“VICTOR BABES” UNIVERSITY OF MEDICINE AND PHARMACY TIMISOARA
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DOCTORAL THESIS

EFFECT OF DIFFERENT LASER WAVELENGHTS ON THE PERIODONTIUM AND ADJACENT STRUCTURES

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CONTENTS

Periodontal disease is a major public health concern due to its prevalence and link to systemic health issues such as cardiovascular disease and diabetes. The major cause of periodontal disease is the accumulation of bacterial plaque, which triggers inflammatory reactions in the tissues surrounding and supporting the teeth. Traditional treatment methods, such as scaling and root planing (SRP), attempt to mechanically remove these microbial deposits. However, the complexity of periodontal pockets, as well as the persistence of certain periodontal infections, necessitate the use of adjuvant medicines to improve treatment efficacy and patient outcomes.

Photodynamic therapy (PDT) has emerged as a promising treatment option for periodontal disorders. PDT uses a photosensitizer, which is activated by light of a specified wavelength, resulting in the generation of reactive oxygen species with antimicrobial properties. The focused application of PDT in periodontal pockets is expected to improve bacterial decontamination while avoiding the negative effects associated with antibiotic therapy, such as drug resistance and systemic spread.

Furthermore, the use of modern diagnostic techniques such as PCR testing enables accurate quantification and identification of bacterial species before and after therapy. This methodological rigor is required to validate the specific antibacterial effects of PDT in the context of periodontal treatment. Understanding the varying effects on different pathogens can also help physicians tailor treatment approaches based on the microbial composition of periodontal locations. Furthermore, the study investigates the patient-centered outcomes of pain and discomfort related with various treatment options. The study tackles an often-overlooked facet of periodontal therapy: patient experience—by analyzing patient feedback via structured questionnaires after treatment. This comprehensive approach focuses not only on microbiological and clinical aspects, but also on enhancing patients' quality of life during periodontal treatments.

On the same broad topic, the complex environment of the oral cavity, which is characterized by a diverse microbial landscape and the presence of both soft and hard tissues, poses a unique challenge in the field of dental medicine, particularly in the management of prosthodontic and implant materials.

Traditional cleaning approaches, such as using chemical agents like chlorhexidine and mechanical treatments like airflow, have been the foundation of implant maintenance. These treatments seek to reduce the incidence of peri-implant infections by lowering microbial burden on these surfaces. However, the persistence of biofilms and the possibility of microbial resistance need the development of adjuvant treatments that can improve the efficacy of current decontamination techniques.

The combination of these technologies is thought to have a synergistic impact, potentially surpassing the results of traditional treatments.

The team at "Victor Babes" University of Medicine and Pharmacy undertook the study with the goal of carefully evaluating the comparative effectiveness of these sophisticated technologies against regular treatments.

Using modern imaging and microbiological techniques such as scanning electron microscopy (SEM) and optical coherence tomography (OCT) improves the study's ability to examine surface morphology and integrity after treatment. These technologies provide important insights into the microscale effects of various medicines, which are critical for understanding their safety and efficacy.

The incorporation of temperature readings during laser treatments solves a major safety concern about thermal harm to adjacent tissues and the material itself. The clinical implementation of these novel treatments requires that they maintain a safe operational temperature.

This interdisciplinary research effort, which included experts in microbiology, oral medicine, and optical electronics, demonstrates the collaborative approach required to address complicated clinical challenges in dentistry. By carefully analyzing the impact of these modern decontamination technologies, the study hopes to make a substantial contribution to the field of dental implantology by offering evidence-based guidelines for improving clinical procedures and patient outcomes.

The current PhD research at the "Victor Babes" University of Medicine and Pharmacy in Timisoara includes a thorough investigation into the efficacy of photodynamic therapy in conjunction with advanced laser treatments for the decontamination of dental materials and periodontal pockets.

This PhD research takes an interdisciplinary approach, combining skills in periodontology, microbiology, laser technology, oral surgery, implantology, and dental materials. By the end of the experiments, the researchers hope to have provided substantial new insights into the optimization of dental treatments employing PDT and laser technology. The findings are expected to not only advance our understanding of microbial dynamics on tooth surfaces and within periodontal pockets, but also to potentially change routine techniques in dental decontamination and disease treatment.

The thesis is structured in four main parts 1. Introduction, 2. General Part with three chapters, 3. Special part- with three chapters, and 4. Conclusions.

The general section of the thesis will describe Physiology of periodontal tissue and the biological mechanism of periodontal disease, methods of treatment and maintenance in periodontal therapy, types of lasers used in non-surgical periodontal therapy and mechanism of action of laser therapy and in the third part methods of evaluating periodontal status and the effectiveness of periodontal treatment.

The specific section is structured in three chapters

In the first chapter of the specific section named “The Efficiency of Photodynamic Therapy in the Bacterial Decontamination of Periodontal Pockets and Its Impact on the Patient”,we aimed to compare the reduction in the number of specific periodontopathogens in two test groups according to different therapeutic approaches in periodontal disease and to show possible differences. This article is based on a prospective clinical study involving eighteen subjects with forty-four average periodontal pockets assigned to study groups treated by two different methods, SRP and SRP followed by a single PDT application. Efficiency in removing specific bacterial species was evaluated by PCR testing, at baseline and immediately after treatment. The hypothesis that using SRP + aPDT results in an increased decontamination potential was confirmed statistically, when all five specific bacterial pathogens were investigated together. When the pathogens were considered separately, two of the five microorganisms tested were significantly lower in the SRP + PDT group ($p < 0.00$), and important germ counts reductions were also observed for the other three. There is also a statistically significant relation between the pain at 48 h postoperatively and the type of treatment the patients received, as resulted from the Questionnaire Form. Our results demonstrate that aPDT, as an adjunctive treatment to conservative mechanical cleaning of root surfaces at sites affected by periodontitis, represents an effective tool in terms of reducing specific periodontopathogen germs.

In the second chapter “Microbiological and Imaging-Based Evaluations of Photodynamic Therapy Combined with Er:YAG Laser Therapy in the In Vitro Decontamination of Titanium and Zirconia Surfaces”” we took in consideration thet the oral cavity’s soft and hard tissues create a conducive environment for microbial proliferation and biofilm development, facilitating the colonization of prosthodontic and implant materials such as titanium (Ti) and zirconia (Zr). Startin from this premise we aimed to compare the efficacy of conventional decontamination methodologies (i.e., chemical and mechanical, using 0.12% digluconate chlorhexidine (CHX) solution-treatment and airflow) to adjunctive laser-based interventions on Ti and Zr substrates inoculated with Staphylococcus (S.) aureus ATCC 25923. Additionally, this investigation sought to elucidate the impact of these treatments on temperature variations and surface integrity, analyzing the laser irradiation effects on these prevalent dental materials. Experimental configurations were delineated for both Ti and Zr samples across four groups: (1) a conventional treatment group (CV); (2) a photodynamic therapy group (PDT); (3) an Er:YAG laser treatment group (Er); (4) a combined PDT and Er:YAG treatment group (PDTEr). Also, a negative control group (C) that received no treatment was considered. The decontamination of the inoculated disc samples was evaluated by quantifying the microbial colonies in colony-forming units per milliliter (CFU/mL). Temperature variations on the surface of the samples were determined during laser treatments. Surface modifications were investigated using scanning electron microscopy (SEM) and optical coherence tomography (OCT).

For statistical analysis, Fisher 95% confidence intervals, Hsu’s MCB method, and the Kruskal–Wallis test were applied. With regard to the 105 CFU/mL of the negative control group, results indicated average values equal for each study group to (1) 2.66 CFU/mL for Ti and 2 CFU/mL for Zr for the CV group; (2) 0.33 CFU/mL for Ti and 1 CFU/mL for Zr for the PDT group; (3) 1.25 CFU/mL for Ti and 0 CFU/mL for Zr for the Er group; (4), and 0 CFU/mL for both Ti and Zr for the PDTEr group. Therefore, the combined PDT and Er:YAG treatment (PDTEr) and the singular PDT modality outperformed conventional decontamination methods in eradicating S. aureus biofilms from both Ti and Zr surfaces. Notably, the PDTEr regime achieved a comprehensive elimination of microbial colonies on treated substrates. Surface examination employing OCT demonstrated discernible alterations in the surface morphology of samples subjected to Er:YAG and combined PDT and Er:YAG treatments. Temperature checks during treatments showed no major changes, suggesting the applied laser methods are safe. In conclusion, PDTEr and PDT eliminated bacteria more effectively, but Zr surfaces were more resilient, making them better for microbe-controlling applications. Also, the study demonstrated that the (less costly but lower resolution) OCT method can replace SEM for such investigations.

In the last chapter of the specific section entitled “Effectiveness of diode laser therapy in non-surgical treatment of peri-implantitis” we took the knowledge of prior studyes to investigate more.To attain these therapeutic objectives, it is imperative that the implant surface remains free from any extraneous cells and toxins. Ensuring a clean and biocompatible surface allows the inflammation in the surrounding tissue to subside, facilitating the re-establishment of a healthy peri-implant interface. The successful decontamination of the implant surface is thus a critical step in the overall treatment process, enabling host cells to reattach to the implant and restore the stability and function of the dental implant. Ongoing research and advancements in decontamination techniques are essential for improving the outcomes of peri-implantitis treatment and ensuring the long-term success of dental implants.

As the periimplant defect becomes deeper, the process of removing infected material from the implant surface through non-surgical means becomes more challenging and less effective. This difficulty is further compounded by the presence of macro- and micro threads on the implant. Nevertheless, non-surgical therapy enhances the inflammatory condition of the tissue. The clinicians can evaluate the tissue reaction to antibacterial therapy and verify the effectiveness of the patient's oral hygiene routine at home. Prior to any surgical intervention, it is imperative to first undergo non-surgical therapy. The quest for reliable treatment protocols is still in progress. This preliminary study focuses on a case of chronic peri-implantitis in a 61-year-old female patient.

The findings presented in this study underscore the efficacy of diode laser therapy as a treatment modality for peri-implantitis. The laser-assisted approach not only facilitated the reduction of probing depths but also contributed to the overall stabilization of the peri-implant environment. The absence of antibiotics in the treatment regimen further emphasizes the capability of mechanical debridement and laser therapy in managing peri-implant infections effectively. This minimally invasive approach aligns with contemporary trends in periodontal therapy, aiming to reduce reliance on pharmacological interventions.

Despite these promising results, it is imperative to recognize the need for further research to substantiate the findings. The current study, being preliminary in nature, provides an initial insight into the potential benefits of diode laser treatment. However, additional randomized controlled clinical trials are necessary to comprehensively evaluate the efficacy of diode laser therapy compared to conventional treatment modalities. Such studies would provide more robust evidence and potentially lead to the establishment of standardized protocols for the management of peri-implantitis.

While the current evidence on the efficacy of diode lasers in peri-implant therapy is promising, it is also varied. The discrepancies in study findings highlight the need for standardized research protocols and more rigorous clinical trials. By addressing the variables such as laser parameters, wavelengths, and treatment protocols, future studies can provide clearer insights into the true benefits of diode lasers. This will help in developing more effective, evidence-based treatment strategies for peri-implant diseases, ultimately enhancing patient outcomes and advancing the field of dental implantology .

The general conclusions of the doctorate thesis, described in detail in the last chapter were:

- Comparative studies to evaluate patient-reported outcomes such as pain and satisfaction with different periodontal treatments can enhance understanding of the subjective benefits of aPDT.
- Exploration of the cost-effectiveness of integrating aPDT into routine periodontal care is crucial, as this will help determine the practicality of widespread adoption in various healthcare settings.
- This phD research also demonstrated that the combined photodynamic therapy (PDT) and Er laser treatment (PDTEr), as well as PDT alone, were more effective than conventional decontamination methods (chemical and mechanical) in eradicating Staphylococcus aureus biofilms from both titanium (Ti) and zirconia (Zr) surfaces.

- PDTEr achieved a complete elimination of microbial colonies on treated substrates, showcasing its potential as a superior method for disinfecting dental implant materials.
- Zirconia surfaces exhibited greater resilience to microbial colonization compared to titanium, suggesting that Zr may be a preferable material for applications where microbial control is critical.
- Further studies should explore the long-term effectiveness of PDT and PDTEr treatments in clinical settings to confirm their utility and sustainability in routine dental practice.
- Research focusing on the comparative resilience of different dental materials, such as titanium versus zirconia, under various decontamination methods could guide material selection in dental implantology.
- Standardized protocols for both technologies are crucial for ensuring consistent and effective treatment outcomes. Future research should focus on the long-term outcomes of using Er:YAG laser in periodontal treatment, as well as exploring patient experiences and satisfaction levels with both PDT and Er:YAG laser treatment.