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THERMOELECTRIC DEVICE FOR TREATMENT OF SKIN DISEASES

The paper presents the results of development of a thermoelectric device for treatment of skin diseases. The developed device has an extended range of operating temperatures (-50 ÷ 0) °C and visual control of the temperature of cooling work tools during therapeutic procedures. The design features of the device, its technical characteristics and the results of testing in clinical practice are given. Bibl. 44, Fig. 6, Tabl. 1.

Key words: thermoelectric device, thermoelectric cooling, treatment of skin diseases, dermatology, cosmetology.

Introduction

According to experimental and clinical studies, the influence of temperature factors is one of the effective methods for treatment of many human diseases, including skin [1-5]. However, the majority of technical devices that are currently used for temperature exposure in medical practice are cumbersome, without the proper ability to control the temperature and reproduce thermal conditions. To achieve low temperatures, in most cases, chloroethyl or liquid nitrogen systems are used, which have a number of drawbacks that significantly limit the possibilities of their use in dermatology and cosmetology practice [1 – 9].

To solve this problem, it is possible to use thermoelectric cooling [10 – 15], which has several advantages over the traditional methods of temperature exposure. Existing thermoelectric devices are used in various fields of science and technology, in particular in medicine. Structural plasticity, reliability, ease of operation and the ability to accurately adjust the temperature create favorable conditions for their wide practical application in medical practice. In particular, in dermatology and cosmetology, thermoelectric devices are promising for cryomassage in order to accelerate the regression of skin rash elements and stimulate the metabolic processes in the skin in various dermatoses, as well as for conducting cryodestruction of skin neoplasms, freezing of warts, papillomas, etc [3, 5]. Thermoelectric devices for treatment of skin diseases, created by this time, usually have a range of operating temperatures (-30 ÷ +5) ° C [11 – 15]. In most cases, such temperatures are sufficient for complex treatment of various skin diseases [16 – 21], but not

enough for the cryodestruction of pathological changes and skin neoplasms.

Therefore, *the purpose of this work* is design development and manufacture of a thermoelectric device for treatment of skin diseases with an extended range of operating temperatures (50 ÷ 0) ° C and testing the device in clinical practice.

Design and technical characteristics of device

At the Institute of Thermoelectricity of the NAS and MES of Ukraine, in the framework of an agreement on cooperation with the Higher State Educational Establishment of Ukraine "Bukovinsky State Medical University", a thermoelectric device was developed for treatment of skin diseases (Fig.1) [22]. The technical characteristics of the device are listed in Table 1.

Fig.1. Thermoelectric device for treatment of skin diseases:
1 – thermoelectric cooling unit, 2 – work tool

Table 1

Technical characteristics of the device

№	Technical characteristics of the device	Parameter values, measurement units
1.	Operating temperature range	(-50 ÷ 0) °C
2.	Temperature accuracy	± 1 ºC
3.	Time required for the device to reach temperature mode	10 min
4.	Device AC supply voltage	(220 ± 10) V
5.	Device power consumption	200 W
6.	Overall dimensions of thermoelectric cooling unit	(135×120×110) mm
7.	Overall dimensions of work tool	(215×23×18.5) mm
8.	Thermoelectric cooling unit weight	1.5 kg
9.	Work tool weight	0.08 kg
10.	Continuous work time of the device	8 h

The device consists of two main functional units (Fig. 1): thermoelectric cooling unit 1 and a set of work tools 2 with variable tips of different configuration. Moreover, the work tools of the device are not connected and functionally independent of the thermoelectric cooling unit. In turn, the thermoelectric cooling unit consists of the following elements: housing, high-efficiency two-stage thermoelectric modules "Altec-2", cooling chamber for work tools, liquid heat exchangers, thermal insulation and a set of pressure plates. The heat is removed from the hot sides of thermoelectric modules by two liquid heat exchangers. The electric power of the thermoelectric cooling unit is supplied from the power supply unit.

The work tools of the device (Fig. 1) contain built-in electronic thermometers with a stand-alone power supply unit for visual control of temperature during therapeutic procedures. Cylindrical copper nozzles of various configurations are attached to the lower part of the work tools, the internal volume of which is filled with a high heat capacity fluid. This enables sessions of the necessary therapeutic manipulations to be carried out alternately for 2-5 minutes, after which the work tool is replaced with the next cooled one. It should be noted that the work tools of the appliance are sterilizable and safe for future reuse. The availability of a replaceable set of work tools ensures continuous operation of a thermoelectric device for a long time. At the same time, it is essential that the work tool is much lighter and more compact in comparison with analogs and does not contain electrical connections to control and power units. Such a device allows with high accuracy to control the temperature of cryothermic effect on the corresponding areas of the patient's skin during therapeutic manipulations.

A block diagram of a thermoelectric device for treatment of skin diseases is shown in Fig. 2, where 1 is a cooling chamber, 2 is a two-stage thermoelectric Peltier module, 3 is a liquid heat exchanger, 4 is a housing, 5 is a power supply unit, 6 is an electrical terminal connection, 7 - union fluid connection, 8 - water supply network. The use of thermoelectric Peltier modules in the design of a system for liquid cooling of the hot sides of the thermoelectric modules makes it possible to extend the operating temperature range of the device to (-50 ÷ 0) ° C.

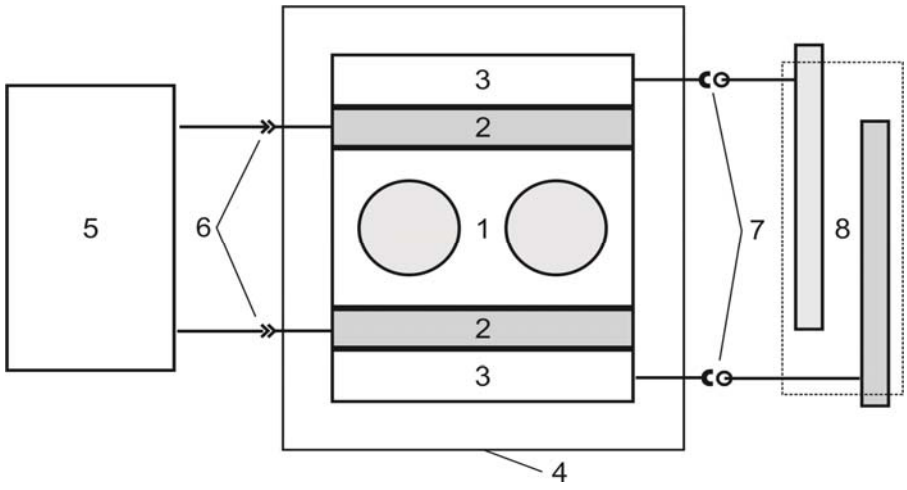

Fig.2. Block-diagram of thermoelectric device for treatment of skin diseases:
1 – cooling chamber, 2 –two-stage thermoelectric Peltier modules, 3 –liquid heat-exchangers,
4 – housing, 5 – power supply unit, 6 – electrical terminal connection, 7 –union fluid connection,
8 –water supply network

The operating principle of the device

The operating principle of the device is to cool work tools with the help of thermoelectric Peltier modules. The cooled work tool has a temperature effect on the corresponding areas of human skin. The advantages of such a device include: the presence of electronic thermometers of work tools, the lack of connection of work tools with the cooling unit and the small overall dimensions of work tools.

Cooling of work tools takes place in a thermoelectric cooling unit based on thermoelectric Peltier modules, the heat from the hot sides of which is removed using a coolant flowing through liquid heat exchangers. For this, the proposed device is connected to a central water supply. The device makes it possible to maintain the temperature of work tools in the range (50 ÷ 0) ° C, which makes it possible to carry out cryodestruction of skin defects and complex treatment of various skin diseases.

The specified device is simple, compact and reliable in operation, which allows a doctor or medical professional to use it without special training, having previously read the instructions. Therefore, the use of such a device is possible both in state medical institutions and in private practice. The introduction of such a device into medical practice will provide physicians with an effective method for the comprehensive treatment of dermatological diseases and cosmetological defects. Such a device can be recommended for practical use in dermatology and cosmetology both in Ukraine and abroad.

In order to determine the effectiveness of the created thermoelectric device and to develop methods for its application, its clinical trial was conducted in the complex treatment of skin diseases with the involvement of employees of the Department of Dermatovenerology, the HSEE of Ukraine "Bukovinsky State Medical University" in the framework of agreement on cooperation. Preliminary results of clinical trials of the device testify to its high prospects in medical practice.

Cryotherapy

A total of 43 patients (31 women, 12 men) aged 19 to 58 years were monitored, of which 22 were diagnosed with acne vulgaris (acne), and 21 were diagnosed with rosacea. During treatment, patients were divided into 2 similar groups by gender, age and diagnosis: the first (comparative) amounted to 21 people who were prescribed standardized therapy for dermatoses, and the second (main) - 22 patients who used cryomassage method in complex therapy with the aid of the developed thermoelectric device for treatment of skin diseases. Statistical processing of the research results was carried out on a personal computer using the licensed software packages Microsoft Excel and Statistica 6.0 StatSoft Inc. Student's t-test was used to assess the probability of differences in the indicators, the difference in indicators was considered probable at $p < 0.05$. To evaluate the nature of the relationships between the indicators, Friedman nonparametric analysis of variance with the definition of χ-square (χ^2),) was used, the dependence between the indicators was considered probable if the χ-square value exceeded the critical value. Examples of clinical applications of a thermoelectric device are given below.

Acne vulgaris (acne). Among the examined patients, common acne was diagnosed in 22 people, of which 18 - clinical manifestations of moderate acne, 4 - severe acne. All patients were prescribed standard therapy for dermatosis, which included means of systemic and external exposure. After regression of pustular acne (purulent rash) in order to accelerate the resolution of inflammatory infiltrative manifestations of acne elements and prevent the development of post-acne, 11 patients (the main group), of which 9 people were previously diagnosed with moderate acne, 2 - with severe acne, additionally used the method of cryomassage with the aid of a thermoelectric device. Cryomassage sessions for patients with acne vulgaris were prescribed for 20-30 seconds 3-4 times in each field (with a total exposure of up to 7-8 minutes) daily for 5-7 days and every other day for the next 10-12 days (total for the course - 10 -12 treatments). According to the analysis of the regression dynamics of the rash elements, which were evaluated 3 months after completion of the course of treatment,

significantly better treatment results were observed in patients with acne of the main group who additionally used the method of cryomassage with the aid of a thermoelectric device (Fig. 3).

Fig.3. Patient M, 23 years. Diagnosis: Common acne, moderate severity (before and 3 months after treatment).

So, among 11 patients with acne from the main group, the state of clinical recovery or mild manifestations of acne was noted in 9 people, moderate in 2 patients (in the comparison group, respectively, 4 and 7). When conducting Friedman's nonparametric analysis of variance, it was found that a statistically significant relationship is found between the number of patients with a clinical recovery or mild acne and the number of patients with moderate acne 3 months after standard treatment and complex therapy using cryomassage sessions (calculated value $\chi^2 = 4.0$ at a critical value of 3.84).

Rosacea (acne pink). Among the examined persons, 21 patients were diagnosed with rosacea (acne pink), 12 of them had papulo-pustular and 9 had erythematous-telangiectatic form of dermatosis. All patients were assigned standard rosacea therapy, which included systemic and external exposure, and in complex therapy, 11 patients (the main group) additionally used the method of cryomassage with the aid of the developed thermoelectric device. The cryomassage method was prescribed to 5 patients with an erythematous-telangiectatic form of dermatosis from the first days of treatment, and to 6 patients with a papular-pustular form - after regression of pustular elements of the rash (7-10 days after the start of treatment). Cryomassage sessions using a thermoelectric device for patients with rosacea of the main group were performed for 20-30 seconds 3-4 times in each field (with a total exposure of up to 10 minutes) daily for 5 days, and the next 10-12 days - every other day (total for the course - 10-12 procedures).

To assess the dermatological status in patients with rosacea before and after their treatment, the rosacea diagnostic assessment scale (SDOR) was used, which includes the sum of the severity of the clinical manifestations of dermatosis: erythema (0 - no erythema; 1 - mild erythema; 2 - moderate; 3 - expressive erythema); determination of the number of papules and pustules (0 - up to 10 elements; 1 - from 11 to 20; 2 - from 21 to 30; 3 - more than 30 elements); presence of telangiectasia (0 - absence; 1 - telangiectasia occupy less than 10% of the face; 2 - from 11% to 30%; 3 - more than 30%); skin dryness and flaking (0 - dryness absent; 1 - weak; 2 - moderate dryness with slight peeling; 3 - strong with pronounced peeling); burning and tingling sensation (0 - absence; 1 - mild; 2 - moderate; 3 - severe); presence of facial edema (0 - no edema; 1 - weak; 2 - moderate; 3 - pronounced). According to clinical observations, within 3 months from the start of treatment, significantly better treatment results were observed in patients with rosacea of the main group, who additionally used the cryomassage method with the aid of the developed thermoelectric device (Fig. 4).

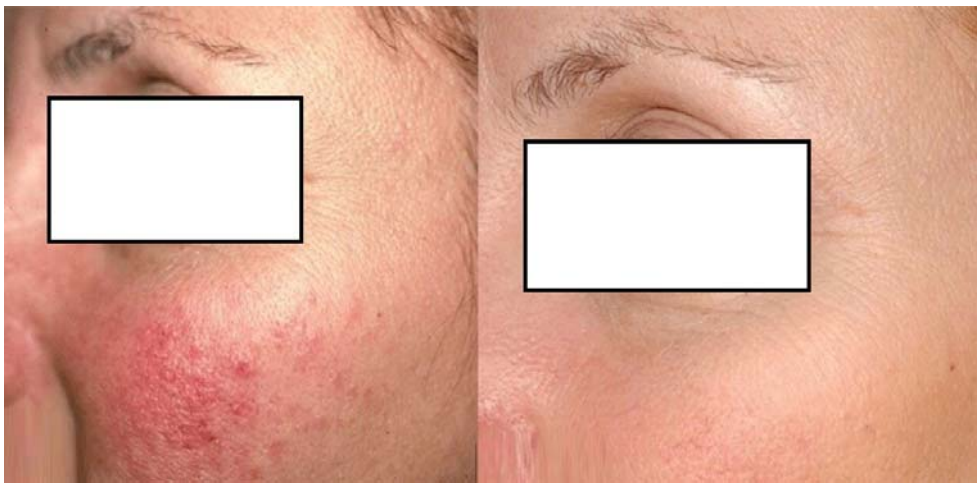

Fig.4. Patient B., 53 years. Diagnosis: Rosaceaa, erythematous-telangiectatic form (before and 3 months after the start of treatment).

As the results of clinical observation showed, a positive dynamics of the clinical manifestations of rosacea after treatment was noted in patients of both groups, however, a more significant decrease in the SDOR was observed in patients of the main group as compared to its initial values before treatment (2.64 times, $p < 0.001$), and relative to the values of the SDOR after treatment in patients of the comparative group (respectively: 1.57 times, $p = 0.007$).

Cryodestruction

Clinical testing of the use of the developed thermoelectric device for cryodestruction of viral warts using special nozzles, the working surface of which corresponds to the area of the affected skin areas, was also conducted. The results of using the created thermoelectric device with an extended range of operating temperatures with maximum cooling to -50 ° C are presented in Fig. 5 and Fig. 6.

Fig.5. Patient M., 26 years. Diagnosis: common wart (vulgar) (before and after cryodestruction).

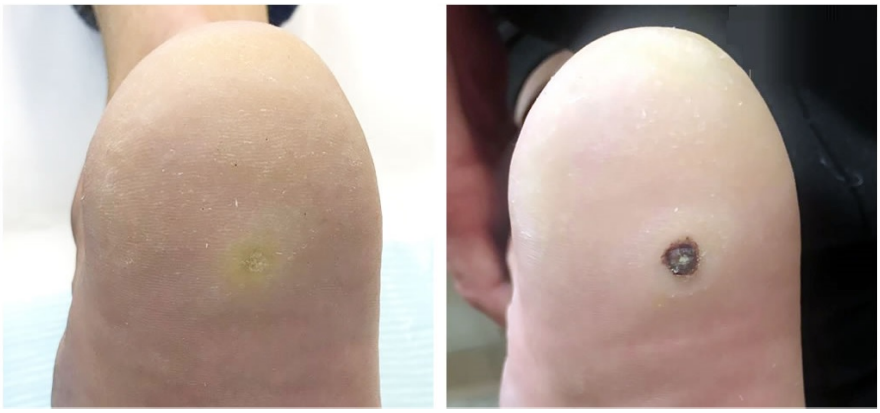

Fig.6.Patient C., 19years. Diagnosis: plantar wart (before and after cryodestruction).

It should be noted that all patients underwent the use of cryomassage or cryodestruction sessions with the aid of the developed thermoelectric device for treatment of skin diseases well, without adverse reactions or complications.

So, according to the results of our studies, the created thermoelectric device with an extended range of operating temperatures (50 ÷ 0) °C is effective for cryodestruction of skin defects, in particular, common and plantar warts, as well as for cryomassage in the complex treatment of chronic skin diseases (common acne, rosacea), which indicates its promise and expediency for a widespread use in both cosmetology and dermatology practice to increase the effectiveness of treatment of chronic dermatoses.

Conclusions

1. A thermoelectric device has been designed and manufactured for treatment of skin diseases that has an extended range of operating temperatures (-50 ÷ 0) °C and a visual temperature control of cooling work tools during therapeutic procedures.
2. Clinical testing was carried out and therapeutic efficiency and safety of using the elaborated thermoelectric device with an extended range of operating temperatures (-50 ÷ 0) °C for treatment of skin diseases in dermatology (acne vulgaris, rosacea) and cosmetology (ordinary warts, plantar) was established, which makes it possible to increase significantly the effectiveness of treatment of such patients.
3. The results of the studies indicate the prospects and the expediency of application of the developed thermoelectric device for treatment of skin diseases in dermatology and cosmetology practice.

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ТЕРМОЕЛЕКТРИЧНИЙ ПРИЛАД ДЛЯ ЛІКУВАННЯ ЗАХВОРЮВАНЬ ШКІРИ

У роботі наведено результати розробки термоелектричного приладу для лікування захворювань шкіри. Розроблений прилад має розширений діапазон робочих температур (-50 ÷ 0) °С та візуальний контроль температури охолоджуючих робочих інструментів під час проведення терапевтичних процедур. Наведено особливості конструкції приладу, його технічні характеристики та результати апробації у клінічній практиці. Бібл. 44, рис. 6, табл. 1.

Ключові слова: термоелектричний прилад, термоелектричне охолодження, лікування захворювань шкіри, дерматологія, косметологія.

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ТЕРМОЭЛЕКТРИЧЕСКИЙ ПРИБОР ДЛЯ ЛЕЧЕНИЯ ЗАБОЛЕВАНИЙ КОЖИ

В работе приведены результаты разработки термоэлектрического прибора для лечения заболеваний кожи. Разработанный прибор имеет расширенный диапазон рабочих температур (-50 ÷ 0) °С и допускает визуальный контроль температуры охлаждающих рабочих инструментов во время проведения терапевтических процедур. Описаны особенности конструкции прибора, его технические характеристики и результаты апробации в клинической практике. Библ. 44, рис. 6, табл. 1.

Ключевые слова: термоэлектрический прибор, термоэлектрическое охлаждение, лечение заболеваний кожи, дерматология, косметология.

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