Treatment Alternatives to Gingival Hyperpigmentation Using Neutrosophic Correlation Coefficients

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Abstract

Among the main techniques described in the literature for treating 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 implements a selective evaluation of therapeutic alternatives for gingival hyperpigmentation through the use of neutrosophic correlation coefficients. For this, a bibliographic review was carried out on the specialized documentary base to determine the main treatments in the matter of the object of study and the logic of neutrosophic sets, and the evaluation of experts. Using correlation coefficients between two single-valued neutrosophic numbers allowed the selection of a therapeutic alternative according to the experts' evaluations. This work allowed to verify the usefulness of neutrosophy as a means for solving complex real-life problems through the incorporation of uncertainties.

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 specific 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.

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 [1].

The coloration 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. Hyperpigmentation in this area is usually relatively frequent and, in general, can be a cause of low self-esteem in patients with a gummy smile.

One of the main factors of overcoloration of the oral mucosa is the amount and melanogenic activity produced by melanocytes. 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.

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Gingival pigmentation may be associated with endogenous causes due to the melanoblastic activity of each and even exogenous. This pathology is more prevalent 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.

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

Although gingival melanin pigmentation is a benign condition and not a medical problem, it is a major cosmetic concern for many patients. In this sense, different procedures are 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.

Most of these techniques can provide 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 the neutrosophic logic and its contributions to the decision-making process are developed.

Neutrosophy is the branch of philosophy that studies origin, scope a nature of neutralities. The incorporation of neutrosophic sets during decision-making guarantees that the uncertainty of decision-making, including indeterminacies, is taken into account during the process [2].

In this sense, correlation coefficients are important for judging the relationship between two objects. These coefficients have been widely applied to data analysis and classification, decision making, pattern recognition, etc. [3], [4]. The present study aims to conduct a selective evaluation of therapeutic alternatives for gingival hyperpigmentation through the use of neutrosophic correlation coefficients [19–24]. This is a subject of Neutrosophic Statistics as we can read in [11]–[13].

1. Preliminaries

Definition 1. [14] 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 TA(x), an indeterminacy-membership function $IA(x)$, and a falsity-membership function $FA(x)$. The functions $TA(x), IA(x)$ and $FA(x)$ are real standard or nonstandard subsets of $]-0,1+[, ie, TA(x): X \rightarrow]-0,1+[, IA(x): X \rightarrow]-0,1+[$, and $FA(x): X \rightarrow]-0,1+[$. There is no restriction on the sum of $TA(x)$, $IA(x)$ and $FA(x)$, so there is $-0 \leq sup\, TA(x) + sup\, IA(x) + sup\, FA(x) \leq 3+$.

It is challenging to apply the neutrosophic set to practical problems. Therefore, Wang in [15] introduced the concept of a single-valued neutrosophic set (SVNS), an instance of a neutrosophic set, to be used in real scientific and engineering applications. Below is the definition of a SVNS.

Definition 2. [15] 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 falsity-membership function $FA(x)$ for each point x in X, $TA(x), IA(x), FA(x) \in [0,1]$. Thus, A SVNS A can be expressed as

$$A = \{x, TA(x), IA(x), FA(x) \mid x \in X\}$$

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

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Definition 3. [15] The complement of a SVNS A is denoted by A^c and is defined as

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

Definition 4. [15] A SVNS A is contained in the other SVNS B, A ⊆ B if and only if $TA(x) \leq TB(x), IA(x) \geq IB(x)$, and $FA(x) \geq FB(x)$ for every x in X.

Definition 5. [15] Two SVNSs A and B are equal, written as $A = B$, if and only if $A \subseteq B$ and $B \subseteq A$

1.1 Correlation coefficient of SVNSs

Definition 6. [1] For any two SVNSs A and B in the universe of discourse $X = \{x1, x2, \ldots, xn\}$, the correlation coefficient between two SVNSs A and B is defined as follows:

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

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 $xi \in X$ and i = 1, 2, . . ., n

However, the differences of importance are considered in the elements in the universe. Therefore, it is necessary to take into account the weight of the element *xi* (*i*= 1, 2,..., *n*). In the following, we introduce a weighted correlation coefficient between SVNSs.

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

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

1.2 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:

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$Ai = \{Cj, TAi\ (Cj), IAi\ (Cj), FAi\ (Cj) | Cj \in C, j = 1, 2, \ldots, n\}$

where $TAi\ (Cj), IAi\ (Cj), FAi\ (Cj) \in [0, 1]$ and $0 \leq TAi\ (Cj) + IAi\ (Cj) + FAi\ (Cj) \leq 3$ for $Cj \in C, j = 1, 2, \ldots, n$, and $i = 1, 2, \ldots, m$.

For convenience, the values of the three functions $TAi\ (Cj), IAi\ (Cj), FAi\ (Cj)$ are denoted by a single valued neutrosophic value (SVNV) $dij = < tij, iij, fij >$ $(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)$, 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, it is possible to elicit a single valued neutrosophic decision matrix $D = (dij)m \times n$.

In multiple attribute decision-making problems, the concept of an 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 [16].

In the decision-making method, an ideal SVNV can be defined by $dj* = < tj*, ij*, fj* > = < 1, 0, 0 >$ $(j = 1, 2, \ldots, n)$ in the ideal alternative A*. Hence, by applying Equation (2) the weighted correlation coefficient between an alternative $Ai\ (i = 1, 2, \ldots, m)$ 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 $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. By the correlation coefficient $Mw\ (Ai, A*)\ (i = 1, 2, \ldots, m)$, it is possible to obtain the ranking order of all alternatives and determine which are the best one(s).

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1.3 Methodology

A bibliographic review and analysis of original articles and systematic reviews, obtained from the last 5 years including information related to the subject, was carried out. The search was done by consulting specialized databases such as the Google Scholar search engine. Scientific articles were searched using the words: gum; treatment; Gum melanosis; Pigmentation; Gingival depigmentation techniques.

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, in order to facilitate the work and the processing of the data, it was decided to make a synthesis of the information obtained. Table 1 shows a summary of the main treatments to be considered in the development of the study.

Table 1: Treatment alternatives to be evaluated

Surgical treatment alternatives	Characteristics
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.
A2. Surgical technique with 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.
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), and erbium: yttrium aluminum garnet (Er: YAG), and erbium, yttrium doped lasers. with chromium, scandium, gallium, and garnet (Er,Cr:YSGG)
A4. Cryosurgery or cryotherapy	It consists of the use of freezing substances (tetrafluoroethane, liquid nitrogen, nitrous oxide, etc.) to cause protein denaturation, destruction of mitochondria, 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.
A 5. 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
A6. Abrasion method	It consists of the elimination of the epithelium that contains melanin deposits. It is done through the use of rotary abrasive instruments. Fine-grain diamond burs in the form of flame, round diamond, polishing discs, and even the ceramic bur are generally used for sectioning soft tissues. It is a non-

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	aggressive, simple, economical method, with reduced surgical time, produces little bleeding, provides comfort to the patient, and provides satisfactory results

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 compared 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.

2. 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. This way, the resulting decision matrix D is shown below.

$$D = [\langle 0.5;\ 0.3;\ 0.2\rangle\ \langle 0.4;\ 0.2;\ 0.3\rangle\ \langle 0.2;\ 0.2;\ 0.5\rangle\ \langle 0.6;\ 0.1;\ 0.2\rangle\ \langle 0.6;\ 0.1;\ 0.2\rangle\ \langle 0.4;\ 0.2;\ 0.3\rangle\ \langle 0.5;\ 0.3;\ 0.2\rangle\ \langle 0.7;\ 0.1;\ 0.1\rangle\ \langle 0.3$$

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.

Table 2: Values of φ, μ, and ψ for each alternative

	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
TO 5	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

Source: own elaboration

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

	A1	**A2**	**A3**	**A4**	**TO 5**	**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

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.$M_w(A_i, A^*)$

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Table 4: Weighted correlation coefficients

	A6	A2	A3	A4	TO 5	A1
MW	0.7243	0.7147	0.6862	0.6338	0.6318	0.5797

Source: own elaboration

In this way, it is valid to point out that, according to the analysis executed, alternative 6 (abrasion method) is the 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, because the data obtained have a certain degree of imprecision, variable from one person to another.

3. Conclusions

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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