



Laser Coagulation of the Pilonidal Sinus with Morphological Assessment

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Aim: to determine the safest and most effective parameters for the laser coagulation method of uncomplicated pilonidal sinus.

Materials and methods. Three single-center randomized pilot studies were conducted, involving 21 patients with chronic inflammation of the pilonidal sinus. During the operation, depending on the randomization group, fiber laser devices with wavelengths of 970, 1560, and 1940 nm were used, with end or radial light guides and varying amounts of energy. To determine the effectiveness, safety, and characteristics of laser exposure, the sinus tract was excised, and the removed specimen was subjected to morphological examination. This study demonstrated the depth of thermal laser exposure on the structures of the pilonidal sinus at different wavelengths, amounts of energy transferred, and types of fiber instruments.

Results. Lasers with wavelengths of 970, 1560, and 1940 nm can be used for laser coagulation of the pilonidal sinus. The use of end-face and radial light guides is acceptable, but from the point of view of technical characteristics and safety, the use of an end-face type is most justified. The study demonstrated a direct relationship between the level of energy delivered and an increase in the depth of thermal damage, but it is not possible to definitively determine the optimal amount of energy per 1 cm of pilonidal sinus length due to the small sample of patients.

Conclusions. Laser coagulation is a minimally invasive, highly effective method of treating the pilonidal sinus, with an efficiency rate of 90–97 %. The results of the studies showed that lasers of different wavelengths can be used for this surgical method. But considering the penetration depth of laser radiation with a wavelength of 1940 nm, its use is preferable. The use of an end-face light guide is the most appropriate in terms of its technical characteristics, safety, and ease of use. The results of the study also demonstrated a direct relationship between the level of energy delivered and the depth of thermal impact on tissue.

Keywords: epithelial coccygeal tract, pilonidal cyst, laser coagulation of epithelial coccygeal tract, fiber laser, end-face light guide, radial light guide

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Лазерная коагуляция эпителиального копчикового хода с морфологической оценкой

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Цель: определить наиболее безопасные и эффективные параметры для метода лазерной коагуляции неосложненного эпителиального копчикового хода.

Материалы и методы. Проведено три пилотных одноцентровых рандомизированных исследования, в которые вошел 21 пациент с хроническим воспалением эпителиального копчикового хода. Во время операции в зависимости от группы рандомизации применялись лазерные аппараты с длиной волны 970, 1560 и 1940 нм, с использованием торцевого или радиального световода и различных уровней энергии. Для оценки эффективности, безопасности и особенностей лазерного воздействия выполняли иссечение эпителиального копчикового хода с последующим морфологическим исследованием удаленного препарата. В исследовании определена глубина термического воздействия лазера на структуры эпителиального копчикового хода при различных длинах волн, уровнях подводимой энергии и типах световодов.

Результаты. Для выполнения лазерной коагуляции эпителиального копчикового хода возможно использование лазеров с длиной волны 970, 1560 и 1940 нм. Допустимо применение торцевых и радиальных световодов, однако с точки зрения технических характеристик и безопасности наиболее оправданно использование

торцевого волокна. В исследовании продемонстрирована прямая взаимосвязь между уровнем подводимой энергии и увеличением глубины термического повреждения, однако однозначно определить оптимальную величину энергии на 1 см длины хода не представляется возможным из-за малой выборки пациентов.

Выводы. Лазерная коагуляция — малоинвазивный высокоэффективный метод лечения эпителиального копчикового хода, эффективность которого достигает 90–97 %. По результатам проведенных исследований было установлено, что для данного хирургического метода возможно применение лазеров различных длин волн. Однако, учитывая глубину проникновения лазерного излучения с длиной волны 1940 нм, его применение является предпочтительным. Использование торцевого световода наиболее оправданно с точки зрения его технических характеристик, безопасности и удобства в работе. Результаты работы также продемонстрировали прямую взаимосвязь между уровнем подводимой энергии и глубиной термического воздействия на ткани.

Ключевые слова: эпителиальный копчиковый ход, пилонидальная киста, лазерная коагуляция эпителиального копчикового хода, волоконный лазер, торцевой световод, радиальный световод

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Introduction

Pilonidal sinus disease is a chronic inflammatory condition of the subcutaneous tissue, characterized by one or more sinus tracts lined with stratified squamous epithelium containing hair follicles, sebaceous glands, and opening onto the skin of the gluteal fold with one or more punctate openings (Fig. 1) [1].

Treatment of the pilonidal sinus disease is only surgical and directly depends on the course of the inflammatory process: in acute inflammation, emergency opening and drainage of the abscess is performed, while in chronic inflammation, various surgical techniques are used.

All methods of treating chronic epithelial coccygeal tract can be conditionally divided into “classical” (with excision of the tract itself) and minimally invasive (without its excision). Classical methods include operations with or without wound closure, as well as plastic surgery with flap transfer. These surgical techniques have a low recurrence rate (2.5–8 %), but they have a number of disadvantages, including severe postoperative

pain, the presence of an extensive wound in the sacrococcygeal region with a high probability of infection, as well as the risks of prolonged wound healing and severe scarring of the intergluteal region [2–5]. This leads to a significant increase in the period of temporary disability of patients.

In this regard, special attention is currently being paid to minimally invasive methods of treating pilonidal sinus, which include techniques using chemical agents (phenol) and fibrin glue, endoscopic methods (EPSiT, VAAPS), and techniques using laser technologies. The small size of the postoperative wound provides advantages of these interventions over methods with excision of the tract, as it allows maintaining the patients’ ability to work and achieving a good cosmetic effect [2–6]. In addition, these methods can be applied in day hospital settings [7].

The most common laser techniques for the treatment of chronic inflammation of the pilonidal sinus are SiLAC (Sinus tract Laser Closure) and PE+LAT (Pit Excision + Laser Ablation

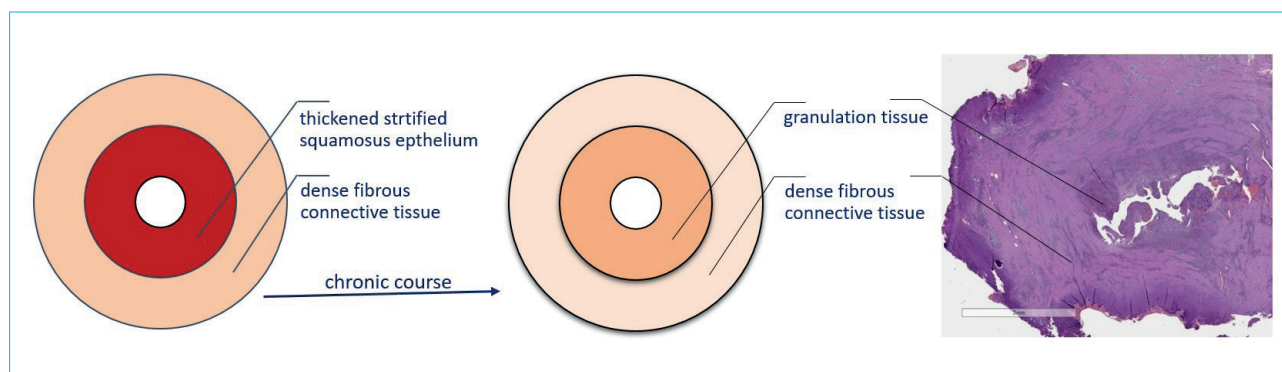


Figure 1. Microscopic structure of the pilonidal sinus

Technique), first proposed about 10 years ago in Denmark [8, 9]. They consist of eliminating the epithelial lining of the sinus tract by thermal exposure to laser radiation. To perform this technique, foreign authors most often use 1.5-micron lasers with a wavelength of 1470–1560 nm. According to international literature, the treatment effectiveness reaches 90 % [10]. Recently, fiber lasers with a wavelength of 1940 nm and the ablation depth of 0.7 mm have been increasingly used in medical practice. Increasing the laser wavelength and decreasing the operating power reduce the areas of carbonization and thermal impact. Thus, the use of long-wave lasers makes it possible to achieve effective targeted laser exposure with a lower risk of thermal damage to surrounding tissues [11].

The effectiveness of the laser coagulation method for the epithelial coccygeal tract has been proven, which allows it to be successfully used in the clinical practice of a proctologist. A systematic review of the literature in 2021 involving 971 patients demonstrated high treatment efficacy (94.4 %) with a follow-up period of approximately 12 months [12]. However, there is still no consensus on what parameters should be used for laser coagulation of the sinus, whether there is a difference in the wavelength used, the type of light guide, and the amount of energy transmitted. These questions are of practical interest and require further study.

Materials and methods

At the National Medical Research Center of Coloproctology named after A.N. Ryzhikh, from 2023 to May 2026, laser coagulation (wavelength 1940 nm) is used to treat chronic epithelial coccygeal tract. During this period, 91 patients were treated using this wavelength. The effectiveness of the method was 93.4 %: relapse of the disease was diagnosed in 6 (6.6 %) patients with a median observation period of 12 months.

According to the literature, microscopically the epithelial coccygeal tract is represented by multilayered squamous epithelium and surrounding coarse fibrous connective tissue. However, as acute inflammation transitions into a long-term chronic process, the multilayered epithelium of the canal is replaced by granulation tissue [13, 14]. Given this fact, the condition for radical cure and, accordingly, prevention of relapse of the disease can be considered the complete destruction of the entire epithelial or granulation lining of the sinus tract. Considering the wide range of lasers, their technical features, and the variety of fiber

laser instruments, the following tasks were formulated to determine the most effective parameters of laser exposure for the planned studies:

- 1) to determine the optimal wavelength of laser radiation for exposure to granulation tissue;
- 2) to evaluate the effect of different levels of supplied energy on the structures of the tract;
- 3) to determine the most suitable type of laser fiber instrument for performing the operation.

To solve these tasks, three single-center randomized prospective pilot studies were conducted, which included 21 patients with chronic inflammation of the pilonidal sinus. The main objective of the studies was to determine the most effective parameters of laser coagulation in patients with uncomplicated chronic inflammation of the pilonidal sinus.

The first pilot study assessed the effect of laser wavelength on the structure of the epithelial coccygeal tract. It included 9 patients, randomly distributed into three equal groups (3 people each). In the first group, a laser system with a wavelength of 970 nm was used, in the second — 1560 nm, in the third — 1940 nm. In all groups, other parameters remained constant: power — 9 W, continuous mode, and energy input — 100 J per 1 cm of tract length. Following laser treatment, the epithelial coccygeal tract was excised, and the removed tissue was sent for pathological examination to assess changes in granulation tissue.

The second study was designed to evaluate the effect of the amount of energy transferred on the structures of the canal. In all 6 patients in this group, the epithelial coccygeal canal was marked on the skin and divided in half before surgery. During the operation, the proximal part of the sinus tract was exposed to laser radiation with an energy transfer of 100 J per 1 cm, and the distal part was exposed to laser radiation with an energy transfer of 200 J per 1 cm. (Fig. 2). In this study, only the total amount of energy transferred was changed, while the wavelength remained unchanged at 1940 nm, the power used was 9 W, and the work was carried out in continuous mode using an end-face fiber tool. After the procedure, sinus was excised within the subcutaneous fatty tissue and divided according to the preoperative markings. The two parts of the sinus were sent for pathomorphological examination to determine the depth of coagulation necrosis at different amounts of energy transferred.

According to the literature, in Russia and abroad, both end-face and radial-emitting laser fiber can be used for laser coagulation of the sinus tract, however, there is no comparative assessment of the effectiveness of using one or another type

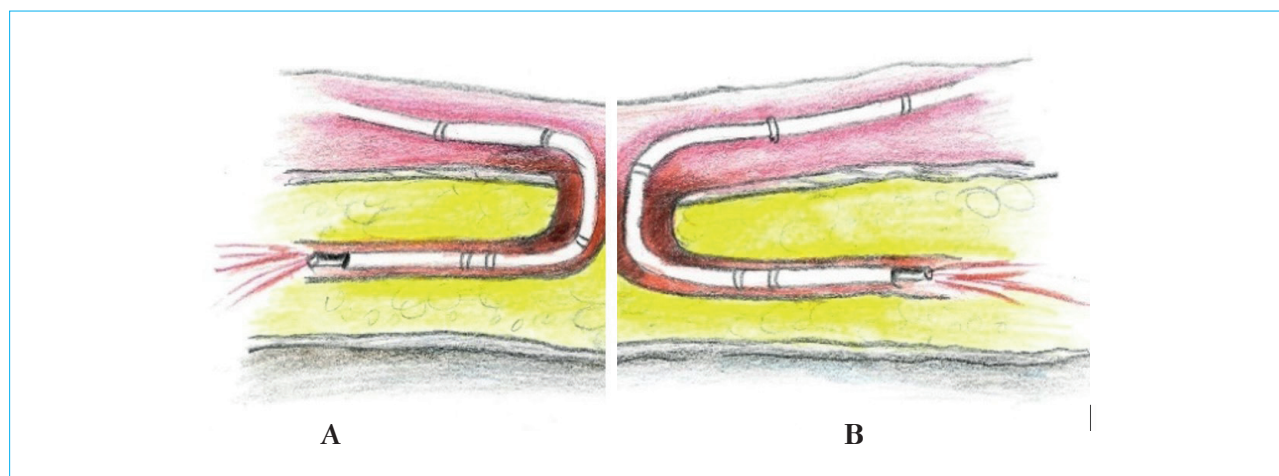


Figure 2. Stages of laser coagulation of the tract using an end-on light guide: A — exposure in the proximal section (100 J/cm); B — exposure in the distal section (200 J/cm)

[12, 15, 16]. To this end, a third prospective pilot study was conducted. Six patients were randomly assigned to two groups. In the first group, an end-face light guide was used during surgery, while in the second group, a radial light guide was used. The laser radiation parameters in both groups were identical: power — 9 W, operating mode — continuous, input energy level — 100 J/cm. The surgical procedure concluded with excision of the epithelial coccygeal tract, followed by a pathological examination.

Results

The results of the pathomorphological study within the first pilot project demonstrated a relationship between the wavelength and the depth of thermal changes: as the wavelength decreased, the

zone of necrosis expanded, indicating more pronounced tissue destruction. Thus, when using a hemoglobin-absorbing laser with a wavelength of 970 nm, the treatment depth was 2–3 mm in two cases and 2 mm in one. Using a water-absorbing laser with a wavelength of 1560 nm resulted in a narrowing of the thermal damage zone to 2 mm in two of the three cases. When using a 1940 nm dual-micron laser, the depth of exposure was no more than 1–2 mm (Fig. 3). However, regardless of the wavelength of the laser exposure, in all 9 preparations, a pathomorphological examination revealed loci of granulation tissue with no thermal exposure.

The results of the second pilot study established a direct correlation between the level of energy input and the depth of coagulation necrosis. At an energy of 100 J/cm, the zone of thermal damage

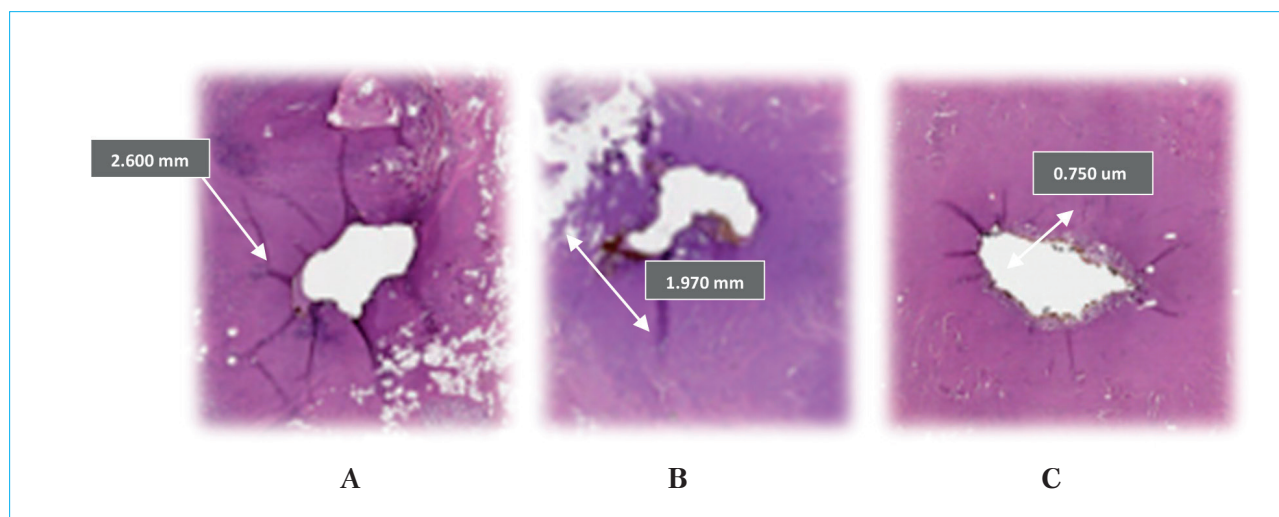


Figure 3. Microscopic preparations after laser coagulation of the tract using radiation with different wavelengths: A — 970 nm; B — 1560 nm; C — 1940 nm

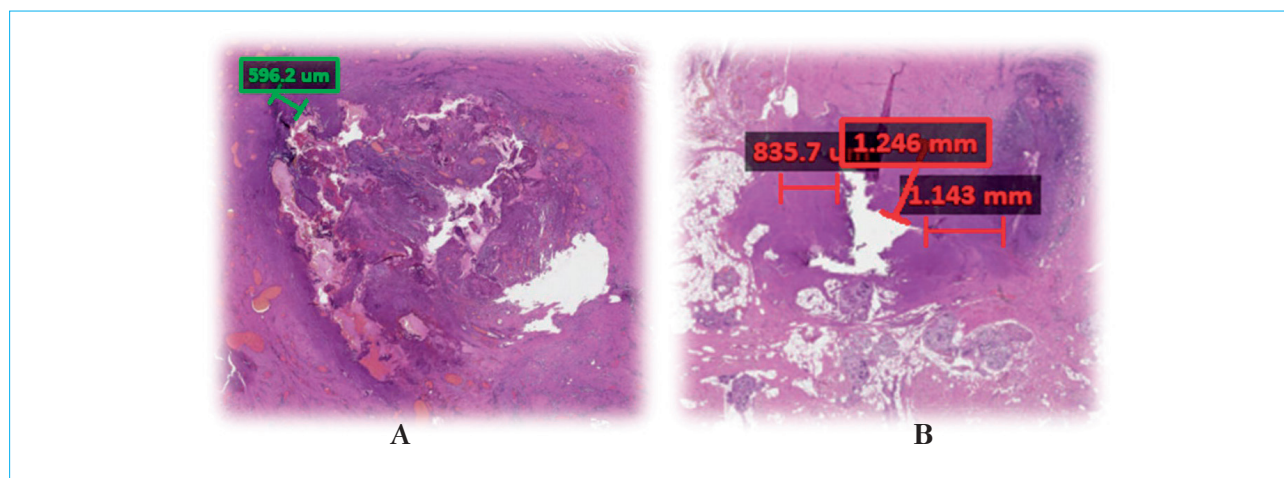


Figure 4. Microscopic preparations after laser coagulation of the tract with different levels of energy input: A — 100 J/cm; B — 200 J/cm

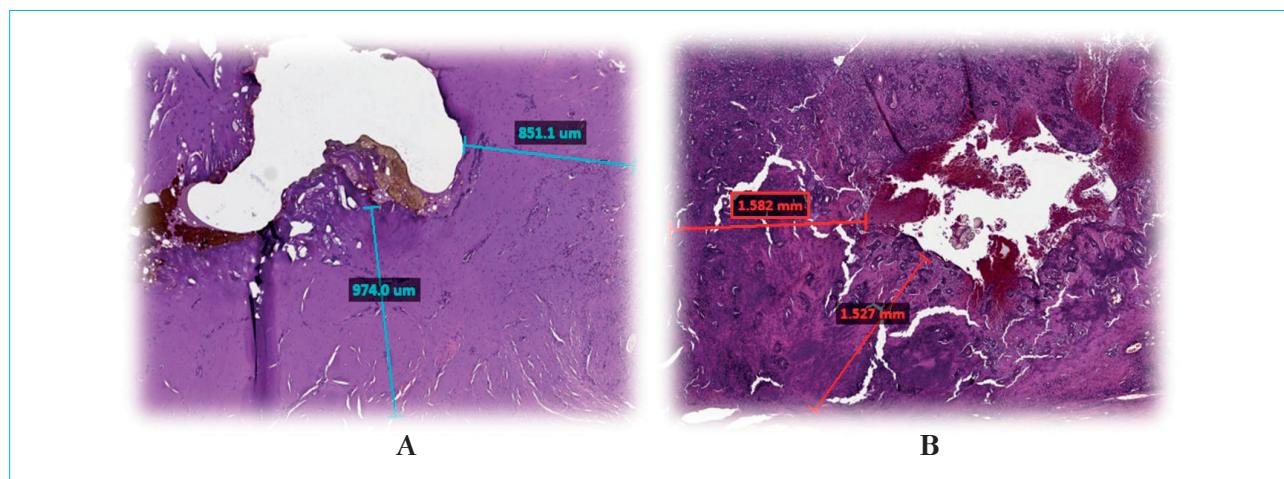


Figure 5. Microscopic preparations after laser coagulation of the tract using different types of light guides: A — end-face; B — radial

was about 500 μm, and at 200 J/cm it doubled and reached 1000 μm, without signs of excessive alternative effects on the surrounding tissue (Fig. 4).

The results of the third pilot study demonstrated a circular zone of necrosis regardless of the type of light guide used (Fig. 5). During pathomorphological examination, areas of residual granulation tissue were found in all samples, which may serve as a basis for conducting double mechanical and laser treatment.

Discussion

In modern coloproctology, laser coagulation is increasingly preferred for the treatment of chronic inflammation of the pilonidal sinus disease as a minimally invasive and effective method. This operation is minimally traumatic, characterized by low pain levels, good cosmetic results, and shorter rehabilitation and temporary disability periods.

However, the likelihood of recurrence after laser surgeries is higher than with traditional interventions, making 3–15 % [5, 6]. One of the main causes of recurrence of epithelial coccygeal tract is incomplete removal of the epithelial lining of the tract. Therefore, an important aspect of surgical treatment is complete radical laser exposure to all structures of the sinus.

Three pilot studies have demonstrated the possibility of using lasers with different wavelengths, levels of energy, and types of light guides. In the surgical treatment of the pilonidal sinus it is possible to use lasers with a wavelength of 1560 nm, as well as with a wavelength of 970 nm and 1940 nm, and the longer the wavelength, the more gentle the effect will be. According to the second pilot study, there is a direct relationship between the level of energy supplied and the increase in the depth of thermal action: the more energy is transferred per 1 cm of tissue, the wider the zone of thermal

exposure. However, it is currently not possible to accurately determine the required level of energy supplied per 1 cm of epithelial pilonidal sinus due to the small sample size of the study; this requires further investigation. The use of end-face and radial light guides is acceptable, but from the point of view of technical properties and ease of implementation of the method, the use of an end-face laser fiber guide is most justified.

Conclusion

For the treatment of the pilonidal sinus, it is possible to use both 1-micron and 1.5- and

2-micron lasers, and it is also acceptable to use both types of light guides — end-face and radial. Changing the above-described technical characteristics while adhering to the surgical technique does not lead to recurrence and/or complications. The width of necrosis directly depends on the wavelength of the laser and the level of energy supplied per 1 cm of tissue: the higher the power or the shorter the wavelength, the deeper the thermal effect. An increase in the area of thermal exposure may lead to an increase in the duration of epithelialization, but this needs to be confirmed by clinical studies.

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Statistical processing: Korolik V.Yu., Zhinkina Ya.N.

Writing of the text: Korolik V.Yu., Zhinkina Ya.N.

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