Original Research

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Experimental evaluation of the effectiveness of non-pigmented laser photoablation in the treatment of periodontal diseases

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Abstract

INTRODUCTION. High-quality treatment of periodontitis and prevention of further progression of periodontal diseases can be achieved with complex and systematic adherence to algorithms for performing manipulations at all stages of therapy using physical factors. This is possible with the use of laser radiation with the effects of non-pigmented laser photoablation.

AIM. Improving the effectiveness of periodontal disease treatment using pigment-free laser photoablation.

MATERIALS AND METHODS. An experimental comparative study of 70 animals with model periodontitis under the influence of laser radiation with non-pigmented photoablation, photodynamic laser therapy and standard drug therapy was conducted in 3 groups. Morphological studies were performed for group I (main) and group II (comparison) were withdrawn from the experiment on the 7th, 14th and 21st days of treatment. Animals of group III (control) were withdrawn from the experiment on the 21st day.

RESULTS. Morphological analysis showed that the use of non-pigmented laser photoablation helps to reduce inflammation in periodontal tissues, accelerate regeneration due to stimulation of fibroblast production and stimulation of neoangiogenesis. On the 21st day of the experiment, in the group using non-pigmented laser photoablation, based on morphological analysis, acceleration of the processes of formation of the periodontal ligament with even bundles of collagen and elastic fibers perpendicular to the tooth root was confirmed.

CONCLUSIONS. Our experimental studies confirm the effectiveness of non-pigmented laser photoablation in the treatment of periodontitis.

Keywords: periodontitis, non-pigmented laser photoablation, diode laser

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Экспериментальная оценка эффективности применения беспигментной лазерной фотоабляции при лечении заболеваний пародонта

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Резюме

ВВЕДЕНИЕ. Качественное лечение пародонтита и предупреждение дальнейшего прогрессирования заболеваний пародонта возможно осуществить при комплексном и планомерном соблюдении алгоритмов выполнения манипуляций на всех этапах терапии с использованием физических факторов. Такое возможно при использовании лазерного излучения с эффектами беспигментной лазерной фотоабляции.

ЦЕЛЬ. Повышение эффективности лечения заболеваний пародонта с применением беспигментной лазерной фотоабляции.

МАТЕРИАЛЫ И МЕТОДЫ. Экспериментальное сравнительное исследование у 70 животных с модельным пародонтитом при воздействии лазерного излучения с беспигментной фотоабляцией, фотодинамической лазерной терапии и стандартной медикаментозной терапией проводили в трех группах. Морфологические исследования проводили для группы I (основной) и группы II (сравнения) выводили из эксперимента на 7-е, 14-е и 21-е сутки лечения. Животных группы III (контрольной) выводили из эксперимента на 21-е сутки.

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РЕЗУЛЬТАТЫ. Морфологический анализ показал, что применение что беспигментной лазерной фотоабляции способствует снижению воспаления в тканях пародонта, ускорению регенерации за счет стимуляции выработки фибробластов и стимуляции неоангиогенеза. На 21-е сутки эксперимента в группе с применением беспигментной лазерной фотоабляции на основании морфологического анализа подтверждено ускорение процессов формирования периодонтальной связки с ровными пучками коллагеновых и эластических волокон, перпендикулярных корню зуба.
ВЫВОДЫ. Проведенные нами экспериментальные исследования подтверждают эффективность применения беспигментной лазерной фотоабляции при лечении пародонтита.

Ключевые слова: пародонтит, беспигментная лазерная фотоабляция, диодный лазер

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INTRODUCTION

Periodontal diseases are one of the most common pathologies that occur in all age groups of the population with a sharp further progression. In the treatment of periodontal diseases, a comprehensive approach is used, consisting of high-quality removal of subgingival dental plaque, antiseptic treatment, as well as surgical interventions aimed at eliminating gum recessions and filling bone defects and stimulating the regeneration of periodontal tissues [1; 2].

In recent years, photodynamic therapy techniques have become quite widespread in the treatment of periodontal diseases. To achieve a therapeutic effect when using PDT, photosensitizers are used that are activated with the release of singlet oxygen, low-intensity laser radiation with a wavelength corresponding to the absorption peak of the sensitizer [3; 4].

To date, a new diode laser has been created, which has passed laboratory and clinical tests, capable of generating unique harmonics of laser radiation in a nanosecond pulsed radiation mode. The radiation of such a laser has a bacteriostatic effect, is capable of performing non-pigmented photoablation without the use of photosensitizers, and also has a biostimulating effect to accelerate the regeneration of periodontal tissues after treatment [5; 6].

AIM

Improving the effectiveness of periodontal disease treatment using pigment-free laser photoablation.

MATERIALS AND METHODS

In the experimental part of the study, the effectiveness of non-pigmented laser photoablation and traditional photodynamic therapy of periodontitis was assessed on a model of experimental animals – sexually mature male Wistar rats – using morphological analysis. The studies were conducted in accordance with the rules for working with animals based on the provisions of the Helsinki Declaration and the recommendations contained in EU Directive 86/609/ECC and the Council of Europe Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes. The study included 70 animals, which were divided into 3 groups: I – the main (n = 30), II – comparison (n = 30) and III – control (n = 10). All animals were modeled periodontitis on the central incisors using the technique developed by V.G. Atrushkevich et al., in which prednisolone was administered intramuscularly at a rate of 12 mg/kg of animal weight on the 1st, 3rd and 5th days of the experiment in order to provide an immunosuppressive effect [7]. On the 5th day, the animals were injured by the circular ligament (dentogingival junction) of the lower incisors using a metal iron by peeling off the gums from the vestibular and lingual sides, then a silk ligature was placed deep under the gum in the resulting dentogingival pocket, covering the teeth in the shape of a figure eight. The ligature was installed under premedication and intravenous anesthesia and additionally secured with phosphate cement, left for 14 days, the animals were fed soft food (Fig. 1).

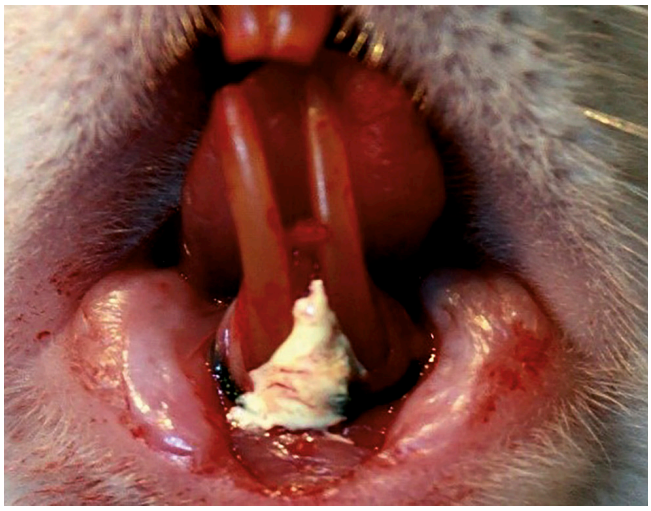

Fig. 1. Photograph of an experimental animal – fixation of the ligature with cement

Рис. 1. Фотография лабораторного животного – фиксация лигатуры с помощью цемента

After 14 days, the ligature was removed, the animals were divided into groups, and manipulations were carried out in accordance with the objectives of the study. After this, the stage of exposure to the simulated periodontitis zone in each group was started using various factors. In Group I, laser radiation of a diode laser with a wavelength of 1265 nm in a nanosecond pulsed radiation mode with the effect of pigment-free laser photoablation was used for exposure. The pockets were processed using a fiber optic light guide with a diameter of 400 μm in a contact manner. The treatment was carried out with circular movements around the lower incisors for 3 minutes. The radiation parameters were set as follows: the average radiation power, set on the control panel of the device, was 1.8 W, which corresponded to the average exposure power at 180 s of radiation – 360 J/cm^2, the pulsed nanosecond radiation mode was selected with a pulse duration of 100 ns and a pause duration of 200 ns. The radiation parameters were selected optimally based on previously conducted studies [8]. Non-pigmented laser photoablation was performed daily for 7 days in a row at the same fixed time for each animal in Group I (main).

In Group II, a standard photodynamic therapy procedure was performed using an exogenous photosensitizer based on chlorin E6, which was applied to the periodontal pocket for 10 minutes, then the residue was washed off using a saline solution, then laser irradiation was carried out with a wavelength of 660 nm in a continuous radiation mode with an exposure of 300 s. The photodynamic therapy procedure in this group was repeated in the same way as in Group I (main), for 7 days at the same fixed time. In Group III (control), antiseptic treatment of inflamed periodontal tissues was carried out as drug therapy. The course of treatment was 7 days. To obtain representative statistically reliable data, 10 animals were withdrawn from the experiment in the main group and the comparison group for morphological examination on the 7th, 14th and 21st days after the start of the sessions of non-pigment laser photoablation and traditional photodynamic therapy; in the control group, animals were withdrawn from the experiment only on the 21st day. The obtained digital data were processed using the variation statistics method using the Student's T-test. The critical level of significance was considered reliable at p <0.05.

RESULTS

On the 21st day in group I (main), morphological examination showed that periodontal pockets were not detected. A regenerated periodontal ligament, rich in fibroblasts, with parallel bundles of collagen and elastic fibers perpendicular to the tooth root, with single dilated vessels only at the border with the bone beams of the alveolar bone is noted. Preserved small foci of granulation tissue with full-blooded vessels without edema and inflammatory infiltration are detected (Fig. 2).

In group II (comparison), on the 21st day of observation, moderately pronounced edema of the regenerated periodontal ligament tissue, rich in fibroblasts, with dilated full-blooded vessels at the border with the bone trabeculae of the alveolar bone is noted. Preserved small foci of granulation tissue with pronounced edema, full-blooded vessels and single leukocytes are encountered (Fig. 3).

In group III (control) on the 21st day of observation, morphological analysis revealed pronounced periodontal pockets with a high content of detritus penetrated by leukocytes, partially epithelialized, with acanthosis of the epithelium and the formation of its strands growing into the granulation tissue. The periodontal ligament was significantly destroyed and replaced by granulation tissue with diffuse infiltration by leukocytes with an admixture of macrophages. Among the growths

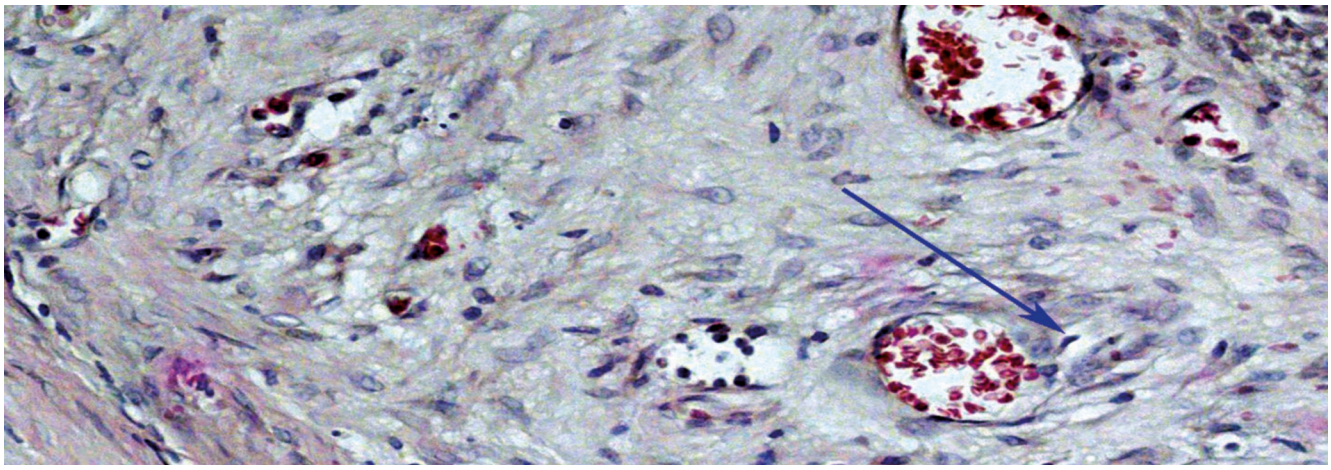

Fig. 2. Morphogram of periodontal tissues in group I on the 21st day of observation: arrow – preserved small foci of granulation tissue with full-blooded vessels without edema and inflammatory infiltration, with single macrophages and lymphocytes (hematoxylin-eosin, Zeiss, x120)

Рис. 2. Морфограмма тканей пародонта в группе I на 21-е сутки наблюдения: стрелкой обозначены сохраненные мелкие очаги грануляционной ткани с полнокровными сосудами, без отека и признаков воспалительной инфильтрации, с единичными макрофагами и лимфоцитами (гематоксилин-эозин, Zeiss, ×120)

of granulation tissue with full-blooded vessels, diffuse infiltration by leukocytes with an admixture of macrophages, at the site of the periodontal ligament, single microabscesses were found. Moderately pronounced edema of the periodontal ligament tissue with partially organized remnants of cellular detritus was revealed. Restored periodontal ligament with multidirectional bundles of collagen and elastic fibers, large fibroblasts, and newly formed bone beams of the alveolar bone (Fig. 4).

Thus, based on the results of morphological analysis, a qualitative assessment of the impact of various types of laser radiation in the complex therapy of model periodontitis in experimental animals was carried out. The results of the study showed that the use of a new laser technology of pigment-free laser photoablation with a wavelength of 1265 nm promotes stimulation of vascular growth in periodontal tissues compared to traditional photodynamic laser therapy.

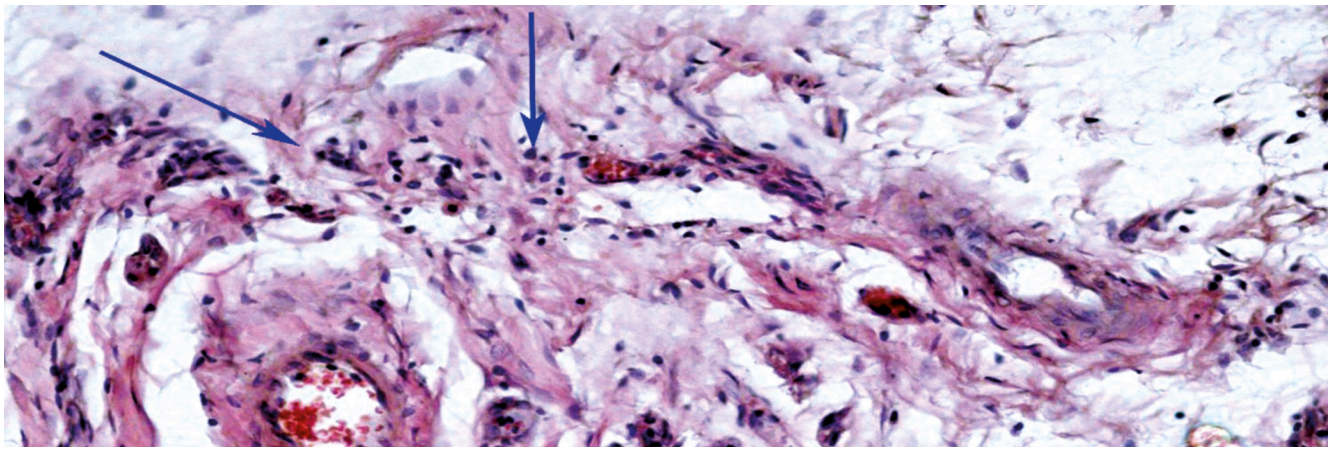

Fig. 3. Morphogram of periodontal tissues in group II on the 21st day of observation: arrows – preserved foci of granulation tissue with pronounced edema, full-blooded vessels and single leukocytes with an admixture of macrophages. (hematoxylin-eosin, Zeiss, x120)

Рис. 3. Морфограмма тканей пародонта во II группе на 21-е сутки наблюдения: стрелками обозначены сохраняющиеся очаги грануляционной ткани с выраженным отеком, полнокровными сосудами и единичными лейкоцитами с примесью макрофагов (гематоксилин-эозин, Zeiss, ×120)

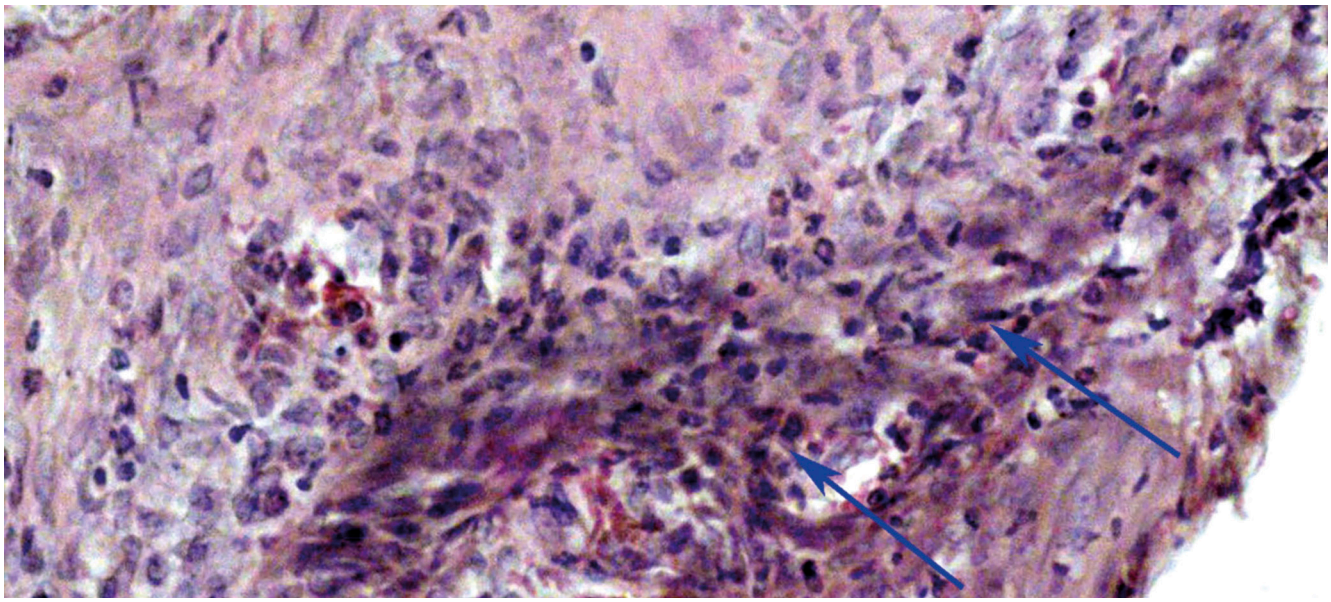

Fig. 4. Morphogram of periodontal tissues in group III on the 21st day of observation: arrows – periodontal ligament destroyed and replaced by granulation tissue with diffuse infiltration of leukocytes with an admixture of macrophages, acanthosis of the epithelium – its strands grow into the granulation tissue. (hematoxylin-eosin, Zeiss, x120)

Рис. 4. Морфограмма тканей пародонта в группе III на 21-е сутки наблюдения: стрелками указано разрушение периодонтальной связки с ее замещением грануляционной тканью, диффузной инфильтрацией лейкоцитами с примесью макрофагов, акантозом эпителия – его тяжи прорастают в грануляционную ткань (гематоксилин-эозин, Zeiss, ×120)

DISCUSSION

Thus, based on the results of morphological analysis, a qualitative assessment of the impact of various types of laser radiation in the complex therapy of model periodontitis in experimental animals was carried out. The results of the study showed that the use of a new laser technology of pigment-free laser photoablation with a wavelength of 1265 nm promotes stimulation of vascular growth in periodontal tissues compared to traditional photodynamic laser therapy.

The conducted experimental morphological study allowed to prove that pigment-free laser photoablation helps to reduce inflammation, accelerate regeneration by stimulating the production of fibroblasts and stimulating neoangiogenesis. On the 21st day of the experiment in the group using pigment-free laser photoablation, based on morphological analysis, acceleration of the processes of formation of the periodontal ligament with even bundles of collagen and elastic fibers perpendicular to the root of the tooth was confirmed.

CONCLUSIONS

A comparative assessment in an experimental in vivo study on animals (rats) using morphological and morphometric analysis made it possible to prove the effectiveness of non-pigmented laser photoablation by reducing inflammation, accelerating tissue regeneration, and stimulating neoangiogenesis by increasing the number of full-blooded vessels by 3.5 times compared to traditional photodynamic therapy ($p < 0.05$).

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AUTHOR'S CONTRIBUTION

Andrey A. Chunikhin – significant contribution to the concept and design of the study; preparing the article or critically revising it for significant intellectual content; collecting data, analyzing and interpreting data; final approval of the article for publication.

Natalya E. Andriyanova – significant contribution to the concept and design of the study; conducting research; collecting and analyzing data; preparing the article.

Ernest A. Bazikyan – preparing the article; critically revising the article for significant intellectual content; final approval of the article for publication.

ВКЛАД АВТОРОВ

А.А. Чунихин – существенный вклад в замысел и дизайн исследования; подготовка статьи или ее критический пересмотр в части значимого интеллектуального содержания; сбор данных, анализ и интерпретация данных; окончательное одобрение варианта статьи для опубликования.

Н.Е. Андриянова – существенный вклад в замысел и дизайн исследования; проведение исследований, сбор и анализ данных, подготовка статьи.

Э.А. Базикян – подготовка статьи; критический пересмотр статьи в части значимого интеллектуального содержания; окончательное одобрение варианта статьи для опубликования.