Lasers in Medical Science (2019) 34:921–927
https://doi.org/10.1007/s10103-018-2678-3

ORIGINAL ARTICLE

Blue light-emitting diode in healthy vaginal mucosa—a new therapeutic possibility

Maria Clara Pavie[1,2] · Mariana Robatto[1,2] · Milena Bastos[1] · Sibele Tozetto[1] · Andrea Vilas Boas[1] · Salvatore Giovanni Vitale[3] · Patrícia Lordelo[1,2]

Received: 13 June 2018 / Accepted: 30 October 2018 / Published online: 7 November 2018

Abstract

A healthy female genital mucosa has an ecosystem that remains in balance through interactions between endogenous and exogenous factors. The light-emitting diode (LED) is a device that emits light at different wavelengths, with varying color and effects. Blue light in humans is most commonly used for antimicrobial purposes and has been already applied to treat facial acne and gastric bacteria. Although blue LED therapy in humans has been reported, its properties against vaginal infections have not yet been investigated. This study aims to test the safety and effects of 401 ± 5 nm blue LED on healthy vaginal mucosa. Phase I clinical trial involving 10 women between 18 and 45 years old with healthy vaginal mucosa. The participants were illuminated by 401 ± 5 nm blue LED for 30 min and anamnesis, oncotic cytology, and pH measurement were made again after 21/28 days of treatment. In the re-evaluation, adverse effects were investigated. The mean age was 27 ± 5.4 years and one of the women was excluded due to interruption of use of oral contraceptives. Oncotic cytology done before and after therapy showed that the composition of the microflora remained normal in all participants. Vaginal pH remained unchanged in eight of the women and had a reduction in one woman (5.0–4.0). No adverse effects were observed during or after illumination. 401 ± 5 nm blue LED did not generate any adverse effects or pathogenic changes in the microflora and vaginal pH. The effects of 401 ± 5 nm blue LED still need to be tested in vulvovaginal pathogens. Trial registration number: NCT03075046

Keywords Vulvovaginitis · Microflora · Light-emitting diode (LED) · Blue light · Phototherapy

Introduction

The female genital mucosa presents an ecosystem that remains in balance through the interactions between vaginal microflora, products of microbial metabolism, hormonal conditions, and immune response. Vaginal health depends on the interaction between endogenous and exogenous processes. The microflora, through its defense mechanisms, represents one of the main factors responsible for maintaining normal vaginal physiology [1, 2].

Different species of microorganisms considered pathogenic or nonpathogenic are part of the vaginal microflora [3]. The main bacteria present in healthy vaginal mucosa are *Lactobacillus* sp., the producer of lactic acid which is responsible for maintaining the vaginal pH acid. In turn, this pH causes the vaginal environment to become inhospitable for pathogens [2, 4, 5]. Besides this organic acid, lactobacilli also produce hydrogen peroxide and bacteriocins that are capable of inhibiting or destroying potentially harmful microorganisms [4]. Several factors such as hormonal variations, sexual activity, and use of medications may alter the composition of the vaginal microflora, causing an imbalance in the system and consequent predisposition to infections in the genital tract [2].

Light-emitting diode, commonly known as LED, is a semiconductor device that, through the process of electroluminescence, generates light emitted at different wavelengths,

✉ Patrícia Lordelo
pvslordelo@hotmail.com

[1] Bahiana School of Medicine and Public Health, Av. Dom Joao VI, 275, Brotas, Salvador, Bahia 40290-000, Brazil

[2] Center for Care of Pelvic FLoor, Av. Dom Joao VI, 275, Brotas, Salvador, Bahia 40290-000, Brazil

[3] University of Messina, Italy, Piazza Pugliatti, 1, 98122 Messina ME, Italy

causing a differentiation also in color and effects [6, 7]. LED has several therapeutic applications in view of its including antimicrobial action and potentiating effects on cellular proliferation and cicatrization [7, 8].

Most studies with blue light report its antimicrobial use. Phototherapy has already been used to destroy bacteria in the human skin and gastric mucosa without thermal effect or damage to local cells, which points to the possibility of a treatment with minimal adverse effects [9–11]. Blue LED has also been used in the treatment of recurrent vulvovaginal candidiasis without causing adverse effects [12].

Although the therapeutic efficacy of blue LED in humans and its curative properties against vaginal infections have been reported in a case report, it is necessary to test the safety of the technique in order to start the next stages of the study. This calls for the need to carry out extensive research. Thus, we carried out a phase I study with the objective of testing the safety and effects of 401 ± 5 nm blue LED on healthy vaginal mucosa.

Study design

The study was approved by the Ethics Committee of the Federal University of Recôncavo da Bahia (UFRB) through CAAE: 56391416.1.0000.0056, and is in accordance with the standards established by the Declaration of Helsinki. The Clinical Trials registration number is NCT03075046.

This is a phase I clinical trial, of a descriptive nature, developed in a gynecological clinic in Salvador, Brazil, from April to June 2017. Asymptomatic women were invited to participate in the study during their routine gynecological consultations. Ten participants aged between 18 and 45 years, with healthy vaginal mucosa and vaginal cytology for cancer presenting normal findings, were included in the study. Women were excluded if they (i) were using medications that could influence the composition of the vaginal microbiota such as antibiotics, corticoids, or immunosuppressants; (ii) had a pacemaker; (iii) changed the contraceptive method they had been using for more than 6 months; (iv) had a neoplasia in the genital area; (v) had amnesia; (vi) were pregnant; and (vii) presented neurological and/or psychiatric disorders.

The sociodemographic data collected included age, body mass index (BMI), history of pregnancy/delivery/abortion, presence of regular menstrual cycle, use of oral contraceptives, frequency of sexual intercourse, use of condoms, use of mini sanitary pads, use of specific products for intimate hygiene; and realization of intimate showers.

The ten participants underwent physical examination in a private environment, always by the same professional. Findings obtained from the examination of the vaginal mucosa determined the participant's eligibility to participate in the study. Women with no signs and symptoms indicating pathologies such as pruritus, pain, burning, dysuria, erythema, fissure, edema, excoriations in the vulva and uterus, and leukorrhea were included. In addition, a potassium hydroxide (KOH) test and fresh cytology with saline solution were used to analyze the composition of the vaginal discharge under optical microscope. In these tests, cells typical of a healthy vagina such as *Lactobacillus sp.* and/or other bacilli should be visualized, as well as absence or rare leukocytes, fungal hyphae and pathogenic bacteria.

After analyzing these data, the participants who met the criteria of normality were referred to the next phase of the study. Vaginal pH was assessed using specific tapes (MColorpHast™, Germany) which were introduced into the vaginal canal for 1 min. Oncotic cytology was performed by collection of vaginal discharge by pap smear, using a spatula and an endocervical brush to collect ecto and endocervial material, respectively. The presence of *Lactobacillus* sp. and/or other bacilli, absence of inflammation or presence of discrete inflammation and absence of cellular atypia were considered as normal pattern.

The blue LED prototype was specifically developed for this study and had a wavelength of 401 ± 5 nm, a power of 30 W and a mean irradiance of 0.000773 W/cm^2. Light was applied to healthy women for 30 min and during application they were in dorsal decubitus with flexed knees, hips in abduction, and feet supported on the stretcher to provide them greater comfort. To avoid discomfort, a small speculum was used in the vaginal canal, and the LED device was statically positioned in front of the vulvovaginal region, from a distance of about 5 cm (Fig. 1).

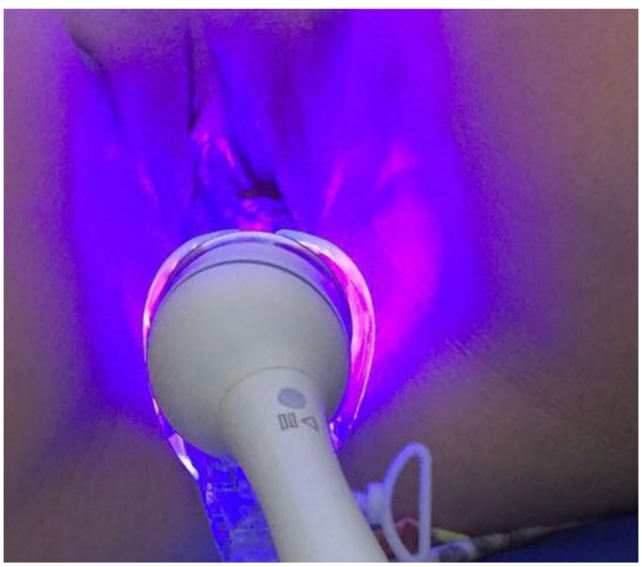

Fig. 1 Application of 401 ± 5 nm blue led with use of speculum in the vaginal canal

Phototherapy was performed by a physiotherapist in a closed environment and the protocol consisted of only one session. Depending on the menstrual cycle of the participants, after an interval of 21 to 28 days they underwent a similar reassessment to investigate the appearance of symptoms such as pruritus, pain, burning, dysuria, erythema, fissure, edema, excoriations in the vulva and uterus, and leukorrhea and to perform tests such as oncotic cytology and measurement of vaginal pH, for later comparative analysis. During this interval of days, the participants were asked to return to the clinic for gynecological consultation in case of appearance of any discomfort or alteration, and if necessary, appropriate referrals would be provided. The women submitted to therapy were questioned about the presence of adverse effects such as heating or pain during and/or after the application of 401 ± 5 nm Blue LED, and the therapist observed whether erythema appeared in the region exposed to light.

In accordance with ethical principles, no sample calculation was performed because this was a phase I clinical trial to test the safety and effects of 401 ± 5 nm Blue LED in healthy vaginal mucosa.

A database was prepared for statistical descriptive analysis using the SPSS (Statistical Package for the Social Sciences) 14.0 (IBM Corporation, New York, USA) and the results were presented in tables. Numerical variables were expressed as means and categorical variables were expressed as absolute values.

Results

Twenty women were initially invited to participate in the study. Among these, ten women were included. The exclusions occurred for the following reasons: four women presented numerous leukocytes and supracytoplasmic bacilli (suggestive of *Gardnerella*/*Mobiluncus* spp.) in the visualization of vaginal discharge through fresh examination and presented positive KOH test with exacerbated odor; two women presented fungal hyphae of *Candida* sp.; and four women presented numerous leukocytes, also visualized under fresh cytology. One of the ten participants included in the study was excluded at the time of reassessment because she reported the interruption of the use of oral contraceptives (OC) (Fig. 2).

Sociodemographic characteristics and gynecological data are shown in Table 1. The mean age of the participants was 27 ± 5.4 years and the mean BMI was 25.25 ± 3.05 kg/m^2. Most women (seven) had a regular menstrual cycle and five reported the use of OC (Table 1).

Regarding life habits, among the five women who were sexually active, three of them reported not using preservatives in sexual intercourse. Most participants did not use specific intimate hygiene products and mini sanitary pads; half of the women reported frequent use of tampons (Table 2).

Cytological data showed that the composition of the normal vaginal microflora was maintained in all participants. No differences were seen in relation to benign cellular alterations and discrete inflammation. In eight of the participants, the vaginal pH was the same in the two assessments and in one of the women there was a reduction of pH from 5.0 to 4.0 (Table 3).

None of the participants reported adverse effects such as heating and pain during or after exposure to 401 ± 5 nm blue LED, and the therapist did not find the appearance of erythema in the exposed area. One of the participants reported discomfort during the passage of the speculum through the vaginal canal; nevertheless this episode was solved after seconds with a better positioning of the speculum in the region.

Discussion

This study is a phase I clinical trial, pioneering the use of the blue LED with a wavelength of 401 ± 5 nm in the healthy vaginal mucosa. There were not pathogenic modifications observed in the short-term evaluation of the vaginal mucosa that received the emission of light. By being a resource with an unknown effect in the vaginal region, it is important to carry out phase I clinical studies, that is, in healthy women to test the safety of the method. However, it should not be forgotten that studies with a larger population and with different characteristics should be performed to ensure the safety of the blue LED on the vaginal mucosa.

The fact that no adverse effects were observed among the participants of this study during or after the application of blue LED can be explained by the fact that this phototherapy is considered non-invasive, athermic, and has superficial

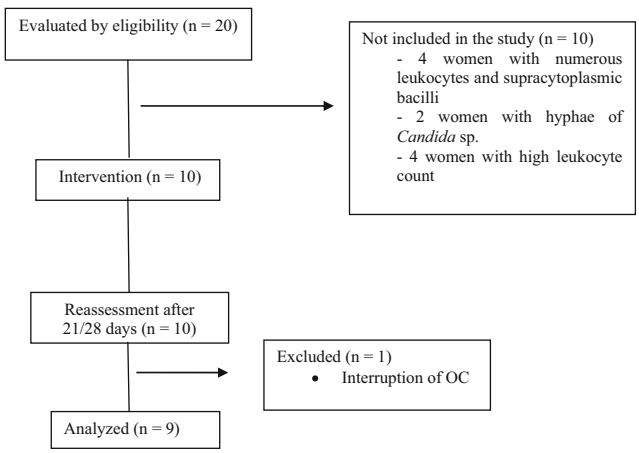

Fig. 2 Flowcharts of randomization recommended by the Consort Statement

Table 1 Sociodemographic characteristics and gynecological data of the study population (Salvador-BA)

SI	Age	BMI	Use of OC	MC	Change or interruption of OC	VV History	G/C/A
1	22	31.2	No	Regular	No	No	0/0/0
2	31	22.4	Yes	Regular	No	No	0/0/0
3	25	28.7	Yes	Absent	No	Yes	0/0/0
4	25	24.7	Yes	Regular	No	Yes	0/0/0
5	22	23.3	Yes	Regular	–	Yes	0/0/0
6	24	24.0	Yes	Absent	No	No	0/0/0
7	21	22.4	No	Irregular	No	No	0/0/0
8	29	27.3	No	Regular	No	Yes	0/0/0
9	36	22.2	No	Regular	No	Yes	0/0/0
10	35	25.9	No	Regular	No	No	0/0/0

SI = sample identification; BMI = body mass index; OC = oral contraceptive; MC = menstrual cycle; OC = oral contraceptive; VV = vulvovaginites; GCA = gestation, childbirth, abortion

penetration. Some studies have already used blue LED in humans in different regions and have demonstrated the absence of adverse effects [10, 12, 13].

In this study, some women were excluded due to the presence of pathogens identified in the KOH test. This can be explained by the fact that in some cases findings considered pathogenic may be present, but they are part of the woman's vaginal flora and do not cause exacerbation of symptoms [14].

Blue LED (405–420 nm) with irradiance ranging from 50 to 200 W/cm^2 was applied in the face of 46 participants with acne and no adverse effects, pain, or discomfort were observed in any of the participants [13]. Likewise, blue light (409–419 nm) with a dose range between 24 and 48 J/cm^2 was used in 30 patients with facial acne and self-limited reactions were observed exclusively on the lesioned sites. Erythema, dry skin, and mild pruritus were observed in 53%, 13%, and 16% of the patients, respectively [15]. These reactions can be explained by the inflammatory characteristics of the lesioned areas and due to the interaction between blue light and the bacteria present in the acne.

In this study, there was no complaint of warming or pain by the participants, nor any changes such as erythema or edema seen by the professional during the physical examination. Only one participant reported discomfort during the passage of the speculum through the vaginal canal. It is believed that this can be explained by the incomplete relaxation of the pelvic floor musculature during the introduction of the device because this complaint is common among women and it is even the justification for the non-performance of periodical gynecological exams. The non-use of lubricants and tension of the pelvic musculature can also explain the discomfort during the passage of the speculum reported by the participant [16, 17].

The mechanism of action of LED involves photobiomodulation, that is, the action on local cells exposed to light to promote activation and regulation of their functions with the minimal possible adverse effects. Furthermore, light at appropriate wavelengths and irradiances is considered benign for use in humans. The use of light has already been approved by the Food and Drug Administration (FDA)

Table 2 Life habits of the 10 women submitted to the application of 401 ± 5 nm blue LED (Salvador-BA)

SI	Sexually active	Male condom	Use of MSP	Sl	Place where underwear is dried	Use of PIH
1	No	–	No	No	Dry	No
2	Yes	Yes	Yes	Yes	Wet	No
3	No	–	No	No	Wet	No
4	Yes	No	No	Yes	Wet	Yes
5	Yes	No	No	Yes	Wet	Yes
6	Yes	No	Yes	No	Dry	Yes
7	No	–	No	No	Wet	No
8	No	–	No	Yes	Wet	No
9	Yes	Yes	No	No	Wet	No
10	No	–	No	Yes	Dry	Yes

IS = identification of the sample; MSP = mini sanitary pads; TP = tampon; PIH = product for intimate hygiene

Table 3 Chemical and cytological data of the study population (Salvador-BA)

SI	pH		Microflora		BCC		Cellular atypia	
	T 1	T2	T1	T2	T1	T2	T1	T2
1	4.0	4.0	LB	LB	MI	MI	Absent	Absent
2	4.0	4.0	LB + OB	LB + OB	MI	MI	Absent	Absent
3	4.0	4.0	LB	LB	MI	MI	Absent	Absent
4	5.0	5.0	LB + OB	LB + OB	MI + AT	MI + AT	Absent	Absent
5	4.0	–	LB	–	MI	–	–	–
6	4.0	4.0	LB	OB	MI	MI	Absent	Absent
7	4.0	4.0	LB	LB	MI	MI	Absent	Absent
8	4.0	4.0	LB	LB	Absent	Absent	Absent	Absent
9	5.0	4.0	LB + OB	LB	Absent	Absent	Absent	Absent
10	4.0	4.0	LB + OB	LB + OB	MI	MI	Absent	Absent

IA = sample identification; T1 = time 1: before illumination with blue light; T2 = time 2: after illumination with blue light; pH = hydrogenionic potential; LB = *Lactobacillus sp.*; OB = other bacilli; BCC = benign cellular changes; MI = mild inflammation; AT = atrophy

[17–19]. These characteristics of LED light can explain why no pathogenic changes occurred in the vaginal microflora of the studied women.

Through the universal photoactivation mechanism, LED light is able to promote cell proliferation, increased ATP production, and increased local vascularization [8, 17]. The participants in this study had a healthy vaginal mucosa and these characteristics remained the same in the reassessment. It is believed that, although local cell activation occurred due to the action of the light, the balance of the vaginal microbiota was maintained and there was no appearance of pathological or atypical changes. Studies involving cytokine analysis and genetic tests such as polymerase chain reaction (PCR) are being conducted to better clarify this hypothesis.

A pilot study including eight individuals with healthy skin found that after use of blue light therapy (380–480 nm) for five consecutive days with a daily irradiance of 20 J/cm^2, there were no pathological modifications in the analyzed samples. Transient melanogenesis was observed in one participant and greater vascularization without consequent apoptosis in all the involved participants, which allowed suggesting that the use of blue light in human skin for a short period of time is safe [20]. Another study performed in symptomatic patients with a diagnosis of *H. pylori* in the stomach region used blue light with an irradiance of 40 J/cm^2 and no adverse effects or histological changes were observed after therapy [10].

Although there are no reports in the literature of the use of vaginal lasers for the treatment of infections, problems such as genitourinary syndrome or urinary incontinence and for promotion of rejuvenation of the region, some of these studies report the appearance of secondary effects of the use of light. LED was chosen in the present study because it presents lower cost, generates less heat, and has more superficial penetration. Furthermore, light output of a laser is punctual; on the other hand, in the case of LED, the light propagates in a divergent way, facilitating the therapy of more extensive areas [21–23].

A study using microablative fractional CO_2 laser in the vaginal region for treatment of genitourinary syndrome showed that there were some mild adverse effects such as irritation and burning sensation in the vaginal introitus that started soon after the therapy and lasted for about 2 h. Another study that also used fractional CO_2 laser in perimenopausal women also indicated that there was immediate discomfort in the vaginal region, characterized by burning, pruritus, altered sensitivity, hematoma, and edema, with resolution of the problem in hours or 1 to 2 days [21, 22]. Such adverse effects were not found in our study with blue LED on healthy vaginas.

A case report was developed with a patient diagnosed with recurrent vulvovaginal candidiasis. The patient was submitted to three blue LED sessions (401 ± 5 nm) in the vaginal region. No adverse effects were reported during or after the use of light and no changes suggestive of malignancy appeared when oncotic cytology exams done before the therapy and 3 months after therapy were compared. The study also pointed out that there were no variations in the composition of healthy vaginal microflora, but the fungus was eliminated. Thus, this light can be used to eliminate signs and symptoms of the disease [12].

In this study, the typical vaginal microflora composition remained the same in all participants, which suggests that 401 ± 5 nm blue LED did not generate risks to healthy vaginal ecosystem balance. Two participants showed a change in the composition of the microflora in relation to the types of bacilli found, but these new findings seen in the reassessment were typical of a healthy vaginal microbiota.

These differences observed in the two participants can be explained not specifically as a change in the types of bacilli found, because they were certainly already present but were

not seen in the first oncotic cytology as they were not the most prevalent at that time. Furthermore, these variations are considered normal because endogenous and exogenous factors can exert direct influence on the composition of the vaginal ecosystem and its consequent fluctuation. It is also known that a healthy vagina can host *Lactobacillus* sp. and other types of bacilli [1, 2, 24].

Sexual intercourse is one of the main factors that can cause physiological fluctuations in the composition of the vaginal microflora. The friction that occurs in the mucosa during the sexual act can cause micro traumas and lead to changes in the local characteristics. The contact of the acidic vaginal mucosa with the semen that is alkaline, or the contact of the mucosa with the chemicals present in condoms can also induce oscillations in the composition of the microbiota [1, 2, 25, 26].

One of the participants who presented a change in the vaginal microflora mentioned the frequent use of specific intimate hygiene products and mini sanitary pads, what can also explain the variations in the composition of the vaginal ecosystem. These products can also in some cases still interfere in the local health [27]. Non-use of OC and the presence of a regular menstrual cycle, which was the case of the other participant, are responsible for promoting hormonal oscillations in the number of days of the menstrual pariod and may interfere with the composition of the vaginal microbiota [1, 2, 4]. In all participants, a discrete inflammation was observed in both assessments and this finding is considered normal and typical of healthy vaginal mucosa [24, 26].

The vaginal pH value of most of the study participants remained the same according to the comparison of the two assessments. One participant presented a reduction of pH (from 5.0 to 4.0). This reduction is considered an adjustment of the vaginal pH, since values lower or equal to 4.5 are considered physiological and protective for the flora, while acid environments are unfavorable to infections by pathogens [5, 25, 28, 29]. No correlations were reported between illumination with 401 ± 5 nm blue LED and pH values, but it is known that the oscillations in vaginal acidity are physiologically normal and are connected to maintenance of the balance of the vaginal flora.

In this study, the reassessment took place after 1 month of the application of LED therapy. However, it is possible that light causes changes in longer periods after application. The time of 1 month was chosen based on studies about LED phototherapy for human skin, where patients were followed for 3, 6, or 18 months after completion of therapy and showed no lesions or changes when reevaluated [12, 30, 31].

Some limitations can be mentioned, namely, (i) the non-verification of the period of the menstrual cycle of the participants in the dates of the assessment, what can be a factor that explains some oscillations observed in the vaginal microflora, and (ii) the non-investigation of blood hormone levels and specific local immunity data of the women, such as assessment of defense cells present before and after light therapy. These variables are being analyzed in clinical studies with patients with other infectious etiologies on blue LED response at 401 ± 5 nm in the female vaginal mucosa.

This study showed that there were no pathogenic changes in the mucosal tissue that received the blue light emission, enabling future studies to investigate the effects of the blue LED of 401 ± 5 nm as a possible alternative for the treatment of vulvovaginal dysfunctions, such as for example, vulvovaginal candidiasis, bacterial vaginosis, and vulvovaginal atrophy since this light has a antimicrobial and regenerative action. However, there is a need for further investigations using the blue LED of 401 ± 5 nm in women with pathologies in the genitourinary tract to verify the effect in these cases. The Research Group involved in the development of this study is currently undertaking new phases of clinical trials to clarify the answer of the female vaginal mucosa to the blue LED of 401 ± 5 nm.

Conclusion

The present study led to the conclusion that the use of 401 ± 5 nm blue LED in healthy vaginal mucosa of young women did not cause pathogenic changes in the composition of the vaginal microflora and pH values. No adverse effects such as pain, heating, or discomfort were observed during or after the use of light in the participants.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the declaration of Helsinki of 1964 and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Zhou X, Bent SJ, Schneider MG, Davis CC, Islam MR, Forney LJ (2004) Characterization of vaginal microbial communities in adult healthy women using cultivation-independent methods. Microbiology 150(Pt 8):2565–2573. https://doi.org/10.1099/mic.0.26905-0
2. Linhares IM, Giraldo PC, Baract EC (2010) New findings about vaginal bacterial flora. Rev Assoc Med Bras (1992) 56(3):370–374
3. Mills BB (2017) Vaginits: beyond the basics. Obstet Gynecol Clin 44:159–177. https://doi.org/10.1016/j.ogc.2017.02.010

4. Cribby S, Taylor M, Reid G (2008) Vaginal microbiota and the use of probiotics. Interdiscip Perspect Infect Dis 2008:256490. https://doi.org/10.1155/2008/256490
5. Miller EA, Beasley DAE, Dunn RR, Archie EA (2016) Lactobacilli dominance and vaginal ph: why is the human vaginal microbiome unique? Front Microbiol 7:1936. https://doi.org/10.3389/fmicb.2016.01936
6. Opel DR, Hagstrom E, Pace AK, Sisto K, Hirano-Ali SA, Desai S et al (2015) Light-emitting Diodes: A Brief review and clinical experience. J Clin Aesthet Dermatol 8(6):36–44 PMC4479368
7. Barolete D (2008) Light-emmiting diodes (LEDs) in dermatology. Semin Cutan Med Surg 27(4):227–238. https://doi.org/10.1016/j.sder.2008.08.003
8. Murdoch LE, McKenzie K, Maclean M, MacGregor SJ, Anderson JG (2013) Lethal effects of high-intensity violet 405-nm light on Saccharomyces cerevisiae, Candida albicans, and on dormant and germinating spores of Aspergillus niger. Fungal Biol [Internet] 117(7–8):519–527. https://doi.org/10.1016/j.funbio.2013.05.004
9. Maclean M, McKenzie K, Anderson JG, Gettinby G, MacGregor SJ (2014) 405 nm light technology for the inactivation of pathogens and its potential role for environmental disinfection and infection control. J Hosp Infect 88(1):1–11. https://doi.org/10.1016/j.jhin.2014.06.004
10. Ganz RA, Viveiros J, Ahmad A, Ahmadi A, Khalil A, Tolkoff MJ et al (2005) Helicobacter pylori in patients can be killed by visible light. Lasers Surg Med 36(4):260–265. https://doi.org/10.1002/lsm.20161
11. Baroni A, De Filipéia A, Oliviero G, Fusco A, Perfetto B, Buommino E et al (2017) Effect of 1064-nm Q-switched Nd: YAG laser on invasiveness and innate immune response inkeratinocytes infected with Candida albicans. Lasers Med Sci 33(5):941–948. https://doi.org/10.1007/s10103-017-2407-3
12. Robatto M, Pavie MC, Tozetto S, Brito MB, Lordêlo P (2017) Blue light emitting diode in treatment of recurring vulvovaginal candidiasis: a case report. Brazilian Journal of Medicine and Human Health 5(4):162–168. https://doi.org/10.17267/2317-3386bjmhh.v5i4.1472
13. Elman M, Slatkine M, Harth Y (2003) The effective treatment of acne vulgaris by a high-intensity, narrow band 405–420 nm light source. J Cosmetic & Laser Ther 5:111–116. https://doi.org/10.1080/14764170310001276
14. Babu G, Singaravelu BG, Srikumar R, Raddy SV, Kokan A (2017) Comparative study on the vaginal flora and incidence of asymptomatic vaginosis among healthy women and in women with infertility problems of reproductive age. J Clin Diagn Res 11(8):DC18–DC22. https://doi.org/10.7860/JCDR/2017/28296.10417
15. Morton CA, Scholefield RD, Whitehurst C, Birch J (2005) An open study to determine the efficacy of blue light in the treatment of mild to moderate acne. J Dermatolog Treat 16:219–223. https://doi.org/10.1080/09546630500283664
16. Hill DA, Lamvu G (2012) Effect of lubricating gel on patient comfort during vaginal speculum examination: a randomized controlled trial. Obstet Gynecol 119(2 Pt 1):227–231. https://doi.org/10.1097/AOG.0b013e3182426275
17. Higgins JA, Smith NK (2016) The sexual acceptability of contraception: reviewing the literature and building a new concept. J Sex Res 53(4–5):417–456. https://doi.org/10.1080/00224499.2015.1134425
18. Inamura T, Tatehara S, Takebe Y, Tokuyama R, Ohshima T, Maeda N et al (2014) Antibacterial and antifungal effect of 405 nm monochromatic laser on endodontopathogenic microorganisms. Int J Photoenergy 387215:7. https://doi.org/10.1155/2014/387215
19. Whelan HT, Smits RL Jr, Buchman EV, Whelan NT, Turner SG, Margolis DA et al (2001) Effect of NASA light-emitting diode irradiation on wound healing. J Clin Laser Med Surg 19(6):305–314. https://doi.org/10.1089/104454701753342758
20. Karu T (1987) Photobiological fundamentals of low-power therapy. IEEE Journal of Quantum Electronics, New York 23(10):1703–1717. https://doi.org/10.1109/JQE.1987.1073236
21. Pitsouni E, Grigoriadis T, Falagas M, Tsiveleka A, Salvatore S, Athanasiou S (2017) Microablative fractional CO2 laser for genitourinary syndrome of menopause: power of 30 or 40 W? Lasers Med Sci 32(8):1865–1872. https://doi.org/10.1007/s10103-017-2293-8
22. Arroyo C (2017) Fractional CO2 laser treatment for vulvovaginal atrophy symptoms and vaginal rejuvenation in perimenopausal women. International Journal of Women's Health 9:591–595
23. Opel DR, Hagstrom E, Pace AK, Sisto K, Hirano-Ali SA, Desai S et al (2015) Light-emitting diodes: a brief review and clinical experience. J Clin Aesthet Dermatol 8(6):36–44
24. Kleinpenning MM, Smits T, Frunt MH, van Erp PE, van de Kerkhof PC, Gerritsen RM (2010) Clinical and histological effects of blue light on normal skin. Photodermatol Photoimmunol Photomed 26(1):16–21. https://doi.org/10.1111/j.1600-0781.2009.00474.x
25. Consolaro MEL, Engler SSM (2012) Citologia clínica cérvico-vaginal, 1° edição edn. Roca, São Paulo
26. Borges S, Silva J, Teixeira P (2013) The role of lactobacilli and probiotics in maintaining vaginal health. Arch Gynecol Obstet 289(3):479–89. https://doi.org/10.1007/s00404-013-3064-9
27. Fashemi B, Delaney ML, Onderdonk AB, Fichorova RN (2013) Effects of feminine hygiene products on the vaginal mucosal biome. Microb Ecol Health Dis 24. https://doi.org/10.3402/mehd.v24i0.19703
28. Bride MBM, Rhodes DJ, Shuster LT (2010) Vulvovaginal atrophy. Mayo Clin Proc 85(1):87–94. https://doi.org/10.4065/mcp.2009.0413
29. Donders GG (2007) Definition and classification of abnormal vaginal flora. Best Practice & Research Clinical Obstetrics and Gynaecology 21(3):355–373. https://doi.org/10.1016/j.bpobgyn.2007.01.002
30. Trelles MA, Allones I, Mayo E (2006) Combined visible light and infrared light-emitting diode (LED) therapy enhances wound healing after laser ablative resurfacing of photodamaged facial skin. Med Laser Appl 21(3):165–175
31. Sasaki GH, Oberg K, Tucker B, Gaston M (2007) The effectiveness and safety of topical PhotoActif phosphatidylcholine- based anticellulite gel and LED (red and near-infrared) light on grade II-III thigh cellulite: a randomized, double-blinded study. J Cosmet Laser Ther 9(2):87–96