http://doi.org/10.35784/iapgos.5585
received: 19.11.2023 | revised: 22.02.2024 | accepted: 05.03.2024 | available online: 31.03.2024

MEDICAL FUZZY-EXPERT SYSTEM FOR PREDICTION OF ENGRAFTMENT DEGREE OF DENTAL IMPLANTS IN PATIENTS WITH CHRONIC LIVER DISEASE

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Abstract. *The paper presents an information technology for assessing the degree of engraftment of dental implants in the event of a pathology violation through the use of fuzzy sets, which allows using this method for medical diagnostic tasks. Main scientific results: developed algorithms and mathematical models that formalize the process supporting diagnostic decisions based on fuzzy logic; developed mathematical models of membership functions that formalize the presentation of qualitative and qualitative informational features based on the rules of fuzzy logic, which can be used in information expert systems when assessing the degree of engraftment of dental implants in case of disease with pathological diseases.*

Keywords: medical expert systems, fuzzy logic, patient safety, dental implants, chronic liver pathology

MEDYCZNY ROZMYTY SYSTEM EKSPERCKI DO PRZEWIDYWANIA STOPNIA WSZCZEPIENIA IMPLANTÓW DENTYSTYCZNYCH U PACJENTÓW Z PRZEWLEKŁĄ CHOROBĄ WĄTROBY

Streszczenie. *W artykule przedstawiono technologię informacyjną do oceny stopnia wszczepienia implantów stomatologicznych u pacjentów z przewlekłą chorobą wątroby za pomocą zbiorów rozmytych, co pozwala na zastosowanie tej metody do medycznych zadań diagnostycznych. Główne wyniki naukowe: opracowano algorytmy i modele matematyczne formalizujące proces wspomagania podejmowania decyzji diagnostycznych w oparciu o logikę rozmytą; opracowano matematyczne modele funkcji przynależności formalizujące reprezentację ilościowych i jakościowych cech informacyjnych opartych na regułach logiki rozmytej, które mogą być wykorzystane w informatycznych systemach ekspertowych do oceny stopnia wszczepienia implantów stomatologicznych u pacjentów z przewlekłą chorobą wątroby.*

Słowa kluczowe: medyczny system ekspertowy, logika rozmyta, bezpieczeństwo pacjentów, implanty stomatologiczne, przewlekła choroba wątroby

Introduction

Recent years have shown an increase in the number of patients with tooth loss against the background of concomitant pathologies, which can be important when choosing treatment tactics. It is the loss of teeth that necessitates the search for new methods and means of treatment and restoration of the continuity of the dental row. At the moment, in the practice of dentists, more and more are inclined to restore defects of the dentition with the help of dental implants [1–3]. Dental implants can be used with complete and partial edentia, which is important for practical dentistry. When carrying out dental implantation, you need to pay attention to risk factors that can negatively affect the osseointegration of dental implants. There are many multifactorial factors that affect dental regeneration. Among them, we can single out cigarette smoking, poor oral hygiene, concomitant diseases of the liver, pancreas, and osteoporosis. All this creates conditions that negatively affect the implantation of dental implants. When dental implantation is performed, a dental analysis of the functioning of the body is necessary, because any risk factor can affect the progress of dental implant implantation due to the quality of the bone system of the jaw bones. The mineral density of the bone system of the jaw bones directly affects the success of the dental implant surgery and is directly related to the remodeling of the bone system [4, 6, 13]. The very mechanism of bone tissue remodeling takes place in several interrelated phases. At the same time, the processes of osteogenesis and osteoresorption take place. And depending on the state of the body, the first or second process prevails, which affects the occurrence of complications. It should be noted that these two processes can be both physiological and pathological, both local and general. Implantation of dental implants may depend on the conditions under which surgical intervention is performed. Bleeding, pain during surgery and in the postoperative period, inflammation in the area of the surgical wound, separation of sutures often occur [1, 4, 15]. All this can be eliminated in the presence of information about the general state of the body's functioning, which we learn from a detailed history collection and examination of the patient in the pre-operative period [6, 13, 16].

To evaluate and predict the degree of engraftment of dental implants in patients with chronic liver pathology, the authors propose the use of medical expert systems based on fuzzy sets. At the same time, the task of formalizing medical data by creating formalized and standardized outpatient charts, medical histories, and medical knowledge bases is relevant. Therefore, the relevance of the work is the development of expert medical systems, which will make it possible to accelerate the collection and analysis of medical information. In addition to the direct formalization of medical data, it is promising to evaluate their informativeness and develop mathematical methods and models for the synthesis of computer diagnosis [7, 11, 17].

1. Method

All our actions in the preoperative period should be aimed at timely identification and elimination of risk factors and the occurrence of complications during dental implantation. Timely correction of factors that contribute to the occurrence of complications and rejection of dental complications will preserve the functioning of the dental implant for many years, especially if there is a background accompanying pathology, in particular, the hepatobiliary system. After all, the hepatobiliary system is a system that has a significant impact on osteoregenerative and osteoplastic processes, taking into account the function of the liver and bile. Thanks to the function of the liver, the exchange of proteins, fats, carbohydrates, as well as vitamins and hormones takes place [2, 12]. Along with the metabolism, the metabolic and detoxification function of the liver should be noted. The gallbladder and the formation of bile, which in the body allows the gastrointestinal tract to function properly, are inextricably linked to the function of the liver. Bile takes part in the emulsification of fats and their assimilation, the absorption of proteins and carbohydrates, trace elements, including calcium in the distal parts of the intestines.

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The mineral density of bone tissue can be analyzed based on densitometry indicators, as well as biochemical indicators. When analyzing densitometry indicators, it is advisable to measure the mineral density of spongy and compact matter. Alkaline phosphatase, a marker of bone matrix formation, and osteocalcin can be distinguished from biochemical indicators that most successfully characterize metabolic changes in bone tissue. The search of many researchers draws attention to the need for the most reliable prognosis of the implantation of dental implants depending on many risk factors [12, 15, 17].

The purpose of the study is to develop a mathematical model for predicting the implantation of dental implants in patients with chronic liver disease.

2. Peculiarities of using medical information systems

In medical information systems, data and knowledge processing is reduced to three main stages [13,15,16]:

1. Elements of information are placed in certain sections, which have the form of parameters and diagnoses [7, 14, 18].
2. Databases of collected data and theoretical knowledge are organized - their structure is formed, the order of information placement and the nature of the relationship between information elements are determined [19, 20, 25].
3. The most necessary information is selected, a decision is made, the knowledge base and database are edited.

In practice, both approaches are used at MIT, because during research, the obtained biomedical data are quite closely correlated and, thus, the final result of data processing is used for analysis, selection of treatment and rehabilitation methods, and prediction of long-term results. [8, 9, 21] .

When implementing information expert systems, the analysis of biomedical indicators is the basis for making a final diagnostic conclusion.

When creating an expert medical system, it is necessary to solve the following main problems: [18, 19, 24]:

- analysis and area of use of the system,
- synthesis regarding the construction of a logical scheme,
- formation and interpretation of nosological forms, which must be analyzed and based on statistical information containing the classification of symptoms, as well as the peculiarities of the state of a certain body system,
- recommendations regarding the optimality of biomedical information analysis technology,
- implementation of algorithmic software for assessing the level of pathology and determining recommendations for diagnostic and prognostic conclusions.

MIS design will be of high quality only if the study is conducted by an experienced diagnostician. Such research can be designed by a group of qualified experts in this field of diagnostics [23, 26].

3. Materials and methods

53 patients who had dental implants installed were examined in the dental clinic. The age of the patients ranged from 22 to 45 years. All patients underwent densitometric (research of the mineral density of the compact and spongy substance of the jaws), biochemical (alkaline phosphatase, bilirubin) and oral hygiene (Fedorov-Volodkin index). All patients were divided into 2 groups: main (without liver pathology) and comparison (with chronic liver disease). The expert database for determining the degree of engraftment of dental implants in patients with chronic liver pathology is presented in the form of a table 1.

Table 1. Expert database for determining the degree of engraftment of dental implants in patients with chronic liver pathology

Degree of engraftment	Mineral density of compact substance (HU)					Mineral density of spongy substance (HU)					Total hemoglobin level (μmol/l)					Alkaline phosphatase (units/l)					Fedorov-Volodkin Index				
	1250 ÷ 3000	850 ÷ 1249	350 ÷ 850	150 ÷ 350	0 ÷ 150	850 ÷ 3000	450 ÷ 850	250 ÷ 450	150 ÷ 250	0 ÷ 150	0 ÷ 10	10.1 ÷ 20.0	20.1 ÷ 30.0	30.1 ÷ 40.0	40.1 ÷ 100	35 ÷ 79	80 ÷ 119	120 ÷ 159	160 ÷ 199	200 ÷ 500	1.1 ÷ 1.5	1.6 ÷ 2.0	2.1 ÷ 2.5	2.6 ÷ 3.4	3.5 ÷ 5.0
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
High	+					+					+					+					+				
Sufficient		+					+					+					+					+			
Moderate			+					+					+					+					+		
Relative				+					+					+					+					+	
Low					+					+					+					+					+
One-way ANOVA & LSD test		p1-2=0.002																							

Table 2. Features of quantitative assessment for determining the degree of engraftment of dental implants in patients with chronic liver pathology

Factors / Degree of engraftment	Mineral density of compact substance (HU), (X1)	Mineral density of spongy substance (HU), (X2)	Total hemoglobin level (μmol/l), (X3)	Alkaline phosphatase (units/l), (X4)	Fedorov-Volodkin Index, (X5)
High $\mu^{I}(x_1x_2x_3x_4x_5)$	1250 ÷ 3000	850 ÷ 3000	0 ÷ 10	35 ÷ 79	1.1 ÷ 1.5
Sufficient $\mu^{II}(x_1x_2x_3x_4x_5)$	850 ÷ 1249	450 ÷ 850	10.1 ÷ 20.0	80 ÷ 119	1.6 ÷ 2.0
Moderate $\mu^{III}(x_1x_2x_3x_4x_5)$	350 ÷ 850	250 ÷ 450	20.1 ÷ 30.0	120 ÷ 159	2.1 ÷ 2.5
Relative $\mu^{IV}(x_1x_2x_3x_4x_5)$	150 ÷ 350	150 ÷ 250	30.1 ÷ 40.0	160 ÷ 199	2.6 ÷ 3.4
Low $\mu^{V}(x_1x_2x_3x_4x_5)$	0 ÷ 150	0 ÷ 150	40.1 ÷ 100	200 ÷ 500	3.5 ÷ 5.0
min/max	0 ÷ 3000	0 ÷ 3000	0 ÷ 100	35 ÷ 500	1.1 ÷ 5.0

Table 3. Knowledge base for fuzzy for diagnostics determining the degree of engraftment of dental implants in patients with chronic liver pathology

Clinical forms of the degree of engraftment	(X1)	(X2)	(X3)	(X4)	(X5)
$\mu^{I}(x_1x_2x_3x_4x_5)$	A	A	L	L	L
	A	HA	L	L	L
	A	H	L	L	L
	HA	HA	L	L	L
	HA	H	L	L	L
	H	H	L	L	L
$\mu^{II}(x_1x_2x_3x_4x_5)$	LA	LA	L	LA	LA
	A	LA	LA	LA	LA
$\mu^{III}(x_1x_2x_3x_4x_5)$	LA	L	LA	LA	LA
	LA	L	A	LA	LA
	LA	LA	LA	LA	LA
	LA	LA	A	LA	LA
$\mu^{IV}(x_1x_2x_3x_4x_5)$	L	L	LA	LA	A
	L	L	A	LA	A
$\mu^{V}(x_1x_2x_3x_4x_5)$	L	L	A	A	HA
	L	L	HA	HA	H
	L	L	HA	H	HA
	L	L	H	HA	HA
	L	L	H	H	H

According to the methodology for building decisive rules of the decision support subsystem based on fuzzy logic, we break down the range of changes of each of the informative parameters: densitometric (research of the mineral density of the compact and spongy substance of the jaws), biochemical (alkaline phosphatase, bilirubin) and oral hygiene (the index Fedorov-Volodkin) by 5 degrees of engraftment, corresponding to the qualitative fuzzy terms low (L), low average (LA), average (A), high average (HA), high (H) (table 2 and 3).

When setting the functions of belonging of informative features X1 ÷ X5 to fuzzy terms on the interval [0;1], the well-known function [17] is used, the graph of which is shown in Fig. 1.

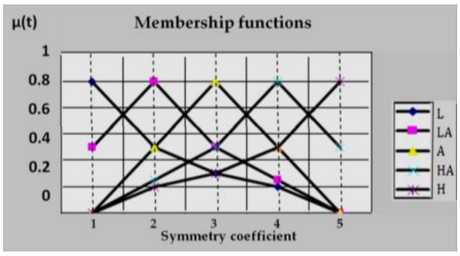

Fig. 1. Membership functions [17, 21, 29]

Based on the knowledge base developed by experts, presented in table 2 and table 3, and the above-mentioned membership functions of fuzzy terms [10, 17], models of decision-making support rules were developed for assessing the degree of engraftment of dental implants in patients with chronic liver pathology.

For degree of engraftment (High) $\mu^{I}(x_1x_2x_3x_4x_5)$

$$\mu^{d1}(X_1,X_2,X_3,X_4.X_5)=\mu^{A}(X_1)\cdot\mu^{A}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)\cup$$
$$\mu^{A}(X_1)\cdot\mu^{HA}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)$$
$$\cup\mu^{A}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)\cup$$
$$\mu^{HA}(X_1)\cdot\mu^{HA}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)\cup$$
$$\mu^{HA}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{L}(_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)\cup$$
$$\mu^{H}(X_1)\cdot\mu^{H}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{L}(X_4)\cdot\mu^{L}(X_5)$$

For degree of engraftment (Sufficient) $\mu^{II}(x_1x_2x_3x_4x_5)$

$$\mu^{d2}(X_1,X_2,X_3,X_4.X_5)=\mu^{LA}(X_1)\cdot\mu^{LA}(X_2)\cdot\mu^{L}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)\cup$$
$$\mu^{A}(X_1)\cdot\mu^{LA}(X_2)\cdot\mu^{LA}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)$$

For degree of engraftment (Moderate) $\mu^{III}(x_1x_2x_3x_4x_5)$

$$\mu^{d3}(X_1,X_2,X_3,X_4.X_5)=\mu^{LA}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{LA}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)\cup$$
$$\mu^{LA}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)$$
$$\cup\mu^{LA}(X_1)\cdot\mu^{LA}(X_2)\cdot\mu^{LA}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)\cup$$
$$\mu^{LA}(X_1)\cdot\mu^{LA}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{LA}(X_5)$$

For degree of engraftment (Relative) $\mu^{IV}(x_1x_2x_3x_4x_5)$

$$\mu^{d4}(X_1,X_2,X_3,X_4.X_5)=\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{LA}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{A}(X_5)$$
$$\cup\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{LA}(X_4)\cdot\mu^{A}(X_5)$$

For degree of engraftment (Low) $\mu^{V}(x_1x_2x_3x_4x_5)$

$$\mu^{d5}(X_1,X_2,X_3,X_4.X_5)=\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{A}(X_3)\cdot\mu^{A}(X_4)\cdot\mu^{LA}(X_5)\cup$$
$$\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{HA}(X_3)\cdot\mu^{HA}(X_4)\cdot\mu^{H}(X_5)$$
$$\cup\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{HA}(X_3)\cdot\mu^{H}(X_4)\cdot\mu^{HA}(X_5)\cup$$
$$\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{H}(X_3)\cdot\mu^{HA}(X_4)\cdot\mu^{HA}(X_5)\cup$$
$$\mu^{L}(X_1)\cdot\mu^{L}(X_2)\cdot\mu^{H}(_3)\cdot\mu^{H}(X_4)\cdot\mu^{H}(X_5)$$

For the formalization of the indices, membership functions are given that correspond to the rules of fuzzy sets [17, 27, 28].

Therefore, logical equations for evaluating the degree of engraftment of dental implants in patients with chronic liver pathology will have the following form for factors (X1 – X5).

For factors X1:

$$\tilde{\mu}^{L}(X_1)=\begin{cases}1.0-0.00067x_1, x_1\in[0;750)\\0.667-0.0002x_1, x_1\in[750;3000]\end{cases}$$

$$\tilde{\mu}^{LA}(X_1)=\begin{cases}0.00067x_1+0.5, x_1\in[0;750)\\1.5-0.00067x_1, x_1\in[750;1500)\\1.0-0.0003x_1, x_1\in[1500;3000]\end{cases}$$

$$\tilde{\mu}^{A}(X_1)=\begin{cases}0.00067x_1, x_1\in[0;1500)\\2-0.00067x_1, x_1\in[1500;3000]\end{cases}$$

$$\tilde{\mu}^{HA}(X_1)=\begin{cases}0.0003x_1, x_1\in[0;1500)\\0.00067x_1-0.5, x_1\in[1500;2250)\\2.5-0.00067x_1, x_1\in[2250;3000]\end{cases}$$

$$\tilde{\mu}^{H}(X_1)=\begin{cases}0.0002x_1, x_1\in[0;2250)\\0.00067x_1-1, x_1\in[2250;3000]\end{cases}$$

For factors X2:

$$\tilde{\mu}^{L}(X_2)=\begin{cases}1.0-0.00067x_2, x_2\in[0;750)\\0.667-0.0002x_2, x_2\in[750;3000]\end{cases}$$

$$\tilde{\mu}^{LA}(X_2)=\begin{cases}0.00067x_2+0.5, x_2\in[0;750)\\1.5-0.00067x_2, x_2\in[750;1500)\\1.0-0.0003x_2, x_2\in[1500;3000]\end{cases}$$

$$\tilde{\mu}^{A}(X_2)=\begin{cases}0.00067x_2, x_2\in[0;1500)\\2-0.00067x_2, x_2\in[1500;3000]\end{cases}$$

$$\tilde{\mu}^{HA}(X_2)=\begin{cases}0.0003x_2, x_2\in[0;1500)\\0.00067x_2-0.5, x_2\in[1500;2250)\\2.5-0.00067x_2, x_2\in[2250;3000]\end{cases}$$

$$\tilde{\mu}^{H}(X_2)=\begin{cases}0.0002x_2, x_2\in[0;2250)\\0.00067x_2-1, x_2\in[2250;3000]\end{cases}$$

For factors X3:

$$\tilde{\mu}^{L}(X_3)=\begin{cases}1.0-0.02x_3, x_3\in[0;25)\\0.67-0.0067x_3, x_3\in[25;100]\end{cases}$$

$$\tilde{\mu}^{LA}(X_3)=\begin{cases}0.02x_3+0.5, x_3\in[0;25)\\1.5-0.02x_3, x_3\in[25;50)\\1.0-0.01x_3, x_3\in[50;100]\end{cases}$$

$$\tilde{\mu}^{A}(X_3)=\begin{cases}0.02x_3, x_3\in[0;50]\\2-0.02x_3, x_3\in[50;100]\end{cases}$$

$$\tilde{\mu}^{HA}(X_3)=\begin{cases}0.01x_3, x_3\in[0;50)\\0.02x_3-0.5, x_3\in[50;75)\\2.5-0.02x_3, x_3\in[75;100]\end{cases}$$

$$\tilde{\mu}^{H}(X_3)=\begin{cases}0.0067x_3, x_3\in[0;75)\\0.02x_3-1, x_3\in[75;100]\end{cases}$$

For factors X4:

$$\tilde{\mu}^{L}(X_4)=\begin{cases}1.15-0.0043x_4, x_4\in[35;151.25)\\0.72-0.014x_4, x_4\in[151.25;500]\end{cases}$$

$$\tilde{\mu}^{LA}(X_4)=\begin{cases}0.004x_4+0.349, x_4\in[35;151.25)\\1.65-0.0043x_4, x_4\in[151.25;267.5)\\1.07-0.002x_4, x_4\in[267.5;500]\end{cases}$$

$$\tilde{\mu}^{A}(X_4)=\begin{cases}0.0043x_4-0.15, x_4\in[35;267.5]\\2.15-0.0043x_4, x_4\in[267.5;500]\end{cases}$$

$$\tilde{\mu}^{HA}(X_4)=\begin{cases}0.002x_4-0.075, x_4\in[35;267.5)\\0.0043x_4-0.65, x_4\in[267.5;383.75)\\2.65-0.0043x_4, x_4\in[383.575;500]\end{cases}$$

$$\tilde{\mu}^{H}(X_4)=\begin{cases}0.001x_4-0.05, x_4\in[35;383.75)\\0.0043x_4-1.15, x_4\in[383.75;500]\end{cases}$$

For factors X5:

$$\tilde{\mu}^{L}(X_5)=\begin{cases}1.57-0.51x_5, x_5\in[1.1;2.07)\\0.85-0.17x_5, x_5\in[2.07;5.0]\end{cases}$$

$$\tilde{\mu}^{LA}(X_5)=\begin{cases}0.52x_5+0.067, x_5\in[1.1;2.07)\\2.06-0.51x_5, x_5\in[2.07;3.05)\\1.67-0.33x_5, x_5\in[3.05;5.0]\end{cases}$$

$$\tilde{\mu}^{A}(X_5)=\begin{cases}0.51x_5-0.56, x_5\in[1.1;3.05]\\3.3-0.67x_5, x_5\in[3.05;5.0]\end{cases}$$

$$\tilde{\mu}^{HA}(X_5)=\begin{cases}0.25x_5-0.28, x_5\in[1.1;3.05)\\0.51x_5-1.06, x_5\in[3.05;4.03)\\3.08-0.52x_5, x_5\in[4.03;5.0]\end{cases}$$

$$\tilde{\mu}^{H}(X_5)=\begin{cases}0.17x_5-0.19, x_5\in[1.1;4.03)\\0.52x_5-1.58, x_5\in[4.03;5.0]\end{cases}$$

Transition from the function $\tilde{\mu}^j(u)$ to required functions $\mu^j(x_i)$ is performed in the following way [17, 30, 31].

$$u_i = 4\frac{x_n - \underline{x}_n}{\overline{x}_n - \underline{x}_n}, \quad \tilde{\mu}^j(u_n) = \mu^j(x_n)$$

In the process of assessing the degree of engraftment of dental implants in patients with chronic disease pathology, the task of developing and configuring a neurofuzzy network becomes. To develop the configuration of the parameters of this network, recurrent components proposed by Professor O. V. Mr. Rothstein [15, 31]. The task of adjustment is carried out in the selection of such factors of membership functions $(b_i^{jp}(t), c_i^{jp}(t))$ and weights of fuzzy rules $w_{jp}(t)$, which ensure the minimum discrepancy between the models and the evaluation results.

$$\sum_{i=1}^{M}(F_y(\hat{x}_1^l, \hat{x}_2^l, \dots \hat{x}_{12}^l, W_i) - \hat{y}_l)^2 = \min_{W_i}$$

where $\langle \hat{X}_l, \hat{y}_l \rangle, l = \overline{1, M}$ experimental research data; b is the maximum coordinate; c is the factor of compression and extension (Fig. 2).

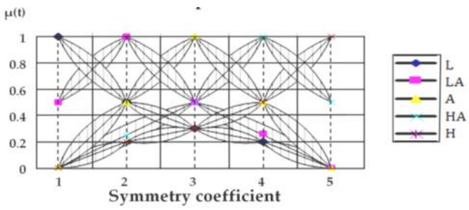

Fig. 2. Function setting procedure

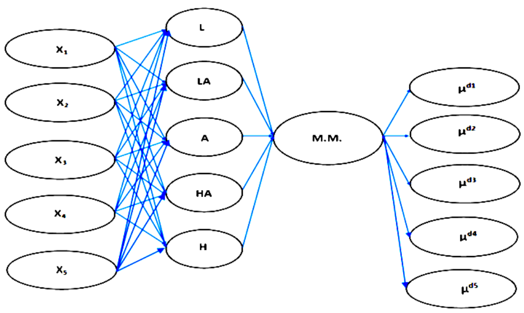

Fig. 3. Medical expert system for determining the degree of engraftment of dental implants in patients with chronic liver pathology

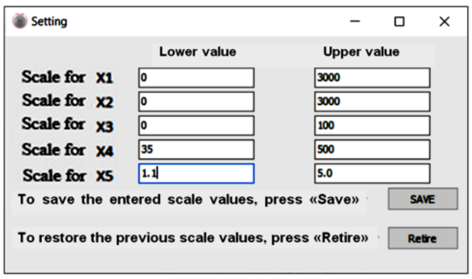

Fig. 4. Function of entering minimum and maximum values for each factor

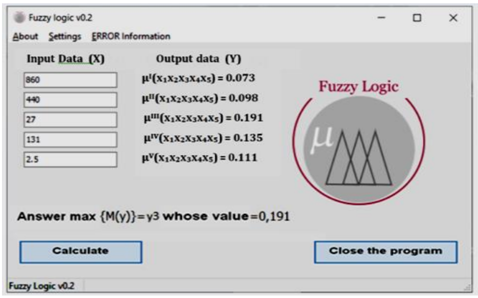

Fig. 5. Medical expert system for determining for determining the degree of engraftment of dental implants in patients with chronic liver pathology

The implementation scheme of the expert medical system in the form of a neural network for assessing the degree of implantation of dental implants in patients is shown in Fig. 3.

An interface was developed for the doctor, which allows to process the results of studies in a convenient way to assess the degree of implantation of dental implants in patients with chronic liver pathology [1, 14, 22].

The result of implementing a user interface is a software system that works like this (Fig. 4 and 5).

It should be noted that the reliability of supporting the correct decision-making of the medical expert system for determining the degree of engraftment of dental implants in patients with chronic liver pathology based on fuzzy sets for expert assessment was 95%.

4. Conclusions

The paper analyzes the main areas of application of mathematical methods in medical diagnostics, formulates the principles of diagnostics based on fuzzy logic. The basic structure of the MIS medical information system for assessing the degree of engraftment of dental implants in patients with chronic liver pathology was developed and the main recommendations for its design were put forward, namely: the selection and purpose of the system; selection of the structural scheme of the system; formation and analysis of the list of nosological forms, collection of statistically reliable information about the severity of symptoms; choosing a method of processing biomedical information; construction of an algorithm for solving the problems of evaluating biomedical information and forming diagnostic and prognostic conclusions.

Hardware and software were developed for the implementation of a convenient interface, which made it possible to formalize quantitative indicators in the form of informational signs when solving the problems of medical diagnosis of assessing the degree of engraftment of dental implants in patients with chronic liver pathology.

The results of the research and the approval of the expert medical system demonstrate the high reliability of the obtained results when assessing the degree of engraftment of dental implants in patients with chronic liver pathology.

The practical value of the work lies in the possibility of using an automated medical expert system to solve the problems of medical diagnosis based on fuzzy logic when assessing the degree of engraftment of dental implants in patients with chronic liver pathology.

Acknowledgments

This research has been is funded by the National Research Fund of Ukraine (Grant No. 2022.01/013).

We would like to thank Sergii Veremienko for reviewing the English language in this manuscript.

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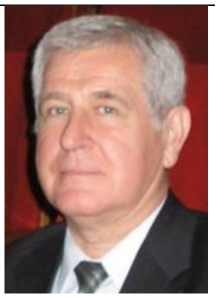

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