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ORIGINAL ARTICLE

Analysis of the MAC® healing acceleration methodology with the use of propolis and toluidine blue in the healing of lower limb ulcers

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Abstract

Introduction: Photodynamic Therapy has been an important ally in tissue repair, with positive effects in the treatment of wounds and infections.

Objective: To analyze the effects of the Healing Acceleration Methodology (MAC®) using propolis and toluidine blue on lower limb ulcers.

Methods: Single-center, experimental, randomized and controlled study. Carried out between April 2021 and May 2022 at the outpatient clinic of the school clinic in a Brazilian capital. Patients were randomly assigned in a 1:1 ratio to receive photodynamic therapy (experimental group) or conventional dressing alone (control group). Patients over 18 years of age diagnosed with lower limb ulcers were included. Ten patients comprised the experimental group and 10 the control group. Patients were seen three times a week and monitored for two months. The primary outcome was the assessment of healing progress and the secondary outcome was the microscopic analysis of wound smears for the presence of cells and microorganisms.

Results: In the experimental group, two wounds did not heal completely while in the control group, none of the 10 wounds healed completely during the 60-day follow-up. In the experimental group, 90% of patients did not have bacteria and fungi at the end of 30 days versus 40% in the control group.

Conclusion: The present study showed that photodynamic therapy is a potential effective treatment in the healing process of lower limb ulcers. This can impact cost reduction and quality of life. Larger, well-designed studies are needed to corroborate the findings of the present study.

Keywords: wounds, wound infection, regeneration, healing, phototherapy.

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Authors summary

Why was this study done?
Chronic leg ulcers are a significant global problem and difficult to heal wounds. Treatment time is generally long and sometimes requires several years, leading to many complications, such as joint deformities, limited mobility, or even permanent disability, negatively impacting quality of life. This study demonstrated a short healing time (up to 60 days) with treatment involving Photodynamic Therapy.

What did the researchers do and find?
In our study (single-center, experimental, randomized and controlled study) we investigated the effects of the Healing Acceleration Methodology (MAC®) using propolis and toluidine blue on lower limb ulcers, concluding that Photodynamic Therapy is a potential treatment effective in the healing process of lower limb ulcers.

What do these findings mean?
This therapy can reduce costs and offer a better quality of life for people with lower limb ulcers, due to a reduction in healing time.

Highlight
After a 60-day follow-up, the control group saw a reduction in the size of the lesion of 6 to 60%, but there was no complete healing, while in the experimental group, 80% of the sample completely healed the lower limb ulcer.
The present study showed that PDT (blue LED with a wavelength of 470 nm associated with 10% propolis ointment + toluidine blue) enhanced the healing of lower limb ulcers in a short period (up to 60 days).
In our study we observed the presence of bacteria and fungi in the lesions before starting treatment. Factor that contributes to delayed healing. Therefore, therapies that contribute to microbiological control can reduce healing time.

INTRODUCTION

Chronic wounds are characterized by interruption in the continuity of the skin, to a greater or lesser extent, of long duration or frequent recurrence, which do not heal within a time interval of up to 3 months. Cellular and molecular disorganization contributes to the lack of healing. The etiology is associated with factors such as: diabetes, neuropathies, chronic venous disease, peripheral arterial disease, arterial hypertension, physical trauma, sickle cell anemia, skin infections, inflammatory diseases, neoplasms, and nutritional alterations[1-3].

The prevalence of chronic leg ulcers in the general population is estimated at 1.5 per 1,000 people[4]. Chronic wounds, especially diabetic ulcers, precede 85% of amputations. The five-year mortality rate after developing a diabetic ulcer is approximately 40%[5]. Although there is no exact estimate, it has been suggested that, in this millennium, in Brazil, 3% of the population may be affected by chronic ulcers[6].

Several studies have shown Photodynamic Therapy (PDT) to be an important ally in tissue repair[7-11]. PDT, when used in conjunction with photosensitizers, has shown positive effects in the treatment of wounds and infections, and in the postoperative period of aesthetic surgery[12-14]. Thus, the photosensitizer - commonly methylene blue or toluidine blue, activated by a light source (laser or LED - Light Emitting Diode), with an appropriate wavelength, generates reactive oxygen species (ROS), such as singlet oxygen and superoxides. The products resulting from this interaction are cytotoxic to the target cell, causing disorders in the cell wall that lead to the death of the microorganism[15]. A previous study on PDT using LED showed increased production of Adenosine Triphosphate (ATP) in mitochondria, which is important for the healing process[16].

MAC® is a method consisting of a PDT device that presents advantages over conventional laser/LED devices. MAC® stands out from other forms of PDT application, as it brings together the best tools for its use, in addition to bringing together a better vector for greater drug penetration, based on the space-time curve. When using phototherapy based on MAC®, it is necessary to evaluate the light emitting system, so that based on the space-time curve it is guaranteed, aiming at a better therapeutic result[11].

On the other hand, studies on the use of propolis in the treatment of wounds that are difficult to heal have advanced in recent decades. This is mainly due to the fact that propolis is an easily accessible product that is available at low cost. The results show beneficial effects with antimicrobial, anti-inflammatory, analgesic, and neoangiogenesis action, optimizing the healing of chronic wounds[17]. In view of the above, the following research question was raised: Is it possible to enhance the healing process of chronic wounds with the use of PDT combined with the use of propolis and toluidine blue? To answer this question, the aim of the present study was to analyze the effects of PDT combined with the use of propolis and toluidine blue on lower limb ulcers.

METHODS

Study design

This is a single-center, experimental, randomized and controlled study carried out at the outpatient clinic of the teaching clinic of the Centro Universitário Vale do Salgado, Ceará, Brazil. This research followed Resolution Nº. 466/12 of the National Health Council and was approved by the Unileão Research Ethics Committee under opinion Nº. 3,376,125.

Study setting and participants

The study was performed between April 2021 and May 2022, at the outpatient clinic of the Centro Universitário Vale do Salgado school clinic, which assists patients with a diagnosis of ulcers of the lower limbs. Patients were randomly assigned in a 1:1 ratio to receive photodynamic therapy (experimental group - EG), or conventional dressing only (control group - CG).

Eligibility criteria

Patients aged 18 years or over, who attend the outpatient clinic of the school clinic, with a diagnosis of lower limb ulcers of any etiology were included in the study. Patients were informed about the study and then received and signed the Free and Informed Consent Form before participating in the research. Patients were ineligible in case of pregnancy or arterial compromise.

Randomization and allocation

This is an experimental, randomized, 2-group study with a 1:1 intervention allocation. The sample was recruited for convenience. The randomization sequence was generated by a researcher who did not participate in the study. The randomization list was computer generated, sequentially assigning patients to the CG or EG. A researcher prepared sealed, opaque, numbered envelopes containing the group allocation. When each patient was enrolled in the study, the investigator opened the envelope with the lowest number to define the group.

Blinding

Image evaluations (photographs) and microscopic analysis of slides were performed by an evaluator who did not participate in the research and was unaware of the allocation of groups. Codes were assigned to images and slides and patient identification information was removed. Patients were blinded to the participation group.

Control group

Patients always received treatment in the afternoon at a previously scheduled time. The assessment, including anamnesis and physical examination, to collect sociodemographic, clinical, and wound history-related data, was performed before starting the first session. A swab was performed through a wound smear and the collected material was deposited on a glass slide and stored in Borel tubes with 95% ethyl alcohol. The tubes were identified with the code corresponding to each patient and the date of collection of the biological material. In the microscopic analysis, the pap smear kit, EA-36, Orange G6, and Harris' hematoxylin were used. The slides were observed for the presence of pathogenic microorganisms.

The CG received conventional dressings at the wound prevention and treatment outpatient clinic by nurses from the school clinic. The wound was cleaned with saline solution at room temperature, punctured with a 25 x 7 needle. The jet was fired at a distance of 10 to 15 centimeters from the wound. Subsequently, cleaning was performed with 2% chlorhexidine, followed by the application of ointment (as prescribed by the attending physician) and covered with sterile gauze, bandage, and adhesive tape.

Participants were treated 3 times a week and followed for a period of 60 days. On the days between the treatment days, the participants were instructed to wash the wound with saline solution and cover it with a sterile gauze dressing.

Experimental group

Patients always received care in the morning at a previously scheduled time. The assessment, including anamnesis and physical examination, was carried out before starting the first session. Sociodemographic, clinical and wound history data were collected. And a swab was collected through a swab of the wound.

The collected mterial was deposited on a glass slide and stored in borel tubes with 95% ethyl alcohol. The tubes were identified with the code corresponding to each patient and date of collection of the biological material. In the microscopic analysis, the Pap smear kit, EA-36, Orange G6 and Harris Hematoxylin were used. The slides were observed for the presence of pathogenic microorganisms.

EG participants underwent a sensitivity test (propolis + toluidine blue) before starting treatment. The sensitivity test was performed on intact skin on the participant's right forearm. No irritation or appearance of an allergic reaction was observed in the EG.

Before the application of phototherapy, the wound was cleaned with saline solution at room temperature, punctured with a 25 x 7 needle. The jet was fired at a distance of 10 to 15 centimeters from the wound. Subsequently, cleaning was performed with 2% chlorhexidine and the wound was covered with a thin layer of ointment based on 10% propolis and 1% toluidine blue.

The 470 nm blue LED was then applied (the cluster has 3 470 nm blue LED emitters and 1200 mW power) with the MAC tissue repair device (figure 1). The cluster was located at a distance of 2 cm from the wound, and the LED was used in scanning mode. Application time was calculated according to the wound area, delivering 20 seconds of radiation per square centimeter. At the end of treatment, the wound was covered with sterile gauze, bandage, and adhesive tape.

Participants were treated 3 times a week until complete wound healing or completion of the study period. On the days between the treatment days, the participants were instructed to wash the wound with saline solution and cover it with a sterile gauze dressing.

This protocol was based on the Scar Acceleration Method (MAC®) which proposes to Identify, Observe, Evaluate and Interpret, so that it is possible to carry out adequate therapy in tissue repair through phototherapy associated with photopharmaceuticals (Figure 1).

Wound healing progress

A digital caliper was used to measure the wound healing progress weekly. Photographic images of the wounds during measurement with the caliper were collected weekly with a 48-megapixel Xiaomi Redmi Note 8 (Hebei, China) smartphone digital camera. All participants signed the image authorization form. The images were always taken in the same location, with good lighting and a background with a smooth and uniform surface, as instructed by researchers[18].

Microscopic analysis

The characteristics of the cells in the material collected through swabs from the wound bed were analyzed. The prepared slides were analyzed using an OPTON® microscope (São Paulo, Brazil). The slides were evaluated by an experienced and blinded biomedical scientist who had no knowledge regarding the study

Figure 1: Application of 10% propolis ointment associated with 1% toluidine blue followed by LED application
FONTE: Pinheiro et al., 2024

groups. Microbiological analysis evaluated the presence of cells and microorganisms. The material was described qualitatively and semi-quantitatively.

Statistical analysis

Continuous variables are described using mean and standard deviation. Categorical variables are presented as absolute values and percentages. For follow-up characteristics, comparisons between groups were calculated using Pearson's chi-square test. A significance level of $\alpha < 0.05$ was adopted in the statistical tests, and the results were considered statistically significant. Study data were collected in an Excel spreadsheet and exported to the Statistical Package for the Social Sciences (SPSS), version 23.0 for Windows for analysis.

The results obtained from the slides were classified according to the characteristics of the cells and microorganisms present, described in a qualitative and semi-quantitative way. The photos were used to evaluate the appearance of the wound, in terms of color, edges, and perilesional skin, as well as height and width measurements, in order to calculate the area squared.

RESULTS

Study population

During the study period, 23 patients were evaluated for selection and, of these, 20 were randomized. Thus, the study included 10 patients in the EG and 10 in the CG. Table 1 presents the baseline sociodemographic characteristics of the patients.

Table 1: Baseline characteristics

Patient characteristics	GROUP			
	EG (n = 10)		CG (n = 10)	
AGE, YEARS				
Mean	63		51,3	
Minimum	46		22	
Maximum	83		80	
SEX, n (%)				
Female	4	40%	4	40%
Male	6	60%	6	60%
ETHNICITY, n (%)				
Caucasian	10	100%	10	100%
COMORBIDITIES, n (%)				
Hypertension	2	20%	3	30%
Diabetes	2	20%	4	40%

Table 1: Baseline characteristics

Patient characteristics	GROUP			
	EG (n = 10)		CG (n = 10)	
SCHOOLING n (%)				
Illiterate	2	20%	2	20%
Elementary School	5	50%	7	70%
High School	3	30%	1	10%
INCOME n (%)				
1 Minimum wage	6	60%	8	80%
2 Minimum wages	3	30%	1	10%
More than 2 Minimum wages	1	10%	1	10%

Considering the EG, one patient had an open wound for more than 36 months, and the other patients had open wounds without healing for a period of 3 months. In the CG, two individuals had an open wound for more than 24 months and the others had open wounds without healing for a period of 3 months.

Table 2 presents the characteristics of the evaluated wounds.

Another variable analyzed was the skin around the wound. The GE patients presented 5 wounds with skin with a red appearance and color, indicative of an inflammatory and/or infectious process, 2 with ochre dermatitis, indicative of a venous wound, and only 3 with normal color and appearance. On the other hand, 2 patients in the CG had edematous skin, 4 had a normal appearance, 3 had red skin around the wound, and only one had ochre dermatitis. In total, 7 individuals in the EG had a normal temperature and 3 had a hot temperature, a similar result to the CG, where the majority also had a normal temperature.

It is worth mentioning that all had fissures or cracks in the lower limbs and popliteal and pedal pulses were present.

Wound healing progress

In the EG, two wounds did not heal completely, while in the CG none of the 10 wounds healed completely (P = 0.000) during the 60-day follow-up. Table 3 shows the occurrence of healing and the comparison between groups.

Table 2: Wound characteristics

GROUP	EG		CG	
WOUND COLOR, n (%)				
Yellowish	5	50%	2	20%
Pinkish	0	0	2	20%
Red	5	50%	6	60%
ODOR, n (%)				
Yes	7	70%	8	80%
No	3	30%	2	20%
PRESENCE OF EXUDATE, n (%)				
Yes	10	100%	10	100%
No	0	0	0	0
TYPE OF EXUDATE, n (%)				
Serous	8	80%	7	70%
Serous/bloody	1	10%	2	20%
Purulent	1	10%	1	10%

Table 3: Occurrence of healing and comparison between groups

		HEALING		
	YES	YES	NO	P
GROUPS	EG	8	2	
		80%	20%	0.000
	CG	0	10	
		0%	100%	

Figure 2: shows the images and the healing process of the EG patients.
A – Wound 3 EG patient 1; B – Wound EG patient 10; C – Wound EG patient 4; D – Wound EG patient 5. Figure 2 - Images of healing in EG patients

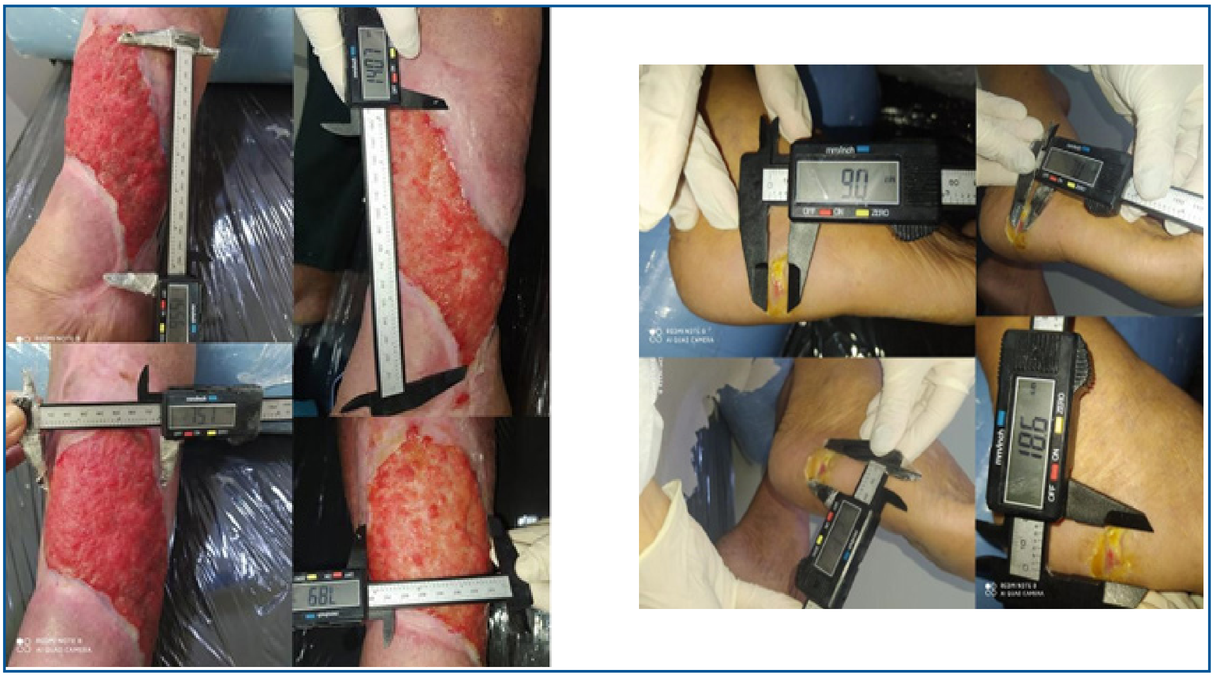

Figure 3: shows the images and the healing process of the CG patients.
A – Wound CG patient 1; B – Wound CG patient 3 Figure 3 - Images of healing in CG patients.

Microscopic analysis

Among the microbiological characteristics present in the wounds, there was a predominance of bacteria and fungi, yeast-like structures, and epithelial cells.

In the EG, the presence of bacteria was detected in all participants and in three wounds this was accompanied by yeast-like structures, indicative of fungi. After 30 days, a smear was collected on a slide and analyzed again, and bacteria were detected in only one wound of the EG (data not shown).

In the CG, bacteria were present in seven wounds and three had yeast-like structures. After 30 days the microbiological analysis showed the presence of bacteria in four individuals and fungi in two individuals. All presented microorganisms in smaller numbers (data not shown).

Another characteristic detected was the presence of mucus filaments, present before and after 30 days of treatment in both groups, indicative of exudate. Epithelial cells were detected after 30 days of treatment in six individuals from the EG and two from the CG.

DISCUSSION

The results of the present study demonstrate that PDT combined with the use of própolis and toluidine blue seems to potentiate the healing process of lower limb ulcers. However, two wounds in the EG were not fully healed at the end of 60 days of follow-up.

In the EG, two wounds did not heal completely, while in the CG none of the 10 wounds healed completely during the 60-day follow-up. This indicates the need for new tools and methods that enhance the healing process.

Healing is a complex process, which involves vascular and cellular alterations, mechanisms of cell proliferation, collagen synthesis and deposition, elastin production, and revascularization, until wound contraction[19]. Thus, the use of phototherapy in association with a photosensitizer aids in the healing process.

In cases of loss of skin integrity, several processes need to be carried out to restore the skin to its normal functions. The healing process involves a series of complex interactions between different cell types, growth factors, chemokines and cytokines, enzymes, and extra cellular matrix (MEC) components. The wound closure process involves several steps which are triggered by vasoactive molecules, producing a domino effect of various autocrine, paracrine, and endocrine signals[13].

Chronic leg ulcers are a significant global problem and wounds are difficult to heal. Treatment time is usually long and sometimes requires several years, leading to many complications, such as joint deformities, mobility limitations, or even a permanent disability, negatively impacting quality of life[10,19].

When using phototherapy based on the MAC® method, it is necessary to evaluate the light emitting system, the property of the electric field of the matter through which this light propagates, and the space-time curve, aiming at the therapeutic result. This is due to the fact that the method uses non-conventional optics in the use of lasers and LEDs. When the photon emission time is doubled, the cell responds because the stimulus is maintained without changing the peak power density velocity, without decay or bioinhibition[11].

Photodynamic therapy aims to eliminate the microorganisms that persist in the chemical-mechanical preparation, and is based on the interaction between a photosensitizer, a light source, and oxygen. Of these factors, the photosensitizer and its concentration, and the light source and its wavelength and power, can vary the most, affecting the result. The mechanism of action occurs through the administration of a photosensitizer, which is irradiated by a visible light source. The absorption of light excites the photosensitizer which, in the presence of oxygen, generates substances toxic to bacterial cells[9]. The light source transfers energy to the photosensitizing agent, and reacts with intracellular substrates, forming free radicals, which interact with molecular oxygen to form reactive oxygen species and destroy the microbial wall[20].

In a study using photodynamic therapy for the treatment of infected leg ulcers, with 20 patients, allocated into two groups. The first group received photodynamic therapy with 5-aminolevulinic acid (ALA-PDT) (10 patients), and the second group of 10 patients received local octenidine dihydrochloride (octenidine gel) exposed to a placebo light source with a filter inserted to imitate the red light. In the ALA-PDT group, complete remission (CR) was achieved in four patients (40%), a partial response (>50% reduction in ulcer diameter) in four patients (40%), and no response in two patients (20%) who also developed deterioration of the local condition, with edema, erythema, and inflammation[10].

In the current research, the presence of bacteria was detected in several wounds. Although the type of bacteria present was not analyzed, the absence or reduction in its presence was evidenced with the use of PDT. Thus, therapies that can perform microbiological control may suggest a reduction in healing time. These results confirm the observation of other authors about the potential of PDT as an alternative to antibiotics[21].

Other authors observed a reduction in the bacterial load of chronic or infected wounds of 66.6% with the use of PDT. In addition, they observed that the PDT method does not cause resistance to microorganisms and has a specific action on devitalized tissues, without damaging healthy cells[8].

Propolis is used by bees against the proliferation of microorganisms and has several other bioactive properties, such as antiviral, anti-inflammatory, antioxidant, and antiparasitic action, as well as immunomodulatory activities, such as macrophage activation and increased humoral and cellular immune responses[22]. An important factor that positively contributes to healing is the antimicrobial action against various etiological agents, for example, Gram positive bacteria such as Streptococcus pyogenes, Staphylococcus aureus, and Gram negative Escherichia coli and yeasts, especially Candida albicans[23].

The healing property of propolis, as well as several other biological properties, is related to flavonoids and phenolic acids. The anti-inflammatory activity observed in propolis seems to be due to the presence of flavonoids, especially galangin, which has an inhibitory action against COX and lipoxygenase. It has also been reported that CAPE has anti-inflammatory activity by inhibiting the release of arachidonic acid from the cell membrane, suppressing the activities of COX-1 and COX-2 enzymes, in addition to inhibiting the synthesis of prostaglandins, activating the thymus gland, aiding the immune system by promoting phagocytic activity and stimulating cellular immunity[24].

In cellular respiration, in the mitochondrial cristae, the space-time curve made by the MAC® methodology accelerates the transport of electrons, consequently accelerating the process of production of reactive oxygen species, and thus, more singlet oxygen is produced. This is due to the fact that the method uses non-conventional optics in the use of lasers and LEDs. When the photon emission time is doubled, the cell responds because the stimulus is maintained without changing the peak power density velocity, without decay or bioinhibition[11].

A study was carried out on bacterial induced keratitis in rabbits, demonstrating in vivo antibacterial efficacy against S. aureus in the group that received the toluidine blue treatment with red light[12]. Toluidine blue has been used in conjunction with LED to provide a photodynamic effect of antimicrobial chemotherapy in order to inhibit the viability of biofilms produced by bacteria and fungi[25]. Photoexcited toluidine blue is widely used as a bactericide[26].

For healing to occur, certain factors are necessary; the absence of infection, stimulation of repair mechanisms to promote cell migration and adhesion, in order to improve the skin's tensile strength, elasticity, and moisturizing properties, in addition to anti-inflammatory, antiseptic, and antimicrobial action, and adequate nutrition to complete wound closure[13].

The limitations of the present study are related to the small sample size. In addition, it was performed in a single center, so the results cannot be generalized to different patients and settings. In this sense, future studies should employ a well-designed randomized clinical trial design with a longer, multicenter follow-up period.

Despite the small sample size, this study provides important insights into potential therapeutic resources that do not use antibiotics in the tissue repair process. This is an important aspect to be taken into account in future research, since bacterial resistance to antibiotics is a problem faced in all parts of the world. In addition, PDT incorporates inexpensive treatments (such as propolis and toluidine blue) within a new perspective, the MAC® methodology, which involves a method aimed at evaluating possible specific factors that may delay healing. In view of the clinical reasoning, we seek to use phototherapy associated with specific photopharmaceuticals allied to tissue repair. In this sense, it is possible to employ a method that can substantially reduce costs in the treatment of chronic wounds, in addition to avoiding amputations and improving the quality of life of patients.

CONCLUSION

The present study showed that PDT used through MAC® combined with the use of propolis and toluidine blue is a potential effective treatment in the healing process of lower limb ulcers. MAC®'s response is accentuated by the use of phototherapy equipment, developed by the method's creator, and by space and time curves that guarantee greater drug absorption. This can impact cost reduction and quality of life. The combination of toluidine blue, propolis and blue LED, through the MAC® methodology, showed microbial control, reduction of exudate, increase in granulation tissue, wound contraction, and, consequently, the healing of ulcers in the lower limbs. These positive results were found in GE patients who had different pathologies (venous hypertension, diabetes and infectious process), being factors that hinder healing. Therefore, proving to be a promising treatment for patients with chronic wounds with different comorbidities.

Author contributions

All authors contributed to the manuscript. CGP and JAC had full access to all study data and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: CGP and JAC. Data acquisition: CGP, JAC, MVMP, MVB, OPG, VFS, ARS, EF and JGASJ. Data analysis and interpretation: MVMP, OPG. Manuscript writing: CGP, JAC, MVMP, MVB, ARS, EF and JGASJ. Critical review of the manuscript for important intellectual content: All authors. Financing obtained: CGP. Administrative, technical or material support: CGP, JAC and VFS. Study supervision: CGP. All authors read and approved the final manuscript.

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Competing interests

Dr. Marcus Vinicius de Mello Pinto is the creator of MAC®. The other authors have no relevant conflicts to disclose.

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Resumo

Introdução: a Terapia Fotodinâmica tem sido uma importante aliada no reparo tecidual, com efeitos positivos no tratamento de feridas e infecções.

Objetivo: analisar os efeitos da Metodologia de Aceleração Cicatricial (MAC®) com uso da própolis e azul de toluidina em úlceras de membros inferiores.

Método: estudo unicêntrico, experimental, randomizado e controlado. Realizado entre abril de 2021 e maio de 2022 no ambulatório da clínica escola em uma capital brasileira. Os pacientes foram distribuídos aleatoriamente em uma proporção de 1:1 para receber a terapia fotodinâmica (grupo experimental), ou apenas curativo convencional (grupo controle). Foram incluídos pacientes com idade superior a 18 anos com diagnóstico de úlceras de membros inferiores. Dez pacientes compuseram o grupo experimental e 10 o grupo controle. Os pacientes foram atendidos três vezes na semana e acompanhados por dois meses. O desfecho primário foi a avaliação do progresso de cicatrização e o secundário, a análise microscópica de esfregaço da ferida quanto a presença de células e micro-organismos.

Resultados: no grupo experimental duas feridas não cicatrizaram completamente enquanto no grupo controle nenhuma das 10 feridas cicatrizou completamente durante o acompanhamento de 60 dias. No grupo experimental 90% dos pacientes não apresentavam bactérias e fungos ao final de 30 dias versus 40% do grupo controle.

Conclusão: o presente estudo mostrou que a terapia fotodinâmica é um potencial tratamento eficaz no processo de cicatrização de úlceras de membros inferiores. Isto pode impactar em redução de custos e qualidade de vida. Estudos maiores e bem desenhados são necessários para corroborar os achados do presente estudo.

Palavras-chave: feridas, infecção da ferida, regeneração, cicatrização, fototerapia.