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Electro-optical system for the automated selection of dental implants according to their colour matching

***Abstract**.. New and original approach towards implants selection in prosthetic dentistry according to the method of implants digital photographs comparison to digital photographs of own bio-objects reflection spectrums – patient's dental prostheses and teeth, was suggested. On this basis, prosthetic objects scanner structure and model providing the possibility of information transfer to the PC have been developed and improved circuit software allows ensuring continuous automatic scanning of bio-objects and avoiding dependence of their digital photographs on external illumination.*

***Streszczenie.** W artykule przedstawiono nowe podejście do selekcji implantów w protetyce dentystycznej za pomocą cyfrowego porównania zdjęć fotograficznych - protez dentystycznych i zębów pacjenta. Na tej podstawie oparto konstrukcję skanera umożliwiającą przekazywania informacji do komputera. Przedstawiono również oprogramowanie pozwalające na zapewnienie ciągłości automatycznego skanowania obiektów biologicznych i eliminujące wpływ zewnętrznego oświetlenia na zdjęcia. (**Elektro-optyczny system do automatycznego wyboru implantów według ich dopasowania kolorystycznego**).*

Keywords: colour matching, scanning, ADC, digital photographs.
Słowa kluczowe: dopasowanie kolorystyczne, skanowanie, przetwarzanie ADC, cyfrowe obrazowanie.

Introduction

The need for high-accurate, convenient, space effective, simple and cheap electro-optical medical systems (EOMS) of automated receiving of information through various types of probing scanners is arising with ever increasing frequency [1]. Creation of EOMS as a tool for the implants selection optimization in the so-called regenerative medicine is a vital task of the present day. Original materials for bacterial nanocellulose (BNC) are one of the recent developments in the field. For instance, CelMat – wet wound dressing made of native NC (BNC 5%, H_2O 95%), CelMat MG – wound dressing made of BNC saturated with glycerol and methylnicotinamide (BNC 5%, H_2O 90%, MNA 0,15%, gl 5%) [2, 3]. The biomimetic structure of BNC – mimicking a body's own tissue is a good matrix for cells seeding. The biomimetic structure of BNC – mimicking a body's own tissue is a good matrix for cells seeding, supports efficient cells adhesion and prevents dedifferentiation, the structure allows the mass transport of nutrients and oxygen to support the survival of cells, etc. BNC, synthesized by Gluconacelobacter strain, is a natural biopolimer already investigated in a wide range of applications, including clinical trials for wet wound dressing and as potential implant e.g. in vascular surgery, dental fillings, peripheral nerves regeneration.

One of the principles of implants selection is a maximum ensuring of their colour matching in relation to the contiguous tissues. Such tasks are typical for a medical practice, particularly, in prosthetic dentistry, cutaneous surgery and cosmetology. Different types of prosthetic objects, particularly, teeth with diseases and various colour characteristics and healthy teeth, dental prostheses, membranes, skin cover and various materials, may be provided for implantation tasks in prosthetic dentistry. Availability of various peculiarities of prosthetic objects must be considered in the methods and means of automated evaluation. Such peculiarities may be even represented by the so-called intrusion effect (intrusion is defined as impacted luxation resulting from a trauma; anomaly characterized by complete or partial displacement of the tooth into the alveolar bone and its root into the jaw bone).

Implantology, maxillo facial surgery and orthopedics pose high requirements to the electronic means of colour matching evaluation. 3D CT scan "GALILEOS", which allows receiving high-quality evaluation accuracy, meets the majority of such requirements [5]. Three-dimensional reconstruction provides highly-informative support as it allows studying the research area under any angle, in all planes and on any section. However, the device is too costly and requires special (also costly) operation conditions, which is not always available for a doctor. Therefore, medical practice requires simple and cost-effective express evaluation devices, in particular, colour matching evaluation devices in case of implant selection.

One of such devices operating according to the principle of colour matching, which was used in medical practice for skin diseases identification, is the one operating according to the principle of the examined skin surface scanning by means of seven-colour LED matrix [6]. The device structure is shown in Fig.1. The device consists of LED matrix of seven colours, which sequentially, by manual operation, illuminate bio-medical object; rays reflected from the objects are directed at photoreceiver input and its signals are shown on digital display meter. For information exchange, microcontroller had hardware-programmed synchronous serial port SPI, I^2C and Universal Synchronous Asynchronous Receiver/Transmitter (USART) [7, 8].

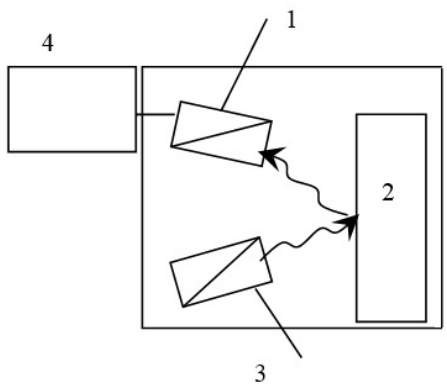

Fig.1. Structure of the device based on the examined skin surface scanning by means of LED matrix. 1 – photoreceiver, 2 – bio-medical object, 3 – LED matrix element, 4 – photoreceiver signal meter with digital display

In order to determine the possibilities of use of the device for implantology purposes, particularly, express evaluation for colour matching, it is necessary to conduct study in clinical setting and obtain recommendations as to the necessity of improvement and development according to the results of clinical trials. This is accepted as the basis for work.

Experimental

Experimental trials have been conducted in order to handle a problem relating to the possibility of application of the considered principle of device structure based on the examined skin surface scanning for implantology tasks in prosthetic dentistry pursuant to the colour matching principle. For this purpose, an experimental device was elaborated with its structure provided in Fig. 2. The device as opposed to the abovementioned device based on the examined skin surface scanning provided a possibility of presenting the information on PC.

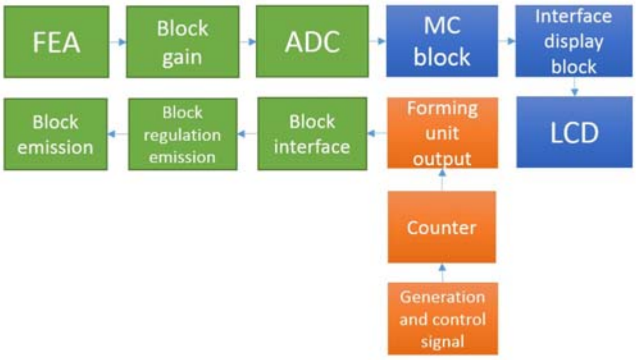

Fig.2. Structure of the suggested experimental device with manual operation and presenting the information on PC

Model of a device schematic circuit created and studied in Proteus is provided in Fig. 3 below.

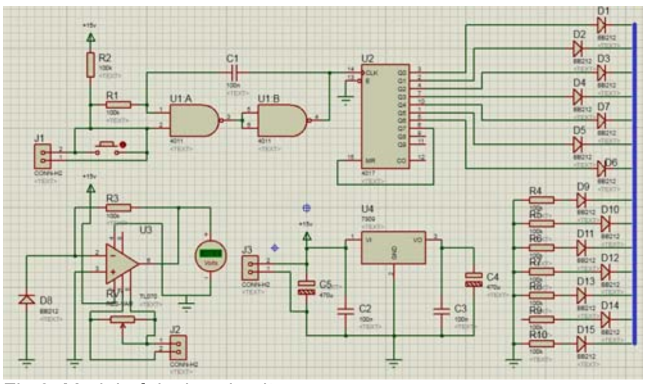

Fig.3. Model of device circuit

AD conversion module of microcontroller PIC16F688 has five analog channels. Voltage on C hold condenser is converted into the relevant 10-digits code by means of charge balancing. The source of upper and lower base voltage may be selected amongst outputs Vdd. Vss. RA2 or RA3. AD conversion configuration is conducted based upon a software-based method by means of special-purpose register setting. Signal source internal resistance influencing C hold internal condenser charging time is considered an important parameter as it plays the role of cumulative resistance from which analog-digit signal conversion is conducted. Clock generator frequency and signal source internal resistance determine the time of C hold charging. For information exchange purposes it is possible to use MSSP hardware-programmed synchronous serial port, SPI master/slave mode, I^{2}C master/slave mode. USART with address detection support, master 8-bit parallel PHP port with RD-WR-CS external signals support (only in 40/44 output microcontrollers), low voltage detector (BOD) for source voltage reduction reset (BOR).

Study of digital photographs of jaw teeth, including teeth with abnormalities, was conducted in the process of clinical trials by means of a developed experimental device. Digital photographs of healthy teeth and teeth with pathologies were used in order to establish a database.

At the beginning of the study, device testing with the use of test surfaces of different color (green, red, blue) as well as device body surface testing was conducted.

In order to select an implant, device workstation (Fig.4) was placed by means of a working window close to the bio-object (patient’s own tooth and present dental implants); then, LED switch button was used for the sequential powering of each of the seven diode colours. The display shows for each colour were fixed and a coloured digital photograph of a bio-object was saved on PC memory and stored as a basic for each individual patient.

Fig.4. Fragment of implant selection using the device

The operation was further repeated for the available implants (artificial teeth, dental prostheses, membranes, skin, various dental materials, etc.). The results were compared to the basic ones stored on PC and automatic selection of one of the available implants was conducted.

Results and discussion

Study results are shown in Fig. 5-7. Columns 1-7 correspond to LED colours from left to right (red, yellow, orange, green, blue, light blue and violet) and figures show the intensity of reflected light.

Using digital photographs, a doctor may obtain information not only about reflected light colours, but also different peculiarities of teeth and dental prostheses, which allows objectively select appropriate implants. Clinical trials showed wide opportunities of the experimental device and allowed establishing a database on PC.

However, the results of trials showed that direct application of such a device as well as similar devices with the use of electro-optical multicoloured scanning systems meets a range of difficulties. As an example, manual colour switching and dependence of digital photographs on external lighting, which is unacceptable for the task of objective implants selection. As lighting is inconstant by its intensity and spectrum, it distorts information about the object. Consequently, implant selection results are insufficiently authentic; therefore, the device is inefficient as far as implantation technologies are concerned.

Fig.5. Image of healthy teeth, teeth with crowns and parodontitis and their digital photographs

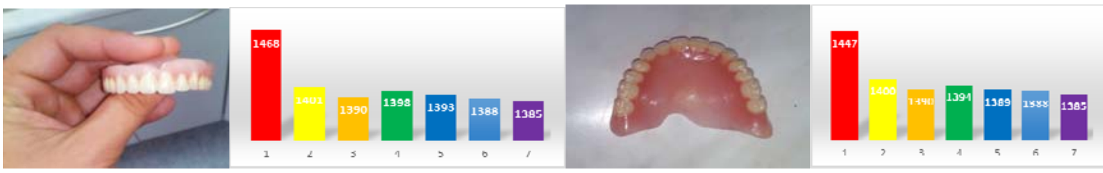

Fig.6. Image of anterior teeth and palatal prosthesis and their digital photographs

Fig.7. Image of palatal prosthesis, teeth with dental plaque and their digital photographs

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In order to avoid the abovementioned drawbacks, an advanced structure of device circuit support provided in Fig. 8 was suggested.

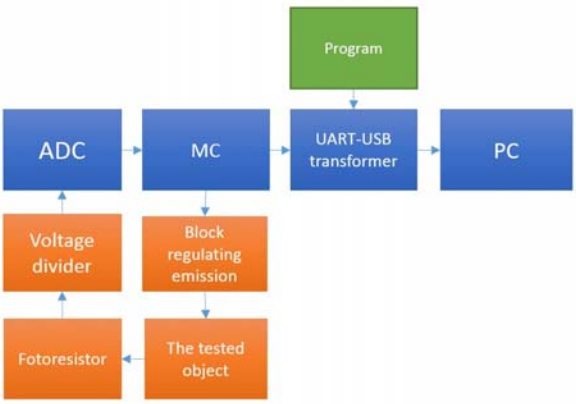

Fig.8. Structure of an advanced device circuit support

An advanced version of the scheme, where Arduino UNO R3 platform is applied on the basis of ATmega 328 microcontroller, was suggested for structure implementation.

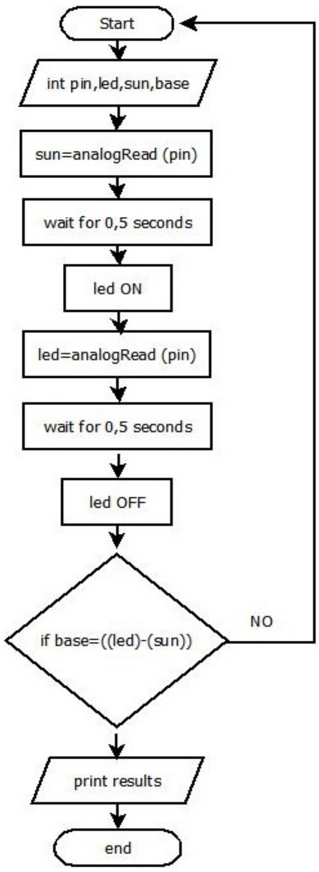

Fig.9. Algorithm structure of device operation

The circuit advanced version includes 14 digital inputs/outputs, 6 analog inputs, USB slot. High signal is sent to the digital output, LED powers on and illuminates tooth surface. The reflected light falls on photoconductive resistor where resistance is changed, which leads to the voltage change on a divider. Voltage coming on A0 analog input changes its meaning from 0 to 5 V; it is thereafter fed to the microcontroller AD converter and transferred into the digital value from 0 to 1023 and displayed on COM port monitor. The pause of 500 ms provided by the circuit is absolutely sufficient for the first LED value readout. After the pause, low signal is fed to the digital output and LED fades. In such a manner, values of reflected light from the tooth surface are gradually readout for the rest of LED. Values transmitted to the COM port are processed and a bar graph is displayed. The following solution was taken in order to eliminate light effect on information. At first, external lighting signal values are readout; then, the values are subtracted from measured values received as a result of illumination of certain colour LED matrix. Therefore, highly accurate information may be obtained, which satisfies our condition. In order to correct the range of signal output values in voltage resistance divider, potentiometer, which allows configuring sensitivity of the photoreceiver to the illumination spectrums, was used. Algorithm structure of device operation is provided in Fig.9.

Conclusions

New and original approach towards implants selection in prosthetic dentistry according to the method of implants digital photographs comparison to digital photographs of own bio-objects reflection spectrums – patient's dental prostheses and teeth, was suggested.

Based on the developed model and results of its experimental studies, an advanced schematic support of the device was suggested. It allows continuous bio-objects scanning in prosthetic dentistry and avoiding dependence of their digital photographs on outdoor illumination as opposed to manual operation of LED matrix colours. At that, the device automatically considers other colour peculiarities.

Methodology of personalized digital photographs application for database establishing and comparison of implants digital photographs the doctor has, which makes possible to quickly make an optimal selection, was elaborated. In contrast to the generally accepted methods of visual evaluation and application of costly laboratory equipment, the suggested method and cost-effective device ensure objective and efficient conformance evaluation, which considerably increases accuracy and speed of the necessary implants selection. Another important thing is that each doctor may create a database on PC with little effort and money.

According to the received results, it is possible to automate the comparison process and, therefore, optimal selection of dental materials for works quality increase in the field of prosthetic dentistry. The suggested device may be considered a perspective tool assisting to make medical decisions in regenerative prosthetic dentistry and a new approach is crucial for further advancement of electronic principles application in the field of implantology.

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