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Treatment Alternatives to Gingival Hyperpigmentation using Neutrosophic Correlation Coefficients

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Abstract. Among the main techniques described in the literature for the treatment of gingival melanosis are the use of chemical agents, free gingival grafts, abrasion with rotary or manual instruments (scalpel), cryosurgery with liquid nitrogen, gingivectomy and gingivoplasty, and the use of lasers. The present study aims to perform a selective evaluation of therapeutic alternatives for gingival hyperpigmentation using neutrosophic correlation coefficients. For this purpose, a bibliographic review of the specialized documentary base was carried out to determine the main treatments for the object of study. Neutrosophic sets logic and expert evaluation were applied. The use of correlation coefficients between two single-valued neutrosophic numbers allowed the selection of a therapeutic alternative according to the experts' evaluations. The present study made it possible to verify the usefulness of neutrosophy as a means for the solution of complex real-life problems by incorporating indeterminacies.

Keywords: correlation coefficient, single value neutrosophic number, gingival hyperpigmentation.

1 Introduction

Melanin is one of the most common and widely distributed pigments in nature. It is a black or blackish-brown endogenous pigment present in the cytoplasm of certain cells. This pigment is responsible for the coloration of plants and animals. In humans, this pigment creates the characteristic coloration of the skin, hair, choroid, gingival tissues, etc. The process of melanin formation in the body is called melanogenesis and occurs in the basal layer (deep layer) of the epidermis, as well as in the matrix cells of the hair follicles of the follicle [1].

It has been suggested that physiological pigmentation is probably genetically determined. Usually, all individuals maintain the same concentration of melanocytes in the skin per unit area. Although the degree of pigmentation is due to the activation and increased activity of the melanocytes and not to their number [2], [3].

The coloration present in the oral mucosa depends on the degree and extent of epithelial keratinization, the increase or decrease of blood vessels, the thickness of the epithelium, and the amount of exogenous or endogenous non-hemoglobin pigments such as melanin [4]. Hyper-pigmentation in this area is usually relatively frequent and, in general, can be a cause of low self-esteem in patients with gummy smiles [5].

One of the main factors in over coloration of the oral mucosa refers to the amount and melanogenic activity produced by melanocytes [6]. Likewise, the differences in the number, size and distribution of melanosomes, the type of melanin, and the masking of the keratinized epithelium are determining factors [7].

In accordance with [8], gingival pigmentation may be associated with endogenous causes due to the melanoblastic activity of each individual and even exogenous. According to Tal et al. (2003), this pathology has a higher prevalence in men and women, blacks, French, Filipinos, Arabs, Chinese, Indians, and Germans. It is important to note that although there is some prevalence in these individuals, it can be present in all races and ethnicities [10] [11].

On the other hand, associations have been reported with the consumption of certain medications [12], smoking, and metallic deposits [13]. The suffering of underlying pathologies such as Kaposi's sarcoma or Addison's disease has also been associated with hyperpigmentation in the oral area [14]. The uncontrolled production of melanin is also caused by DNA damage caused by ultraviolet radiation [15].

Although gingival melanin pigmentation is a benign condition and not a medical problem, it is a major cosmetic concern for many patients [16]. In this sense, there are different procedures used to remove melanocytic pigmentation from the gingival area. Among the main techniques described in the literature, the most common are: the use of chemical agents (90% phenol with 95% alcohol), free gingival grafts, abrasion with rotary or manual instruments (scalpel), cryosurgery with liquid nitrogen, gingivectomy and gingivoplasty and the use of laser [9].

Most of these techniques are capable of providing the patient with an effective treatment to mitigate or eliminate the effects of gingival hyperpigmentation. However, making an effective selection between them is a cumbersome process, since it depends on many factors that are often not mutually comparable or even quantifiable. In this environment of uncertainty, it is where neutrosophic logic and its contributions to the decision-making process are developed.

Neutrosophy is the branch of philosophy that studies the origin, nature, and scope of neutralities [17]. The incorporation of neutrosophic sets during decision-making guarantees that the uncertainty of the decision-making process, including indeterminacies, is considered during the process [18].

In this sense, correlation coefficients are an important tool to judge the relationship between two objects. These coefficients have been widely applied to data analysis and classification, decision-making, pattern recognition, etc. [19], [20]. The present study aims to carry out a selective evaluation of therapeutic alternatives for gingival hyperpigmentation using neutrosophic correlation coefficients. [28, 29, 30]

2 Preliminaries

Definition 1. Let X be a space of points (objects), with a generic element in X denoted by x. A neutrosophic set A in X is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. The functions $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or nonstandard subsets of] −0, 1+ [, i.e., $TA(x)$: $X \rightarrow$] −0, 1+ [, IA(x): X →] −0, 1+ [, and FA(x): X →] −0, 1+ [. There is no restriction on the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$, so there is $-0 \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3+$.

Obviously, it is difficult to apply the neutrosophic set to practical problems. Therefore, [22] introduced the concept of a single-valued neutrosophic set (SVNS), which is an instance of a neutrosophic set, to be used in real scientific and engineering applications. Next, the definition of a SVNS is introduced [22, 31, 32].

Definition 2. [22] Let X be a space of points (objects) with generic elements in X denoted by x. A SVNS A in X is characterized by a truth-membership function TA(x), an indeterminacy-membership function IA(x), and a falsehood-membership function FA(x) for each point x in X, TA(x), IA(x), FA(x) ∈ [0, 1]. Thus, A SVNS A can be expressed as

$A = \{x, T_A(x), I_A(x), F_A(x) \mid x \in X\}$

Then, the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 3. [22] The complement of a SVNS A is denoted by Ac and is defined as

$Ac = \{x, FA(x), 1 - IA(x), TA(x) \mid x \in X\}$

Definition 4. [22] A SVNS A is contained in the other SVNS B, A ⊆ B if and only if TA(x) ≤ TB(x), IA(x) ≥ IB(x), and FA(x) ≥ FB(x) for every x in X.

Definition 5. [22] Two SVNSs A and B are equal, written as A = B, if and only if A ⊆ B and B ⊆ A

2.1 Correlation coefficient of SVNSs

Definition 6. [23] For any two SVNSs A and B in the universe of discourse X = {x1, x2, . . . , xn}, the correlation coefficient between two SVNSs A and B is defined as follows:

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

where

$$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}},$$

$$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}},$$

$$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}},$$

$$\Delta T_i = |T_A(x_i) - T_B(x_i)|,$$

$$\Delta I_i = |I_A(x_i) - I_B(x_i)|,$$

$$\Delta T_i = |T_A(x_i) - T_B(x_i)|,$$

$$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|,$$

$$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|,$$

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

for any $x_i \in X$ and i = 1, 2, . . ., n

However, the differences of importance are considered in the elements in the universe. Therefore, the weight of the element x_i (i=1, 2, ..., n) must be considered. Next, a weighted correlation coefficient between SVNSs is introduced.

Definition 7. [23] Let w_i be the weight for each element x_i (i = 1, 2, . . . , n), $w_i \in [0, 1]$, and $\sum_{i=1}^{n} w_i = 1$, then the following weighted correlation coefficient between the SVNSs A and B:

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (2)$$

2.2 Decision-making method using the correlation coefficient of SVNSs

In the multiple attribute decision-making problem with single-valued neutrosophic information, the characteristic of an alternative Ai (i = 1, 2,..., m) on an attribute Cj (j = 1, 2,..., n) is represented by the following SVNS:

$A_i = \{C_j, T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j)|C_j \in C, j = 1, 2, . . ., n\}$

where $T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) \in [0, 1]$ and $0 \leq T_{Ai}(C_j) + I_{Ai}(C_j) + F_{A}i(C_j) \leq 3$ for $C_j \in C$, j =1, 2, . . ., n, and i = 1, 2, . . ., m.

For convenience, the values of the three functions $T_{Ai}(C_j)$, $I_{Ai}(C_j)$, $F_{Ai}(C_j)$ are denoted by a single-valued neutrosophic value (SVNV) $d_{ij} = <t_{ij}, i_{ij}, f_{ij}>$ (i = 1, 2, . . ., m; j = 1, 2, . . ., n), which is usually derived from the evaluation of an alternative A_i with respect to a criterion C_j by the expert or decision maker. Thus, a single-valued neutrosophic decision matrix $D = (d_{ij})_{m\times n}$.

In multiple attribute decision-making problems, the concept of the ideal point has been used to help identify the best alternative in the decision set. Although the ideal alternative does not exist in the real world, it does provide a useful theoretical construct against which to evaluate alternatives [24].

In the decision-making method, an ideal SVNV can be defined by $dj^* =< tj^*, ij^*, fj^* >=< 1, 0, 0 >$(j = 1, 2,..., n) in the ideal alternative A*. Hence, by applying Equation (2) the weighted correlation coefficient between an alternative Ai (i =1, 2, . . ., m) and the ideal alternative A* is given by

$$M_w(A_i,A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j\left[\phi_{ij}\left(1-\Delta t_{ij}\right) + \varphi_{ij}\left(1-\Delta i_{ij}\right) + \psi_{ij}\left(1-\Delta f_{ij}\right)\right] \quad (3)$$

where

$$\phi_{ij} = \frac{3-\Delta t_{ij}-\Delta t_{i\,max}}{3-\Delta t_{i\,min}-\Delta t_{i\,max}},$$

$$\varphi_i = \frac{3-\Delta i_{ij}-\Delta i_{i\,max}}{3-\Delta i_{i\,min}-\Delta i_{i\,max}},$$

$$\psi_i = \frac{3-\Delta f_{ij}-\Delta f_{i\,max}}{3-\Delta f_{i\,min}-\Delta f_{i\,max}},$$

$$\Delta t_{ij} = \left|t_{ij} - t_j^*)\right|,$$

$$\Delta i_{ij} = \left|i_{ij} - i_j^*)\right|,$$

$$\Delta f_{ij} = \left|f_{ij} - f_j^*)\right|,$$

$$\Delta t_{i\,min} = min_j\left|t_{ij} - t_j^*\right|,$$

$$\Delta i_{i\,min} = min_j\left|i_{ij} - i_j^*\right|,$$

$\Delta f_{i\,min} = min_j \left| f_{ij} - f_j^* \right|$,

$\Delta t_{i\,max} = max_j \left| t_{ij} - t_j^* \right|$,

$\Delta i_{i\,max} = max_j \left| i_{ij} - i_j^* \right|$,

$\Delta f_{i\,max} = max_j \left| f_{ij} - f_j^* \right|$,

for i = 1, 2, . . ., m and j = 1, 2, . . ., n. By the correlation coefficient M_w (Ai, A*) (i =1, 2,..., m), the ranking order of all alternatives and the best one(s) can be obtained.

2.2 Methodology

A bibliographic review was carried out by analyzing original articles and systematic reviews obtained from the last 5 years that include information related to the topic. The search was made by consulting specialized databases and using the Google Scholar search engine. Scientific articles were searched using the words: gingival; treatment; gingival melanosis; pigmentation; gingival depigmentation techniques. [37, 38]

The scientific data obtained were listed and submitted to scientific review by the work team, within which there were 3 specialists in the field with a minimum of 8 years of experience each. Nearly a dozen alternative methods for treating the disease were found; however, to facilitate the work and the processing of the data, it was decided to synthesize the information obtained. In this way, Table 1 shows a summary of the main treatments to be considered in the development of the study.

Surgical treatment alternatives	Characteristic
A1. Electrosurgery	It works according to the principle of electrosurgical fulguration or fulguration (arcing between the tip of the electrode and the conductive tissue that induces coagulation in the tissue). The result is the formation of a clot or carbonization instead of actual cellular vaporization. The resulting thermal effects and collateral damage (coagulative necrosis edema) could cause a measure of postoperative pain and discomfort for the patient proportional to the voltage used and the time of tissue exposure, which in turn prolongs healing [26, 33].
A2. Surgical technique with a scalpel	It consists of the removal of the pigmented gingival epithelium together with a layer of the underlying connective tissue, using the scalpel. The scalpel method is one of the most economical techniques and does not require extensive instrumentation. In addition, the healing period of scalpel wounds is relatively fast compared to other techniques [25].
A3. Laser	It is an effective, comfortable, and reliable technique with good aesthetic results. Various lasers have been used for gingival depigmentation including carbon dioxide (CO_2), diode lasers, neodymium: yttrium aluminum garnet (Nd: YAG), erbium: yttrium aluminum garnet (Er: YAG), and erbium, yttrium doped. with chromium, scandium, gallium, and garnet (Er, Cr: YSGG) [25, 34].
A4. Cryosurgery or cryotherapy	It consists of the use of freezing substances (tetrafluoroethane, liquid nitrogen, nitrous oxide, etc.) to cause protein denaturation, mitochondria destruction, and cell death by freezing the cell cytoplasm. It is an effective, easy treatment, and does not require anesthesia, suture, or surgical dressing. It implies an absence of bleeding during or after treatment and minimal scar formation; it does not harm adjacent tissues, there is no risk of infection, and it does not require expensive equipment [25, 35, 36].
A5. Radiosurgery	It is the removal of soft tissue with the help of radiofrequency energy, from 3.0 MHz to 4.0 MHz. This technique consists of the removal of soft tissue with the help of radiofrequency energy [27]
A6. Abrasion method	It consists of the elimination of the epithelium that contains melanin deposits. It is done using rotary abrasive instruments. Fine-

Surgical treatment alternatives	Characteristic
	grain diamond burs in the form of flame, round diamonds, polishing discs, and even ceramic bur are generally used for sectioning soft tissues. It is a non-aggressive, simple, economical method, with reduced surgical time, produces little bleeding, provides comfort to the patient, and provides satisfactory results [25].

Table 1. Treatment alternatives to be evaluated. Source: own elaboration.

As analysis criteria, cost (C1), effectiveness (C2), and availability of treatment (C3) are selected. Each of the experts is asked to fill in a small form in which a weighting of importance must be included for each of the criteria with respect to the rest. Likewise, they are asked to submit each of the therapeutic alternatives for evaluation based on the selected criteria. For this, the evaluations to be given must specify to what extent the expert considers that the alternative Ai is good (Tx), bad (Fx), or is not entirely sure (Ix) with respect to the criterion Cj. it is considered that the evaluated criteria have the same weight wj=0.33.

3 Results

The results obtained from the evaluations of all the experts are considered of equal importance and the average of the results is determined for the processing and obtaining of the information. In this way, the resulting decision matrix D is shown below.

$$D = \begin{bmatrix} \langle 0.5;\ 0.3;\ 0.2\rangle & \langle 0.4;\ 0.2;\ 0.3\rangle & \langle 0.2;\ 0.2;\ 0.5\rangle \\ \langle 0.6;\ 0.1;\ 0.2\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle & \langle 0.4;\ 0.2;\ 0.3\rangle \\ \langle 0.5;\ 0.3;\ 0.2\rangle & \langle 0.5;\ 0.2;\ 0.3\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle \\ \langle 0.7;\ 0.1;\ 0.1\rangle & \langle 0.2;\ 0.2;\ 0.5\rangle & \langle 0.4;\ 0.2;\ 0.2\rangle \\ \langle 0.3;\ 0.2;\ 0.3\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle & \langle 0.3;\ 0.2;\ 0.3\rangle \\ \langle 0.6;\ 0.1;\ 0.2\rangle & \langle 0.5;\ 0.2;\ 0.3\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle \end{bmatrix}$$

Following the logic of the method used, the values of the operators necessary for the determination of each correlation coefficient are determined, as shown in Tables 2 and 3.

	φC1	*φC2*	*φC3*	*µC1*	*µC2*	*µC3*	*ψC1*	*ψC2*	*ψC3*
A1	1	0.94	0.82	1	0.96	0.87	0.96	1	1
A2	1	1	0.9	1	1	0.96	1	1	1
A3	0.95	0.95	1	1	0.96	1	0.92	0.96	1
A4	1	0.74	0.84	1	0.83	0.96	1	0.96	1
A5	0.84	1	0.84	0.96	1	0.96	0.96	1	1
A6	1	0.95	1	1	0.96	1	1	0.96	1

Table 2. Values of φ, µ, and ψ for each alternative. Source: own elaboration.

	A1	A2	A3	A4	A5	A6
ΔTmin	0.5	0.4	0.4	0.3	0.4	0.4
ΔImin	0.2	0.2	0.2	0.1	0.2	0.2
ΔFmin	0.2	0.1	0.1	0.1	0.1	0.1
ΔTmax	0.8	0.6	0.5	0.8	0.7	0.5
ΔImax	0.5	0.3	0.3	0.5	0.3	0.3
ΔFmax	0.3	0.2	0.3	0.2	0.2	0.2

Table 3. Minimum and maximum values of variation in the functions of belonging to truth, falsehood, and indeterminacy. Source: own elaboration.

In this way, by using equation (3), the values of the correlation coefficients are obtained. Table 4 shows the values obtained and their ranking accordingly.$M_w(A_i, A^*)$

	A6	A2	A3	A4	A5	A1
MW	0.7243	0.7147	0.6862	0.6338	0.6318	0.5797

Table 4. Weighted correlation coefficients. Source: own elaboration.

In this way, it is valid to point out that, according to the analysis carried out, alternative 6 (abrasion method) is the most preferred among the 6 alternatives evaluated, closely followed by the surgical method with a scalpel. It is estimated that the results achieved may vary depending on the criteria to be evaluated and the panel of experts, since the data obtained have a certain degree of imprecision, variable from one person to another.

Conclusion

Gingival melanosis is a condition that can affect all strata of society and affects the aesthetic appearance of patients to a greater extent. There are several surgical treatments to mitigate or eliminate its effects, although the selection between them is sometimes cumbersome. The present study allowed the evaluation of surgical therapeutic alternatives for hyperpigmentation of the gums through expert criteria. A bibliographic review was carried out on the specialized documentary base to determine the main treatments regarding the object of study. Neutrosophic logic was used to achieve the selection of a therapeutic alternative by using correlation coefficients between two single-valued neutrosophic numbers.

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