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Efficacy of topical moxifloxacin on therapeutic laparoscopy-induced wound healing: a double-blind, randomized clinical trial

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Abstract

Background Wound healing is crucial for maintaining healthy skin and preventing complications. Topical administration is a preferred method for delivering therapeutic medicines at the surgery site, as it is simple, affordable, and does not result in systemic harm or antibiotic resistance. Moxifloxacin (MXF), a broad-spectrum antibiotic with anti-inflammatory effects, seems to be effective against bacteria and accelerates wound healing. This study aims to determine the therapeutic effect of topical MXF on wound healing after therapeutic laparoscopy.

Methods This double-blind clinical trial involved 80 patients with therapeutic laparoscopy-induced wounds, randomly assigned to either 0.5% MXF cream or placebo, 24 h after surgery. The primary outcome was wound healing assessment using the REEDA index. Patients were followed by 1, 3, and 5 days of inclusion.

Results Of the 80 study participants included, 50 were women (62.5%), with the mean (SD) age of the participants being 49.5 (19.8) years in the MXF group and 45.8 (17.8) years in the control group. The severity of redness, oedema, and discharge in the MXF group was significantly lower on the first, third, and fifth days of treatment. The case group showed a significant decrease in ecchymosis from the third day of treatment compared to the control group, and no significant difference was observed in wound approximation rate. Hence, topical MXF therapy yielded a significant decrease in REEDA index MXF (P-Value < 0.0001). No treatment-related serious adverse events occurred in the MXF group vs. the comparator group.

Conclusions The results of the current clinical trial demonstrated that the use of topical MXF could be a potential option to expedite therapeutic laparoscopy-induced wound healing by reducing redness, oedema, ecchymosis, and discharge with a satisfactory safety profile.

Trial registration IRCT20181208041882N5, 25/10/2021 (https://en.irct.ir/trial/46768).

Keywords Wound healing, Moxifloxacin, REEDA, Topical, Surgery

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Background

A wound harms the structure and function of the skin [1]. Healthy skin defends against environmental elements. As a result, after tissue damage, an appropriate wound-healing process is crucial. Surgical wounds are categorized as sensory wounds, typically healing over time. Infection at the surgical site is described as a sudden surface infection that expands within the first 30 days following surgery. The process of healing a wound undergoes the following stages: hemostasis, inflammation, migration, proliferation, and maturation [2–5].

A vital aspect of post-surgery rehabilitation is taking excellent care of surgical wounds. After surgery, wound care ought to help the wound heal quickly, as well as minimize interruption and prevent complications for patients to experience the best functional and cosmetic outcomes [5]. Wound healing takes longer as people get older because of decreased blood flow, a lowered inflammatory response, and an increased prevalence of chronic conditions like diabetes mellitus [6].

Unhealed wounds are a significant global health problem. The prevalence of wound issues is associated with demographic factors and the healthcare system. About 1 to 1.5% of people in wealthy countries experience wounds, accounting for 2 to 4% of their overall healthcare expenses. Taking care of the wound before it worsens can significantly lower the cost of treatment for patients with wound issues [7].

The absence of bacteria at the wound site is vital for effective wound healing, hence, it is crucial to include a proper antimicrobial agent in a wound dressing [8]. Escherichia coli (E. coli), Pseudomonas aeruginosa, and Staphylococcus aureus are the most well-known agents responsible for aggravating wound injury [9, 10]. Due to its simplicity and affordability, topical administration is a preferred way of delivering therapeutic medicines at the site of operation. This method of drug administration seeks to achieve the necessary concentration and efficacy at the targeted spot [11]. Additionally, studies indicate that topical use of antibiotics does not result in systemic harm or the emergence of antibiotic resistance [12].

When given directly to the wound, the broad-spectrum antibiotic MXF, a member of the fluoroquinolone family, is particularly efficient against bacteria. According to research on burn-induced wounds, 0.1% topical MXF reduces inflammation, boosts angiogenesis, and promotes tissue granulation to speed up wound healing [13–15]. MXF produces a good concentration and penetrates muscular tissue, fat, subcutaneous tissue, and inflammatory fluid effectively [16].

This study was conducted to determine the impact of topical MXF on wound healing brought on by therapeutic laparoscopy surgery, taking into account the data on the effect of MXF on the acceleration of wound healing, the physiological problems of the wound, and the aesthetic problems of the damaged skin.

Materials and methods

This was a randomized double-blind controlled clinical trial (IRCT20181208041882N5) aimed to assess the effect of topical MXF cream on therapeutic laparoscopy-induced wound healing in patients with non-perforated appendicitis between 22 November 2021 and 16 May 2022. The study protocol followed the Helsinki Declaration of 1975, revised in 2013. In addition, the medicine used in this project does not have any serious or dangerous side effects, and the patient is not charged more than the usual costs. The study was approved by the ethical committee of Shahid Sadoughi University of Medical Sciences of Yazd (IR.SSU.MEDICINE.REC.1398.080). All study cases were selected from the patients who were referred to the surgery department, Shahid Sadoughi Hospital. Patients over 18 of both sexes who received therapeutic laparoscopy surgery without known allergy to Fluoroquinolones were included. If any of the following criteria were present, the patient would be excluded: patients with a history of heart problems such as bradycardia or myocardial infarction (MI), diabetes mellitus, kidney and liver disorders, rheumatoid arthritis, a history of seizures, and those who were unwilling to enter the study.

Preparation of topical MXF

The oil-in-water cream consisted of triethanolamine, glycerin, propylene glycol, and water as the aqueous phase and stearic acid and petroleum jelly as the oil phase. 0.5% MXF cream was prepared after dissolving 0.5 g MXF powder in aqueous phase and gently mixing at 70 °C for 5 min with the oil phase to form a 100 ml homogeneous dispersion. Placebo cream was prepared with a similar formulation without MXF. About 30 g of each cream was filled into the tubes and stored at 2–8 °C.

Randomization and blinding

Six hours after the surgery, patients received an extensive examination of the study wound and overall health status. Eligible wounds were randomly split into two groups, given 0.5% MXF or control using a random number table.

The first dose of the cream was administered by the nursing staff. All patients were self-instructed to apply the topical cream in their study group three times each day. The wounds were assessed on the 1st, 3rd, and 5th days after the operation. To ensure that the non-pharmacological measures used by the two groups were equivalent, the patients were taught non-pharmacological measures like caring for and cleansing the wound. Note that neither the patient nor the nurse applying the covering is aware of the sort of topical ointment being used.

Oral antibiotics were used as prophylaxis by patients in both groups.

Data collection and outcome measures

We retrieved patient data from the file, including age, sex, underlying illnesses, and medications. Along with the first evaluation at the start of the treatment, the wound's severity was also evaluated on the first, third, and fifth days, depending on factors associated with the wound. Using the REEDA index, which rates the wound's redness (hyperaemia), oedema, ecchymosis, discharge, and approximation of the wound edges (coaptation) to determine how quickly the wound is healing. The faster the wound heals, the lower the combined score of these five markers [17].

Sample size calculation

Considering the significance level of 5%, the test power of 80%, and the standard deviation of the REEDA index (S = 0.75) from the previous study [17], to achieve a significant difference of at least 0.5 units in the mean differences of REEDA score in the intervention group compared to the control, a number of 36 people in each group is needed using the following sample size eq: $N = (Z_{\alpha/2} + Z_{\beta})^2\ 2S^2/(X_1 - X_2)^2$.

Statistical analysis

Data were gathered, entered into the SPSS 23 software program, and reported using percentages, means, and standard deviations for frequency distribution indicators. For quantitative variables, the Mann-Whitney U test was employed if the data distribution was non-normal, and the chi-squaredtest was used for qualitative variables. A significance limit of less than 0.05 was taken into consideration in every case.

Results

During the study period, 104 patients were screened for eligibility. Of the 94 patients recruited in the intervention, 14 patients were excluded; 9 because of ignoring the completion of the therapy and 5 because of discontinued intervention, leaving 80 patients (40 in each group) for analysis (Fig. 1). There was no significant difference in the demographic characteristics of the patients enrolled in the two groups. Of the 80 patients enrolled in the study, 40 (50%) were women, while the remainder were men. The patient's average age was 47.69 ± 18.83 years, with a range of 18 to 87 years (Table 1).

The response rate to the MXF or placebo creams in the treatment groups is presented in Table 2. One day following therapeutic interventions, a significant reduction was seen in all parameters of the REEDA score except ecchymosis. Significant decreases in REEDA score from a mean ± SD of 3.65 ± 2.35 to 1.8 ± 1.3 and 1.18 ± 1.06 were seen on days 3 and 5 of MXF application, respectively (*P*-Value < 0.0001).

On the first day after treatment, most patients (90%) in the control group exhibited redness within or beyond 0.5 cm of the incision. In contrast, 45% of those who received MXF had redness within 0.25 cm of the incision, and 40% had none at all on the first following day. On the 3rd day, 80% of patients in the MXF group had no redness compared to 17.5% in the control group. Only 35% of patients in the control group had no redness 5 days after treatment, compared to 90% of patients in the MXF group.

About 65% of the participants first experienced oedema, and there was no noticeable difference between the MXF and control groups (*P*-Value = 0.599) at the beginning of treatment. Three days post-therapy, the MXF group showed 82.5% no oedema, compared to 57.5% in the control groups. Compared to 82.5% of patients in the MXF group, 62.5% of patients in the control group had no oedema 5 days after treatment.

Nearly half of the participants in both the MXF group (55%) and the control group (42.5%) had no bruises one day after therapy. However, the MXF group showed a slight improvement. The vast majority of patients (80%) in the MXF group did not have ecchymosis 3 days post-therapy, although 50% of patients in the control group did. Additionally, the rate of severe ecchymosis in the MXF group was 0%, whereas 15% of patients who received a control got severe ecchymosis. The majority of the MXF group's patients (80%) did not have any ecchymosis five days after surgery, although just half of the control group's patients did not.

When it came to incidents involving discharge, there was no statistically significant difference between the MXF and control groups at the beginning of treatment (*P*-Value = 0.605). Discharges were present at the wound site in 90% of patients receiving MXF and 100% of patients receiving control cream.

Additionally, almost all of the discharges were purulent and bloody. The amount of bloody and purulent discharges decreased to 2.5%, and 62.5% of patients in the MXF group had no discharges one day post-therapy, while only 5% of patients in the control group had no discharges, and the type of discharges had barely changed since the start of the treatment. In the MXF group, discharges were presented 3 days after therapy in 22.5% of patients, but in the control group, 77.5% of patients continued to suffer from wound discharges. About 80% of the MXF group's patients had no discharges five days after therapy, but 60% of the control group's patients still had some.

In both groups, the rate of approximation of the wound at the start of treatment was the same, and 68.8% of the patients had partial closures, meaning the gap between

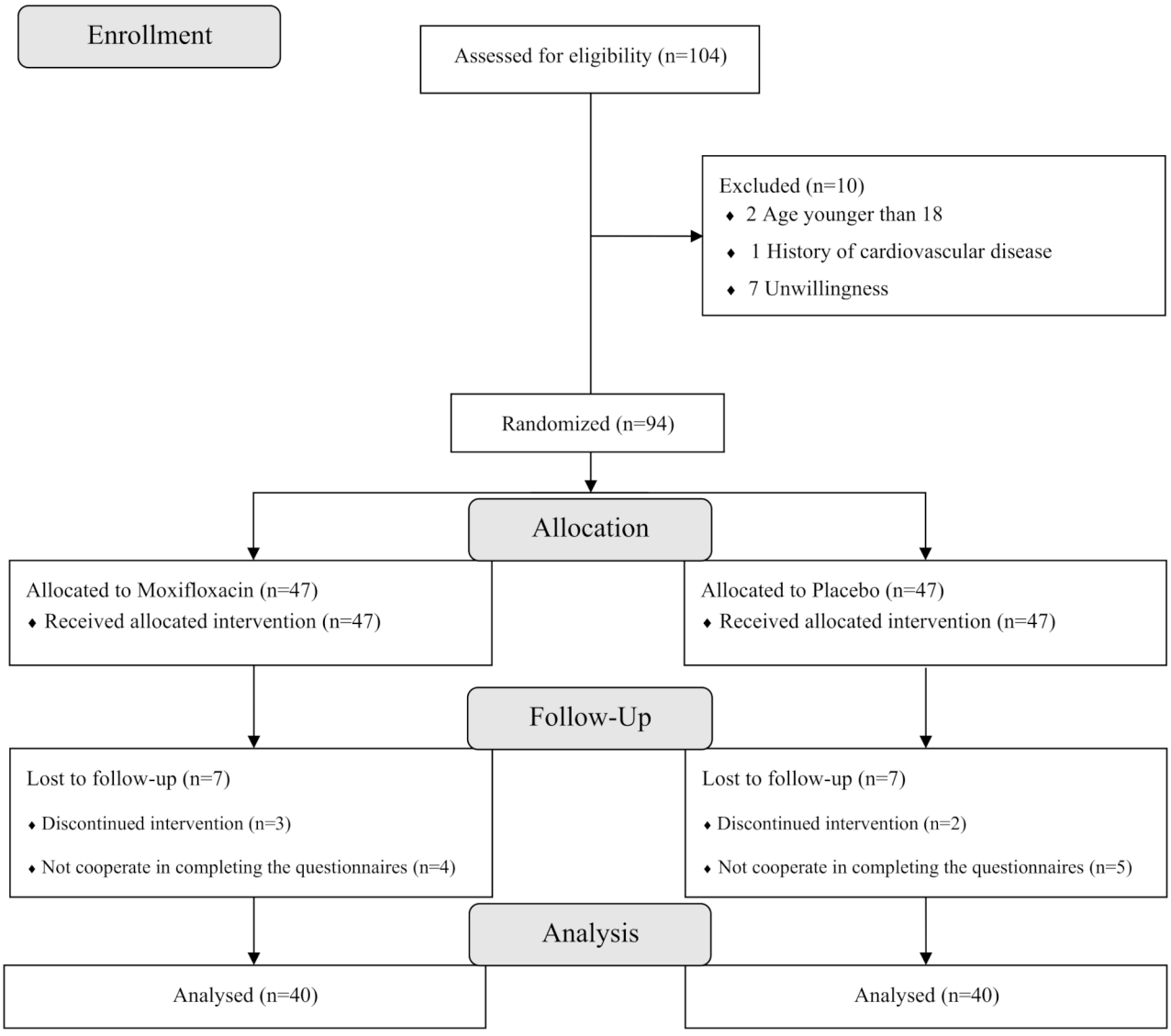

Fig. 1 The consort diagram of the trial of MXF vs. placebo

the two sides of the wound was smaller than 3 mm. Additionally, none of the wounds has fully healed. In terms of wound closure at the start of treatment, there was no significant difference between the two groups, as indicated by *P*-Value = 0.434.

92.5% of the MXF group and 97.5% of the control group had open wounds on the first postoperative day. On the third day following therapy, open wounds were present in 50% of the MXF patients and 32.5% of the control patients. Most surgical wounds were closed by day five (61.3%), 67.5% in the MXF group compared to 55% in the control group. 5% of the lesions in each group did not heal completely, allowing the subcutaneous tissues to separate.

On the first, third, and fifth days of therapy, the wound clustered in a similar. They had *P*-Value of 0.203, 0.123, and 0.285, respectively to support it. As a result, the two groups' wound-healing processes were quite similar (Table 2; Fig. 2).

No adverse effects in the form of itching and scaling were observed in participants who were treated with each of the interventions. None of the patients required redo surgery during the next 3 months.

Discussion

Topical antibiotics are not generally recommended for the prevention of surgical site infections, and the drug concentrations for surgical incision sites are not well established. We must continuously assess the wound healing process under various circumstances to provide better care and a better understanding of the injured tissues. In an intricate physiological natural process, the

Table 1 Patients demographic and baseline characteristics

Characteristics	No. (%) of patients		*P*-Value
	Moxifloxacin ($n=40$)	Control ($n=40$)	
Age, mean (SD), year	49.5 (19.8)	45.8 (17.8)	0.387
Women	23 (57.5)	17 (42.5)	0.183
BMI, mean (SD), kg/m^2	25.66 (3.72)	26.31 (2.98)	0.783
Concurrent comorbidities			
Hypertension	4 (10.0)	4 (10.0)	0.110
Hypothyroidism	3 (7.5)	1 (2.5)	
Migraine	0 (0.0)	2 (5.0)	
Smoking, yes	8 (20.0)	10 (25.0)	0.442
No. (%) of antibiotics category prescribed after surgery			
Cephalosporin	30 (75.0)	22 (55.0)	0.197
Cephalosporin + nitroimidazole	7 (17.5)	9 (22.5)	
Lincomycin + fluoroquinolone	0 (0.0)	2 (5.0)	
Fluoroquinolone + nitroimidazole	0 (0.0)	1 (2.5)	
Penicillin + Macrolides	0 (0.0)	1 (2.5)	
Fluoroquinolone	0 (0.0)	1 (2.5)	
Cephalosporin + Lincomycin	1 (2.5)	0 (0.0)	
Lincomycin	0 (0.0)	1 (2.5)	
Cephalosporin + Penicillin	1 (2.5)	1 (2.5)	
fluoroquinolone + Lincomycin	1 (2.5)	1 (2.5)	
macrolides + Nitroimidazole	0 (0.0)	1 (2.5)	

inflammatory pattern of the healing process begins with the release of inflammatory cells (neutrophils) to eliminate the damaged cells. After the inflammatory phase, mononuclear immune cells travel to the site of the wound to start the regeneration and cell-proliferation phase. To promote wound healing quickly with the least amount of pain, discomfort, and scarring, wound care should be administered effectively [13].

Since topical antibiotics are thought to stop infection at the surgical site, they are frequently applied to wounds following surgery. It is thought that applying antibiotics topically provides a benefit over swallowing them or administering them intravenously. Topical antibiotics have fewer potential side effects, like nausea and diarrhea, as they only affect the areas of the body that they are applied to. Antibiotic resistance is another factor that topical antibiotics are thought to mitigate. However, they can potentially have adverse effects, the most frequent of which is allergic skin reactions (contact dermatitis), which can result in redness, itching, and discomfort in the area where the topical antibiotic is applied.

The efficacy of 0.5% erythromycin prophylaxis in oculofacial plastic surgery was evaluated in a recent trial. The results showed the rate of surgical site infections was less in the erythromycin group, while the rate of wound dehiscence was the same as the placebo group [18]. The efficacy of gentamicin ointment versus petrolatum for the prevention of suppurative chondritis revealed no significant difference between the use of either intervention [19]. The results of putting ointment on a surgical wound before occlusive dressing on 778 patients with 1801 surgical wounds indicated no significant differences in wound infection, scar, hemorrhage, and dehiscence [20]. Application of a single dose of topical chloramphenicol to sutured wounds in surgery reduced the incidence of infection [21]. The result of a systematic review and meta-analysis in 2024 showed that no clinical benefits were found when topical antibiotic agents were used [22].

MXF, as a fluoroquinolone-class broad-spectrum synthetic antibiotic, penetrates well into muscle, fat, subcutaneous tissue, and inflammatory fluids and produces a sufficient concentration due to its molecular structure. Patients with diabetic foot infections, which are among the infections that are resistant to antibiotics, respond well to MXF treatment, as MXF was highly available in extravascular tissues after parental MXF therapy [13, 16]. In addition, previous studies indicated that topical MXF reduces inflammation, boosts angiogenesis, and promotes tissue granulation [13–15], which helps MXF to speed up wound healing along with its antimicrobial properties.

According to Schwartz's Principles of Surgery [23], patients should receive each of cefazolin, vancomycin, or clindamycin + aminoglycoside, aztreonem, or fluoroquinolone, or metronidazole + aminoglycoside or fluoroquinolone as prophylactic antibiotic after non-perforated appendicitis surgery.

As the data on topical moxifloxacin is limited in humans, it was not ethical to deprive patients of prophylactic antibiotics, so the current study was conducted

Table 2 The responses to the Moxifloxacin or placebo creams in the groups

day	Baseline				First day				Third day				Fifth day			
Redness	***R′***	***R″***	***R‴***	***R⁗***	***R′***	***R″***	***R‴***	***R⁗***	***R′***	***R″***	***R‴***	***R⁗***	***R′***	***R″***	***R‴***	***R⁗***
MXF	2 (5.0)	5 (12.5)	12 (30.0)	21 (52.5)	16 (40.0)	18 (45.0)	5 (12.5)	1 (2.5)	32 (80.0)	4 (10.0)	3 (7.5)	1 (2.5)	36 (90.0)	2 (5.0)	1 (2.5)	1 (2.5)
Placebo	3 (7.5)	3 (7.5)	10 (25)	24 (60)	3 (7.5)	1 (2.5)	13 (32.5)	23 (57.5)	7 (17.5)	8 (20.0)	10 (25.0)	15 (37.5)	14 (35.0)	7 (17.5)	9 (22.5)	9 (22.5)
P-Value	0.558				< 0.0001				< 0.0001				< 0.0001			
Oedema	**O′**	**O″**	**O‴**	**O⁗**	**O′**	**O″**	**O‴**	**O⁗**	**O′**	**O″**	**O‴**	**O⁗**	**O′**	**O″**	**O‴**	**O⁗**
MXF	14 (35.0)	12 (30.0)	9 (22.5)	5 (12.5)	27 (67.5)	8 (20.0)	2 (5.0)	3 (7.5)	33 (82.5)	0 (0.0)	1 (2.5)	1 (2.5)	35 (87.5)	4 (10)	0 (0.0)	1 (2.5)
placebo	14 (35.0)	9 (22.5)	9 (22.5)	8 (20.0)	18 (45.0)	7 (17.5)	9 (22.5)	6 (15.0)	23 (57.5)	5 (12.5)	3 (7.5)	3 (7.5)	25 (62.5)	8 (20)	5 (12.5)	2 (5.0)
P-Value	0.559				0.022				0.010				0.008			
Ecchymosis	**E′**	**E″**	**E‴**	**E⁗**	**E′**	**E″**	**E‴**	**E⁗**	**E′**	**E″**	**E‴**	**E⁗**	**E′**	**E″**	**E‴**	**E⁗**
MXF	16 (40.0)	13 (32.5)	7 (17.5)	4 (10)	22 (55.0)	11 (27.5)	4 (10.0)	3 (7.5)	32 (80.0)	6 (15.0)	2 (5.0)	0 (0.0)	32 (80)	7 (17.5)	1 (2.5)	0 (0.0)
placebo	17 (42.5)	6 (15.0)	6 (15.0)	11 (27.5)	17 (42.5)	7 (17.5)	5 (12.5)	11 (27.5)	20 (50.0)	4 (10.0)	10 (25.0)	6 (15.0)	23 (57.5)	6 (15.0)	6 (15.0)	5 (12.5)
P-Value	0.396				0.066				0.001				0.01			
Discharge	**D′**	**D″**	**D‴**	**D⁗**	**D′**	**D″**	**D‴**	**D⁗**	**D′**	**D″**	**D‴**	**D⁗**	**D′**	**D″**	**D‴**	**D⁗**
MXF	4 (10.0)	10 (25.0)	9 (22.5)	17 (42.5)	25 (62.5)	11 (27.5)	3 (7.5)	1 (2.5)	31 (77.5)	8 (20.0)	0 (0.0)	1 (2.5)	32 (80.0)	7 (17.5)	0 (0.0)	1 (2.5)
placebo	0 (0.0)	13 (32.5)	9 (22.5)	18 (45.0)	2 (5.0)	16 (40.0)	8 (20.0)	14 (35.0)	9 (22.5)	14 (35.0)	10 (25.0)	7 (17.5)	16 (40.0)	12 (30.0)	5 (12.5)	7 (17.5)
P-Value	0.605				< 0.0001				< 0.0001				< 0.0001			
Approximation	**A′**	**A″**	**A‴**	**A⁗**	**A′**	**A″**	**A‴**	**A⁗**	**A′**	**A″**	**A‴**	**A⁗**	**A′**	**A″**	**A‴**	**A⁗**
MXF	0 (0.0)	29 (72.5)	11 (27.5)	0 (0.0)	3 (7.5)	29 (72.5)	8 (20.0)	0 (0.0)	20 (50.0)	16 (40.0)	4 (10.0)	0 (0.0)	27 (67.5)	11 (27.5)	2 (5.0)	0 (0.0)
placebo	0 (0.0)	26 (65)	13 (32.5)	1 (2.5)	1 (2.5)	27 (67.5)	12 (30.0)	0 (0.0)	13 (32.5)	21 (52.5)	6 (15.0)	0 (0.0)	22 (55.0)	16 (40.0)	2 (5.0)	0 (0.0)
P-Value	0.434				0.203				0.123				0.285			
REEDA																
MXF	7.65 ± 2.58				3.65 ± 2.35				1.7 ± 1.3				1.18 ± 1.06			
placebo	8.38 ± 2.86				7.8 ± 2.83				5.8 ± 2.9				4.35 ± 2.98			
P-Value	0.209				< 0.0001				< 0.0001				< 0.0001			

Data is based on frequency (%) and mean ± SD

R′: *0 = none*, R″: *1 = mild within 0.25 cm of incision*, R‴:*2 = moderate within 0.5 cm of incision bilaterally*, R⁗: *3 = severe beyond 0.5 cm of incision bilaterally*

O′: 0 = none, O″:1 = mild perineal, less than 1 cm from the incision, O‴:2 = moderate perineal and\or vulvar, between 1 and 2 cm from the incision, O⁗:3 = severe perineal and\or vulvar, greater than 2 cm from an incision

E′: 0 = none, E″:1 = mild within 0.25 cm bilaterally or 0.5 cm unilaterally, E‴: 2 = moderate between 0.25 and 1 cm bilaterally or between 0.5 and 2 cm unilaterally, E⁗:3 = severe greater than 1 cm bilaterally or 2 cm unilaterally

D′:0 = none, D″:1 = serous, D‴:2 = serosanguinous, D⁗:3 = bloody, purulent

A′: 0 = closed, A″:1 = mild skin separation of 3 mm or less, A‴:2 = moderate skin and subcutaneous fat separation, A⁗: 3 = severe skin and subcutaneous fat and fascial layer separation

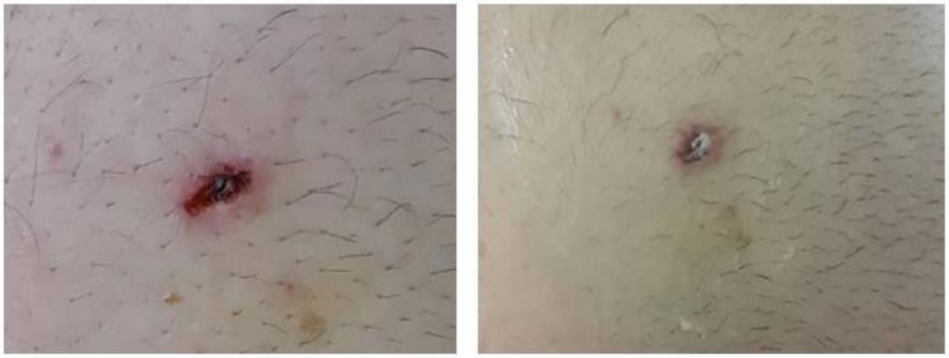

Fig. 2 **A**, Pretreatment. **B**, Posttreatment, showing comparison of wound therapeutic laparoscopy induced wound healing on day 3 of MXF application

in matched groups considering antibiotics after the operations.

Considering that, topical medications can be a good alternative for therapy by lowering the dose, limiting side effects, and also cost, there is currently no topical medication that is acceptable and effective for accelerating wound healing. As well as evidence supporting MXF's ability to do so, the current investigation acted as a clinical trial to examine the impact of MXF on surgical wound healing using the REEDA criteria [17]. Safety and efficacy of Lecoxen vs. vaseline cream on the cesarean wound healing were evaluated recently. The results showed a significant improvement in the REEDA score in terms of vascularization, pigmentation, flexibility, and height [24]. According to the study's findings, the MXF group had considerably less redness, oedema, and discharge on the first, third, and fifth days than the control group. The quantity of ecchymosis was similar in both groups on the first day, however, the MXF group showed less ecchymosis on the third and fifth days. Even though the MXF group showed a better improvement in the approximation of the wound edges, there was no difference in the rates of approximation of the wound edges between the two groups at any of the timeframes under study. Overall, both daily and during treatment, the evaluated parameters (REEDA) showed a higher decline in the MXF group, demonstrating the drug's significant impact on the healing of surgical wounds.

A survey of scientific literature revealed that there has been very little research on the efficiency of topical MXF. Additionally, studies on animals are frequently the only ones to test MXF efficiency in healing wounds. The effectiveness of topical MXF over mupirocin, linezolid, and gentamicin in treating MRSA and Pseudomonas wound infections was demonstrated by Jacobsen et al. in an animal model in 2011 [13]. MXF treatment is beneficial in decreasing inflammation brought on by lung contamination with inactivated Streptococcus pneumoniae and Pseudomonas bacteria, according to research by Kristoff et al. This study demonstrated that MXF has anti-inflammatory capabilities in addition to its antibacterial properties. All inflammatory cells, neutrophils, and inflammatory mediators like IL1 and IL17A were considerably reduced in the lungs of treated mice [15]. In the current study, the wound's reduction in redness and oedema strongly suggests that MXF has anti-inflammatory properties.

The prepared triple-component nanocomposite (chitosan-silver-sericin) films loaded with MXF indicated remarkable wound healing functions with successful fibrosis, collagen reorganization, neovascularization, and mild epidermal regeneration after 7 days of treatment with no silver ions detection in animal's blood, according to Shah et al. that working on wound healing and antibacterial potential against MRSA [25].

The majority of investigations on MXF effects on wound healing in humans focus on corneal repair. MXF can decrease TGFβ (Transforming growth factor beta) by separating fibroblasts from myofibroblasts, which is a key element in corneal wound healing, according to a study by Chen et al. that evaluated the effects of 0.5% eye drops [26]. Even though the patients in the Devrajani et al. trial (2017) had a variety of underlying conditions, including hypertension, diabetes, and IHD, the diabetic foot ulcers on average improved by 84% after 14 days of intravenous or oral MXF treatment. Additionally, younger age was linked to a faster rate of wound healing [27]. In a study on MXF-loaded electrospun polymeric composite nanofibers-based wound dressing for enhanced antibacterial activity and healing efficacy, Hameeda et al. found that MXF-loaded nanofibers demonstrated better stability, antimicrobial activity against S. aureus, E. coli, and P. aeruginosa, as well as wound healing efficacy when compared to blank nanofibers. CS-PEO polymeric composite with MXF loading may therefore be a promising wound dressing for the efficient repair of injured skin [4].

Notably, the hospital's treatment committees have approved several antibiotic options. Based on the patient's conditions and the clinical team's judgment, an appropriate option was selected for each patient

to prevent postoperative infection. No significant differences in the type of antibiotic used were observed between the two groups, indicating that the choice of antibiotic may not influence wound healing outcomes.

It is important to note that the absence of microbial culture analysis, a short-term follow-up period, and the opportunity for comparison were the limitations of our study. Although the findings of the current study were interesting, future multicenter studies with a larger population should be conducted to confirm the results of this study.

Conclusion

Taking all of the above into account, it was demonstrated by the outcomes of this study and previous investigations that MXF can be a potential option to accelerate the healing of therapeutic laparoscopy-induced wounds. One of the advantages of the present study was that the two patient groups were comparable in terms of age and sex, and patients with underlying illnesses that might have acted as confounding factors in the wound-healing process were eliminated from the study. For future studies, it is recommended to explore the optimal dosage and duration of MXF in wound healing in a larger sample size and include microbiological cultures to provide stronger evidence for MXF's antimicrobial efficacy.

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Author contributions
B.H., F.S., and S.K. were involved in the conception and design of the study. V.R. prepared the moxifloxacin and placebo creams. S.K., A.B., and A.Z. evaluated the patients and collected the data. B.H., F.S., and F.H. analyzed the data and drafted the first manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study received the Ethics ID (IR.SSU.MEDICINE.REC.1398.080) by the Ethics Committee of Shahid Sadoughi University of Medical Sciences. This study was also approved in the Iranian Registry of Clinical Trials (IRCT20181208041882N5). Written informed consent was obtained for every participant before administration of any study intervention. The participants did not receive a monetary stipend. All methods were carried out following relevant guidelines and regulations or the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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