

ANALYSIS OF THE EFFICACY OF 430 NM LED IN REDUCING BACTERIAL CONTAMINATION IN RENAL SCAFFOLD SLICES

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ABSTRACT

Objective: This study aims to review the existing literature on the development and applications of 430 nm LED in bacterial inactivation in renal tissue scaffold slices, emphasizing its potential for clinical applicability. **Methodology:** A literature search was conducted in the PubMed database in August 2024, using the descriptors "phototherapy," "urology," "sterilization," or "bacterial inactivation," according to DeCS/BVS. Only original articles published between 2020 and 2024, available in English or Portuguese and open access, that directly addressed the topic were included. Non-original studies that dealt only with LEDs of wavelengths other than blue light were excluded. **Results:** The LED has proven to be a promising alternative to the widespread use of antibiotics, which contributes to bacterial resistance. However, challenges remain. **Conclusion:** The use of LED technology has shown to be effective, but further research is required to refine and optimize its application.

Keywords: Phototherapy; Urology; Sterilization; LED; Bacterial inactivation.

INTRODUCTION

According to the Basic Terminology Index of the Brazilian Ministry of Health, "contamination" consists of any transfer of a microorganism to another organism, object, or substance. However, when this dissemination reaches a human or animal organism and the proliferation of this infectious agent occurs, it actually becomes an "infection." In recent years, it must be highlighted that due particularly to the improper use of antibiotics, infections have become increasingly common and severe as a result of widespread bacterial resistance induced by such behavior (12).

Among these infectious processes that have become increasingly frequent are urinary tract infections (UTIs). According to Soares L.A. et al., UTIs are characterized by the presence of microorganisms in the urine. If untreated, this condition can progress to involve the entire urinary system, such as the bladder, leading to cystitis, or the kidneys, a more serious condition called pyelonephritis (6).

In pyelonephritis, the main symptoms include fever, flank pain, nausea, vomiting, burning sensation during urination, increased urinary frequency, and urgency (1). The most common pathogenic agents (in order of relevance) are *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Enterococcus*, *Staphylococcus*, and other Enterobacteriaceae (6).

Given the high incidence of bacterial infections and the increasing spread of bacterial resistance, alternative techniques to antibiotic therapy have been sought for treatment. Among the techniques developed is phototherapy using blue light LED (405–470 nm) (9). Its main mechanism of action occurs when light waves, at the correct frequency and intensity, are applied to the pathogen, leading to the production of reactive oxygen species (ROS), which cause internal destruction of these microorganisms (12).

In this perspective, the present study aims to review the existing literature on the development and applications of 430 nm LED in bacterial inactivation in renal tissue scaffold slices, emphasizing its potential for clinical applicability.

METHODOLOGY

This study was conducted as an integrative literature review focused on analyzing the effects of 430 nm LED use in renal tissue slices contaminated with bacteria. The literature search was carried out in the PubMed database in August 2024, using the descriptors "phototherapy," "urology," "sterilization," or "bacterial inactivation," according to DeCS/BVS. Only original articles published between 2020 and 2024, available in English or Portuguese and open access, that directly addressed the subject were included. Non-original studies that dealt exclusively with LEDs of wavelengths other than blue light were excluded. The analysis

focused on the critical evaluation of the methodologies used, the results obtained, and the clinical applicability of the LED.

RESULTS

Six studies were found that demonstrated certain applicability of 430 nm blue LED against bacteria commonly associated with urinary tract infections. Table 1 summarizes the main findings and methodological characteristics of each of these studies.

Table 1. Studies evaluating the use of blue LED for antimicrobial treatment

Autor/Ano	Objetivos	Métodos	Resultados
Hasenleitner M., et al. 2019	Demonstrar a eficácia fotodinâmica do uso DE lâmpadas de LED adaptadas para aplicação em PDI associada ao azul de metileno (MB), ou Clorofilina de Sódio e Magnésio (CHL), contra bactérias (Gram+ <i>Staphylococcus aureus</i> , Gram- <i>Escherichia coli</i>) e fungos (a levedura <i>Candida albicans</i>)	Neste estudo, foram apresentadas duas novas lâmpadas LED, a Repuls7PDI-red e a Repuls7PDI-blue, para fototerapia fotodinâmica (PDI). A Repuls7PDI-red emite luz a 635 nm com intensidade de $27,6 \pm 2,4 \text{ mW} \cdot \text{cm}^2$ a 13,5 cm do alvo, enquanto a Repuls7PDI-blue emite luz a 433 nm com intensidade de $6,4 \pm 0,5 \text{ mW} \cdot \text{cm}^2$ à mesma distância. Ambas foram testadas com azul de metileno (MB) e clorofilina de sódio e magnésio (CHL) para avaliar a eficácia contra <i>Staphylococcus aureus</i> , <i>Escherichia coli</i> , e <i>Candida albicans</i> .	As lâmpadas LED Repuls7PDI-red e Repuls7PDI-blue foram eficazes na fototerapia fotodinâmica. A Repuls7PDI-red (635 nm) eliminou mais de 99,999% de <i>Staphylococcus aureus</i> e 99,99% de <i>Candida albicans</i> , enquanto a Repuls7PDI-blue (433 nm) gerou espécies reativas de oxigênio que inativaram quase totalmente essas bactérias e fungos. Ambas as lâmpadas mostram potencial para aplicação clínica devido à sua eficácia e facilidade de uso.
Magni G, et al. 2022	Entender a resposta de infiltrados celulares, o processo angiogênico e a regeneração tecidual dentro de seis dias após o tratamento em um modelo de ferida aguda.	Uma ferida superficial foi feita em 30 camundongos CD1 machos. As lesões foram tratadas com luz LED azul ($20,6 \text{ J/cm}^2$), e as biópsias foram coletadas em 24, 72 e 144 horas. Análise histológica, de fluorescência e técnicas avançadas de microscopia foram utilizadas	Após 24 horas, houve aumento na infiltração celular, na densidade e degranulação de mastócitos, e na expressão do complexo principal de histocompatibilidade. Após seis dias, observou-se maior densidade vascular e expressão do fator de crescimento derivado de plaquetas. As feridas tratadas apresentaram deposição de colágeno e morfologia mais próximas à pele saudável.
Ibrahim R.A, et al, 2023	Determinar o efeito bactericida do laser diodo 445 nm e nanopartículas sobre <i>Enterococcus faecalis</i> .	Cinquenta dentes infectados com <i>Enterococcus faecalis</i> foram tratados com métodos diversos (controle, hipoclorito de sódio, laser, nanopartículas de curcumina e sua combinação com laser). A presença de bactérias remanescentes foi avaliada por contagem de colônias e microscopia confocal, e os dados foram analisados estatisticamente com ANOVA e o teste post hoc de Tamahne usando SPSS.	O grupo controle teve a maior carga bacteriana, enquanto o grupo com hipoclorito de sódio (NaOCl) apresentou a menor. O grupo com nanopartículas de curcumina e laser (CurNP-L) mostrou a maior redução bacteriana, seguido pelo grupo NaOCl, grupo laser, grupo com nanopartículas de curcumina (CurNP), e por fim o grupo controle.
Pedroso	Avaliar a eficácia do LED	Suspensões de *S. aureus* e *S.	As densidades de energia e de potência

J.T., et al. 2022	azul, como modalidade de aplicação em tratamentos estéticos para fotoinativação de cepas de <i>S. aureus</i> e <i>S. epidermidis</i> , in vitro, com comprimento de onda de 450±10 nm, em diferentes energias	epidermidis* foram irradiadas com diferentes densidades de energia e potência. Após a irradiação, as suspensões foram diluídas e alíquotas foram semeadas em placas de ágar. As contagens de UFC foram medidas em log10/mL e analisadas estatisticamente usando ANOVA e o teste de Tukey.	de LED utilizadas foram insuficientes para causar efeito antimicrobiano em culturas planctônicas de <i>S. aureus</i> ou <i>S. epidermidis</i> com uma única aplicação de luz.
Wozniak A., et al. 2022	Investigar o uso da fotoinativação em PDI e/ou aBL como monoterapia ou combinada com antibióticos para erradicação de cepas de Enterobacteriaceae: <i>E. cloacae</i> e <i>K. pneumoniae</i> .	Duas técnicas de fototerapia foram testadas para aumentar a eficácia de antimicrobianos contra <i>Enterobacter cloacae</i> e <i>Klebsiella pneumoniae</i> resistentes. As abordagens incluíram luz azul antimicrobiana (aBL) e fotoinativação com luz verde e Rosa Bengala (aPDI), analisando-se a suscetibilidade bacteriana a antibióticos por diferentes métodos.	A exposição de Enterobacteriaceae à luz azul antimicrobiana (aBL) e à luz verde com rosa bengala aumentou a suscetibilidade de <i>Klebsiella pneumoniae</i> e * <i>Enterobacter cloacae</i> * a antibióticos. A luz azul foi mais eficaz em meio TSB, enquanto a rosa bengala melhorou a fotoinativação em PBS. A eficácia variou entre os isolados, sugerindo que a sensibilização é dependente da cepa.
Yang w. et al. 2021	Este é um estudo piloto para a avaliação do componente bioativo natural curcumina como um possível agente anti-biofilme para controle de biofilme microbiano para garantir a saúde pública associado ao uso de aBL	A eficácia da PDI (fototerapia) com curcumina e LED foi avaliada em biofilmes de <i>S. saprophyticus</i> . Biofilmes foram tratados com diferentes concentrações de curcumina e intensidades de LED. O impacto foi medido na massa do biofilme, viabilidade celular, atividade metabólica e integridade da membrana citoplasmática. Grupos de controle receberam tratamentos separados com curcumina ou luz.	A PDI com curcumina e LED demonstrou eficácia significativa na prevenção e remoção de biofilmes de <i>S. saprophyticus</i> , além de causar inativação metabólica e dano à membrana intracelular. A microscopia eletrônica de varredura revelou lesões estruturais e alterações morfológicas no biofilme após o tratamento. A curcumina se mostrou um fotossensibilizador eficaz para o controle fotodinâmico desses biofilmes.

The analysis of the studies investigated phototherapy with LED for the treatment of bacterial infections, assessing the feasibility of this technology. The bacteria studied, commonly associated with renal infections such as pyelonephritis, included *Enterobacter* spp. (2)(5), *Klebsiella* spp. (11)(13), *Staphylococcus* spp. (4)(9)(14), and *E. coli* (3)(13), all of which are known for developing antimicrobial resistance (2)(13).

This approach is relevant because, according to Wozniak A. et al., bacterial resistance is one of the greatest threats to global health, as stated by the World Health Organization (WHO). The excessive use of antibiotics has led to the development of resistance mechanisms such as biofilm formation and secretion of antibiotic-inactivating enzymes (14), complicating treatment and increasing the need for new therapeutic strategies (2)(4)(5)(6)(11)(12).

Phototherapy has been used since the early 20th century, with 405 nm light demonstrating significant microbicidal activity against both Gram-negative and Gram-positive bacteria (11). More recently, LED technology has been adopted to overcome the limitations of traditional light sources, offering high luminous intensity with low heat production and a narrow wavelength range (4).

Currently, blue LED light (410–430 nm) has shown benefits in skin wound healing by reducing inflammation and stimulating angiogenesis (7)(9). LED technology is also used in the sterilization of meat products (3) and offers advantages such as ease of handling and the absence of bacterial resistance, thus surpassing traditional antibiotics (10)(4).

Despite these benefits, the use of LED still faces challenges. The selection of the optimal frequency and wavelength to destroy specific pathogens is not yet fully established, which may limit its efficacy (11). In addition, light intensity can cause thermal effects that alter the extracellular matrix and cell membrane permeability, potentially affecting adjacent tissue (7). Therefore, further research is required to optimize LED light application and ensure its efficacy and safety in the treatment of bacterial infections.

CONCLUSION

The integrative review on phototherapy with 430 nm blue LED highlights significant advances in the treatment of infections, particularly those caused by bacteria affecting renal tissue. LED has proven to be a promising alternative to the widespread use of antibiotics, which contributes to bacterial resistance. However, challenges remain, such as the need to adjust frequencies, intensities, and wavelengths for different pathogens and the risk of thermal damage to tissues. Ongoing research continues to seek solutions to these limitations and to refine the clinical application of LED in the treatment of renal diseases.

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