting the autoaggregation, coaggregation, and biofilm formation ability of a strain [60]. Previously, G10 was shown to have a high autoaggregation ability and coaggregates with *C. albicans* strongly, indicating to have a lower hydrophobic surface [40, 41]. Additionally, Kim et al. investigated the inhibitory impact of released EPS from *L. acidophilus* on biofilm formation by *E. coli* and performed a transcriptomic analysis [45]. Interestingly, they found that lactobacilli EPS decreased the expression of curli production genes involved in the attachment and biofilm formation of *E. coli* strains and chemotaxis gene. They suggest that EPS has the ability to control biofilm formation via regulation of biofilm associated virulence factors in pathogens. Quorum-sensing molecules are also involved in regulation of the biofilm production and metabolites produced by probiotics such as EPSs are able to diminish the quorum signals produced by pathogens that are essential for biofilm formation [45], [46].

5. CONCLUSION

IUD is one of the effective long-term contraception method commonly used around the world, serving as reservoir for pathogens and carries risk of reproductive tract infections such as bacterial vaginosis and vulvovaginal candidiasis. Probiotic lactobacilli strains have been studied commonly for their probiotic impact; however, their ability to adhere and compete with vaginal pathogens and their application on intravaginal products are limited, although bacterial adhesion to abiotic materials such as suture and prostheses have been the study objects for many researchers. Alternative way of probiotic delivery through female hygiene or intravaginal products have been getting attention recently. In view of potential application of the vaginal isolate *Lactobacillus* strain as vaginal probiotics, we explored the potential use in intravaginal products such as IUD to prevent or manage IUD associated urogenital tract infections in women. The results showed that both G10 and its EPS either alone or together as synbiont have a clear inhibitory effect on urogenital pathogen adherence to IUD and have a potential for alternative use with devices for reproductive system.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

Authors' Contribution

The author contributed100% to the manuscript.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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