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Neutrosophic Orthodontic Treatment Planning

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Abstract: Neutrosophy is a modern philosophical approach that emphasizes seeking balance and comprehension in a complex and polarized world. It encourages the exploration of nuance and the acceptance that truth is not always found in extremes. In the medical realm, especially in dentistry, neutrosophy plays an essential role in providing a philosophical framework for clinical decision making and work planning. This article examines the approach to orthodontic treatment planning using a neutrosophic perspective. Specific criteria are used to evaluate and rank treatment alternatives, employing methods such as TOPSIS and neutrosophic DEMATEL. Key factors considered include clinical effectiveness, long-term stability, impact on quality of life, cost-benefit, and sustainability of materials and techniques. Neutrosophic orthodontic treatment planning aims to achieve a balance amongst clinical, ethical, economic, and psychosocial aspects, enabling more customized and gratifying patient care. The outcomes highlight the significance of considering various outlooks and subtleties during the clinical decision-making process in dentistry, from a neutrosophic viewpoint.

Keywords: TOPSIS, DEMATEL, neutrosophy, dentistry, planning, treatment.

1 Introduction

Neutrosophy is a relatively contemporary philosophy that has gained increasing importance today. It focuses on the search for balance and understanding in a world characterized by polarization and complexity [1]. In a context where extreme opinions and intolerance often prevail in public and political debates. Neutrosophy offers a valuable perspective. It supports the exploration of nuances and the acceptance that the truth is not always found at the extremes, but somewhere in between. This is especially relevant in the age of social media, where information spreads quickly and opinions are easily polarized.[2]

Neutrosophy also plays an essential role in decision-making and conflict resolution. In a globalized and diverse world, it is essential to learn to understand and value different points of view and cultures. Neutrosophy promotes empathy and tolerance, encouraging people to consider multiple perspectives before making important decisions [3]. Many contemporary problems, such as artificial intelligence, biotechnology, and environmental management, require a balanced approach and careful evaluation of their ethical implications. Neutrosophy encourages ethical analysis from an impartial perspective, which can help guide ethical decision-making in an increasingly technological and complex world.[4]

Neutrosophy can be very useful in the medical field, and particularly in disciplines such as dentistry, by offering a balanced and reflective approach to clinical decision-making and work planning [5]. In dentistry, where the focus is on patients' oral health and quality of life, neutrosophy becomes a valuable philosophical framework. Considering nuances and finding balance are essential when evaluating treatment options. This is especially important in cases where different approaches must be weighed, such as in choosing dental materials or planning surgical procedures.[6]

When planning dental work, neutrosophy can be essential in helping professionals address complex clinical situations and make informed decisions. For example, when faced with a dental restoration case, neutrosophy encourages consideration of the patient's needs, budgetary constraints, and available therapeutic options. This can lead to a more personalized and balanced treatment approach, taking into account both oral health and the patient's individual situation.[7-14]

In addition, neutrosophy in dentistry is also related to ethical aspects. Dentists must constantly evaluate ethical issues, such as informed consent, confidentiality, and equity in care. The neutrosophic philosophy provides a basis for addressing these issues in an impartial and thoughtful manner, promoting a more ethical and professional dental practice.

Neutrosophy plays a significant role in the medical field, especially in dentistry. This provides a philosophical framework that favors balanced and ethical decision-making in planning work and patient care. This philosophy helps oral health professionals consider multiple perspectives and make informed decisions that holistically benefit the health and well-being of their patients.

The aim of this study is to investigate and describe in detail the approach to orthodontic treatment planning from a neutrosophic perspective. Through this research, it is intended to provide a solid basis for the implementation of neutrosophic orthodontics as a valuable alternative in contemporary orthodontic practice. Promoting more balanced and personalized care for patients, through planning based on neutrosophy.

2 Preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, T_A(x), I_A(x), F_A(x) x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.[8]

For convenience, a SVN number is denoted by A = ($a\ b\ c$), where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A = (a, b, c) be a SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then:

$$\lambda A = \left(1 - (1 - a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \quad (1)$$

Definition 3. Let $A^* = \{A_1^*, A_2^*, \ldots, A_n^*\}$ be a vector of n SVN numbers, such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \ldots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left(\left|a_{ij} - a_j^*\right|\right)^2 + \left(\left|b_{ij} - b_j^*\right|\right)^2 + \left(\left|c_{ij} - c_j^*\right|\right)^2\right)^{\frac{1}{2}} \quad (2)$$

(i= 1, 2, …, m)

Definition 4. Let $A = \{A_1, A_2, \ldots, A_n\}$ be a set of n SVN numbers, where $A_j = (a_j, b_j, c_j)$ (j= 1,2,…,n). The single value neutrosophic weighted average operator on them is defined by

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n}\left(1 - a_j\right)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \quad (3)$$

Whwre λ_j is the weight of A_j (j= 1,2,…,n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Next, a score function for ranking SVN numbers is proposed as follows:

Definition 5. Let A = (a, b, c) be a single valued neutrosophic number, a score function S of a single-valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity membership degree is defined by

$$S(A) = \frac{1+a-2b-c}{2} \quad (4)$$

where$S(A) \in [-1,1]$

The score function S is reduced the score function proposed by Li (2005)if b = 0 and a + b ≤ 1.

The value of a linguistic variable is expressed as an element of its term set. The concept of a linguistic variable is very useful for solving decision making problems with complex content. For example, the performance ratings of alternatives on qualitative attributes can be expressed by linguistic variables such as very important, important, medium, unimportant, very unimportant, etc. Such linguistic values can be represented using single valued neutrosophic numbers.

In the method, there are *k*-decision makers, *m*-alternatives, and *n*-criteria. *k*-decision makers evaluate the importance of the *m*-alternatives under *n*-criteria and rank the performance of the *n*-criteria with respect to linguistic statements converted into single valued neutrosophic numbers. Here, the decision makers often use a set of weights such that W= {very important, important, medium, unimportant, very unimportant} and the importance weights based on single valued neutrosophic values of the linguistic terms is given as Table 1.

Table 1: Linguistic variable and Single-Valued Neutrosophic Numbers. Note: Source: [10]

Integer	Linguistic variable	SVN numbers
0	No influence/Not important	(0.1,0.8,0.9)
1	Low influence/important	(0.35,0.6,0.7)
2	Medium influence/important	(0.5,0.4,0.45)
3	High influence/important	(0.8,0.2,0.15)
4	Very high influence/important	(0.9,0.1,0.1)

Definition 8 ([10], [11]) Deneutrosophication of SVNS Ñ can be defined as a process of mapping Ñ into a single crisp output for xf: Ñ → $\psi^* \in$X. If Ñ is discrete set then the vector of tetrads Ñ = {(x | TÑ(x), IÑ(x), FÑ(x)) | x ∈ X} is reduced to a single scalar quantity ψ∗∈X by deneutrosophication. The obtained scalar quantity ψ∗∈X best represents the aggregate distribution of three membership degrees of neutrosophic element TÑ (x), IÑ (x), FÑ (x). Therefore, the deneutrosophication can be obtained as follows.

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (\mathrm{F}(x))^2]/3} \quad (5)$$

2.1 Methods

The TOPSIS method for SVNS used consists of the following:

Assuming that $\mathrm{A} = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and $\mathrm{G} = \{\beta_1, \beta_2, \dots, \beta_n\}$ is a set of criteria, the following steps will be carried out [12-14-16-17-18]:

Step 1: Determine the relative importance of experts. To do this, the specialists evaluate according to the linguistic scale that appears in Table 1, and the calculations are carried out with its associated unique neutrosophic number (SVNN), call At = (at, bt, ct) the SVNS corresponding to the t-th decision-maker (t = 1, 2, …, k). The weight is calculated by the following formula:

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)} \quad (6)$$

$$\delta_t \geq 0 \; and \; \sum_{t=1}^{k} \delta_t = 1$$

Step 2: Construction of the neutrosophic decision matrix of aggregated single values. This matrix is defined by $D = \sum_{t=1}^{k} \lambda_t D^t$, where $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ and is used to aggregate all individual evaluations; d_{ij} is calculated as the aggregation of the evaluations given by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$, using the weights λ_t of each one with the help of Equation 1. In this way, a matrix D = (dij)ij is obtained, where each d_{ij} is an SVNN (i = 1, 2, .., m; j = 1,2,…, n).

Step 3: Determination of the Weight of the Criteria. Suppose that the weight of each criterion is given by W = (w_1, w_2, …, w_n), where w_j denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. S_i it is the evaluation of the criterion λ_t by the t-th expert. Then Equation 2 is used to aggregate the weights.

Step 4: Construction of the neutrosophic decision matrix from the weighted average of single values with respect to the criteria.

$$D^* = D * W, \quad (7)$$

$$where \; d_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

Step 5: Calculation of the ideal positive and negative SVNN solutions.

The criteria can be classified as cost type or benefit type. Let G_1 be the set of benefit-type criteria and G_2 be the cost-type criteria. The ideal alternatives will be defined as follows:

The positive ideal solution, corresponding to G_1.

$$\rho^+ = a_{\rho+w}(\beta_j), b_{\rho+w}(\beta_j), ac_{\rho+w}(\beta_j) \quad (8)$$

The negative ideal solution, corresponding to G_2.

$$\rho^- = (a_{\rho-w}(\beta_j), b_{\rho-w}(\beta_j), ac_{\rho-w}(\beta_j)) \quad (9)$$

Where:

$$a_{\rho+w}(\beta_j) = \begin{cases} max_i a_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ min_i a_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases} \qquad a_{\rho-w}(\beta_j) = \begin{cases} min_i a_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ max_i a_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases}$$

$$b_{\rho+w}(\beta_j) = \begin{cases} max_i b_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ min_i b_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases} \qquad b_{\rho-w}(\beta_j) = \begin{cases} min_i b_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ max_i b_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases}$$

$$c_{\rho+w}(\beta_j) = \begin{cases} max_i c_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ min_i c_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases} \qquad c_{\rho-w}(\beta_j) = \begin{cases} min_i c_{\rho iw}(\beta_j), si\ j \epsilon G_1 \\ max_i c_{\rho iw}(\beta_j), si\ j \epsilon G_2, \end{cases}$$

Step 6: Calculation of the distances to the positive and negative SVNN ideal solutions.

With the help of Equation 3, the following Equations are calculated:

$$d_i^+ = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^+\right)^2 + \left(b_{ij} - b_j^+\right)^2 + \left(c_{ij} - c_j^+\right)^2\right\}\right)^{\frac{1}{2}} \quad (10)$$

$$d_i^- = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^-\right)^2 + \left(b_{ij} - b_j^-\right)^2 + \left(c_{ij} - c_j^-\right)^2\right\}\right)^{\frac{1}{2}} \quad (11)$$

Step 7: Calculation of the Coefficient of Proximity (CP).

The CP of each alternative is calculated with respect to the positive and negative ideal solutions.

$$\widetilde{\rho_j} = \frac{s^-}{s^+ + s^-} \quad (12)$$

Where $0 \leq \widetilde{\rho_j} \leq 1$.

Step 8: Sorting of the alternatives.

They are sorted according to what the $\widetilde{\rho_j}$ value. The alternatives are ordered from highest to lowest, with the condition that $\widetilde{\rho_j} \rightarrow 1$ is the optimal solution.

To determine the planning objectives in neutrosophic dental treatment, the use of the DEMATEL method in its neutrosophic variant is proposed through the steps set out below.[13]

1. *Identify the elements to evaluate*: The influencing factors or elements are evaluated by the selected experts through paired comparisons, using the score shown in table 1.
2. *Determine the relative importance of experts:* Each of the selected experts has their own importance value, based on their level of experience and knowledge in the decision problem. Therefore, the weight of each decision maker may be different from that of other decision makers. The weight given to each of the *t* decision

makers is considered linguistic variables and is transmitted in SVNN $E_t = (T_t, I_t, F_t)$ to subsequently be identified using equation 13.

$$\psi_t = \frac{1-\sqrt{[(1-T_t)^2+(I_t)^2+(F_t)^2]/3}}{\sum_{t=1}^{p}\sqrt{[(1-T_t)^2+(I_t)^2+(F_t)^2]/3}} \quad (13)$$

3. *Convert the linguistic evaluations given by the experts into SVNN:* From the individual clear integer matrixes obtained from the experts' evaluations, the individual neutrosophic matrices of the decision makers are constructed according to what is indicated in table 1.
4. *Get the initial direct relationship matrix:* To obtain the initial direct relationship matrix that is in the form of crisp numbers, the neutrosophic matrices of the individual decision makers must be aggregated using equation 3 and deneutrosophied using equation 5.
5. *Identify cause-effect relationships between factors using the DEMATEL method*: Based on the aggregate direct relationship matrix A obtained in step 4, the total relationship matrix T can be easily calculated using equations (14-16) as shown below:

   $$D=A*S \quad (14)$$

   Where

   $$S = \frac{1}{\max\limits_{1\le i\le n}\sum_{j=1}^{n} a_{ij}} \quad (15)$$

   and

   $$T=D*(I-D)^{-1} \quad (16)$$

   where I is the identity matrix. From this, the cause-effect relationship diagram (ri + ci, ri −ci) is constructed.
6. *Analyze the cause-effect relationship diagram.* The (ri −ci) indicates the importance of each factor while (ri −ci) is the net cause or effect group. The (ri+ci) is called "Prominence" and it measures the degree of central role that the factor or criterion plays within the system. While (ri −ci): it is called "Relationship" and means the effect that the factor or criterion produces in the system. If (ri −ci) >0 the factor or criterion is placed in the group of causes. If (ri −ci) <0 the factor or criterion is in the group of effects. The pairs (ri −ci) and (ri +ci) can be represented graphically to give decision makers a graphical idea about the system.

3 Results

Planning neutrosophic orthodontic treatment involves considering a series of variables that reflect the neutrosophic philosophy of balance and understanding in clinical decision making. Some of the key variables to consider include:

- Patient Needs: Assess specific patient needs, such as orthodontic concerns, general oral health, and personal expectations.
- Costs and budget: Evaluate the costs associated with orthodontic treatment and discuss financing options with the patient.
- Techniques and materials: Select the most appropriate orthodontic techniques and materials for each case, considering factors such as durability, aesthetics, and cost.
- Clinical nuances: Consider the particularities of each case, such as the severity of the malocclusion, the health of the periodontal tissues and the conditions of the teeth and gums.
- Medical History: Review the patient's medical history for preexisting conditions that may influence orthodontic treatment, such as allergies, systemic diseases, or medications the patient takes.
- Psychosocial factors: Evaluate the psychological and emotional impact of the treatment on the patient, including their self-esteem, anxiety, and motivation for treatment.
- Treatment time: Determine the estimated duration of treatment and consider the patient's availability to comply with follow-up visits.
- Ethics and informed consent: Ensure that the patient fully understands the risks and benefits of the treatment, as well as obtain informed consent in an ethical manner.
- Long-term outcome evaluation: Plan long-term follow-up to evaluate stability and patient satisfaction with treatment results.

Planning neutrosophic orthodontic treatment is based on the comprehensive consideration of these variables. It seeks a balance between clinical, emotional, and ethical aspects to provide more personalized and satisfactory orthodontic care for the patient.

To determine the main aspects on which orthodontic treatment planning should be directed under neutrosophic standards, the criteria of specialists in the field were considered. A questionnaire was carried out on which the criteria to be evaluated in this research were concluded, and they will help make balanced and well-founded decisions.

The evaluation of the aforementioned aspects is carried out by a group of 5 highly experienced dentists. It is assumed that the individual contribution of each one to the evaluations to be carried out for the execution of the method is of the highest importance according to the linguistic values shown in table 1. The criteria to be considered in this research regarding the variables in planning neutrosophic orthodontic treatment will be the following (Table 2):

Table 2: Criteria to take into account regarding variables when planning neutrosophic orthodontic treatment. Source: Own elaboration

Criteria	
C1 Clinical effectiveness	Consider whether the proposed treatment is clinically effective in correcting the patient's malocclusion or orthodontic problem.
C2 Long-term stability	Evaluate the ability of the treatment to maintain stable and functional results in the long term.
C3 Impact on quality of life	Analyze how the treatment will affect the patient's quality of life, considering aspects such as comfort, aesthetics, and oral functionality.
C4 Cost-benefit	Compare the costs associated with the proposed treatment with the clinical and quality of life benefits expected to be obtained.
C5 Sustainable materials and techniques	Consider choosing materials and techniques that are sustainable from an environmental and economic perspective.

Establishing solid criteria based on these aspects ensures that orthodontic treatment planning from a neutrosophic perspective is comprehensive, balanced and focused on the individual needs and values of the patient, thus promoting more complete and satisfactory orthodontic care.

In this sense, Table 3 shows the aggregate decision matrix obtained after obtaining the evaluations of each of the aspects evaluated based on the selected criteria.

Table 3: Aggregate decision matrix. Source: Own elaboration

Aspects to evaluate	C1	C2	C3	C4	C5
Patient needs	(0.629,0.371,0.325)	(0.856,0.144,0.132)	(0.35,0.75,0.8)	(0.792,0.208,0.174)	(0.88,0.12,0.115)
Costs and budget	(0.856,0.144,0.132)	(0.621,0.379,0.347)	(0.35,0.75,0.8)	(0.67,0.33,0.289)	(0.827,0.173,0.152)
Techniques and materials	(0.88,0.12,0.115)	(0.81,0.19,0.19)	(0.621,0.379,0.347)	(0.827,0.173,0.152)	(0.75,0.25,0.2)
Clinical nuances	(0.725,0.275,0.251)	(0.713,0.287,0.24)	(0.5,0.5,0.5)	(0.792,0.208,0.174)	(0.621,0.379,0.347)
Medical history	(0.834,0.166,0.158)	(0.517,0.512,0.502)	(0.415,0.638,0.663)	(0.67,0.33,0.289)	(0.415,0.638,0.663)
Psychosocial factors	(0.583,0.417,0.365)	(0.517,0.512,0.502)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.67,0.33,0.289)
Treatment time	(0.289,0.711,0.711)	(0.383,0.692,0.728)	(0.383,0.692,0.728)	(0.35,0.75,0.8)	(0.713,0.287,0.24)
Ethics and informed consent	(0.5,0.5,0.5)	(0.556,0.483,0.459)	(0.415,0.638,0.663)	(0.67,0.33,0.289)	(0.415,0.638,0.663)
Long-term results evaluation	(0.67,0.33,0.289)	(0.5,0.5,0.5)	(0.383,0.692,0.728)	(0.621,0.379,0.347)	(0.75,0.25,0.2)

Considering the vector of weights obtained through the expert evaluations, shown in Table 4, the aggregate weighted decision matrix is calculated, remaining as seen in Table 5.

Table 4: Vector of weights of the criteria. Source: Own elaboration

Criterion	Criterion weight
Clinical effectiveness	(0.855;0.144;0.131)
Long term stability	(0.855;0.144;0.131)
Impact on quality of life	(0.760;0.239;0.209)
Cost-benefit	(0.712;0.287;0.240)
Sustainable materials and techniques	(0.855;0.144;0.131)

Table 5: Weighted aggregate decision matrix. Source: Own elaboration

Alternatives	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Patient needs	(0.538;0.461;0.414)	(0.73;0.26;0.246)	(0.266;0.809;0.841)	(0.564;0.435;0.372)	(0.753;0.246;0.231)
Costs and budget	(0.732;0.267;0.246)	(0.531;0.468;0.433)	(0.266;0.809;0.841)	(0.477;0.524;0.45)	(0.707;0.292;0.263)
Techniques and materials	(0.753;0.246;0.231)	(0.693;0.306;0.296)	(0.472;0.527;0.483)	(0.589;0.410;0.355)	(0.641;0.358;0.305)
Clinical nuances	(0.620;0.379;0.349)	(0.610;0.389;0.340)	(0.380;0.619;0.604)	(0.564;0.435;0.372)	(0.531;0.468;0.433)
Medical history	(0.713;0.286;0.26)	(0.441;0.582;0.567)	(0.315;0.724;0.733)	(0.477;0.522;0.459)	(0.355;0.690;0.707)
Psychosocial factors	(0.498;0.501;0.448)	(0.442;0.582;0.567)	(0.266;0.809;0.841)	(0.249;0.821;0.848)	(0.573;0.426;0.382)
Treatment time	(0.247;0.752;0.749)	(0.327;0.736;0.763)	(0.291;0.765;0.784)	(0.249;0.821;0.848)	(0.610;0.389;0.340)
Ethics and informed consent	(0.427;0.572;0.565)	(0.475;0.557;0.530)	(0.315;0.724;0.733)	(0.477;0.522;0.459)	(0.355;0.690;0.707)
Long-term results evaluation	(0.573;0.426;0.382)	(0.427;0.572;0.565)	(0.291;0.765;0.784)	(0.442;0.557;0.503)	(0.641;0.358;0.305)

Finally, the order of the analyzed elements is shown in Table 6, according to the calculated proximity coefficient.

Table 6: Ideal positive and negative distances and proximity coefficient. Source: Own elaboration

Alternatives	d+	d-	$\widetilde{\rho}_J$
Patient needs	0.43	0.64	0.598
Costs and budget	0.45	0.49	0.519
Techniques and materials	0.31	0.7	0.695
Clinical nuances	0.45	0.58	0.565
Medical history	0.7	0.49	0.412
Psychosocial factors	0.74	0.16	0.178
Treatment time	0.91	0.27	0.229
Ethics and informed consent	0.76	0.47	0.383
Long-term results evaluation	0.55	0.33	0.376

The analysis carried out indicates that the patient's needs, costs and budgets, techniques and materials and clinical nuances are the most significant elements associated with the planning of neutrosophic orthodontic treatments according to the evaluation of the experts.

4 Discussion

The results obtained are consistent with the opinion expressed by specialists in the surveys carried out. In this sense, the action plan proposed to plan neutrosophic orthodontic treatments should be focused on improving the aspects previously indicated by the method as those of greatest significance. See Table 7.

Table 7: Proposed action plan to improve neutrosophic orthodontic treatment planning. Source: Own elaboration

Action plan based on the relevant elements for planning neutrosophic orthodontic treatment	
Design of Patient Care Protocols	- Design standardized protocols to evaluate the aesthetic, functional and oral health needs of each patient, using clinical tools and questionnaires.
	- Train clinical staff in the application of evaluation protocols and in effective communication with patients.
Cost and Budget Evaluation	- Calculate the costs associated with neutrosophic orthodontic treatments, including materials, equipment, orthodontist fees and other indirect costs.
	- Create a personalized budget system for each patient, based on their specific needs and expectations, with clear and detailed options.
Selection of Techniques and Materials	- Evaluate the neutrosophic orthodontic techniques available on the market, considering their effectiveness, duration, and benefits for the patient.
	- Research and select high-quality orthodontic materials that conform to the principles of neutrosophy and are safe for patients.
Clinical Planning	- Perform a detailed clinical evaluation of each patient, including radiographs, facial photographs, study models and occlusion analysis.
	- Create specific treatment plans for each patient that address both aesthetic and functional needs, considering their concerns and expectations.

This action plan provides a comprehensive structure to address neutrosophic orthodontic treatment planning from initial evaluation to continuous improvement. It is important to involve the entire clinical team in this process and maintain open communication with patients to ensure satisfactory results and high-quality care.

In order to evaluate the level of priority to be given to the proposed action plan, the influence analysis between the analyzed elements is carried out. In this way, the aim is to determine those that have a greater impact within the system or are a priority over others. To carry out this analysis, each expert evaluates the degree of influence between the elements analyzed by applying the linguistic values in Table 1. By applying equations 3 and 5, the direct relationship matrix is obtained, as shown in Figure 1.

Figure 1: Direct relationship matrix of the factors. Source: Own elaboration

$$A = \begin{bmatrix} 0.0000 & 0.5000 & 0.8788 & 0.8558 & 0.7655 & 0.5000 & 0.6376 & 0.8788 & 0.7655 \\ 0.4370 & 0.0000 & 0.2853 & 0.1925 & 0.5000 & 0.7655 & 0.5000 & 0.3403 & 0.2853 \\ 0.3908 & 0.6833 & 0.0000 & 0.8558 & 0.8788 & 0.5376 & 0.8558 & 0.8788 & 0.8284 \\ 0.4371 & 0.1925 & 0.2853 & 0.0000 & 0.7655 & 0.5000 & 0.8284 & 0.4604 & 0.8558 \\ 0.8026 & 0.1925 & 0.8026 & 0.2853 & 0.0000 & 0.1925 & 0.5000 & 0.5000 & 0.5000 \\ 0.8558 & 0.7655 & 0.4604 & 0.1925 & 0.6092 & 0.0000 & 0.8558 & 0.1925 & 0.5710 \\ 0.2853 & 0.2293 & 0.3403 & 0.1925 & 0.1925 & 0.7746 & 0.0000 & 0.2853 & 0.6588 \\ 0.2853 & 0.1925 & 0.7655 & 0.6833 & 0.7373 & 0.2853 & 0.3706 & 0.0000 & 0.4174 \\ 0.8788 & 0.1925 & 0.2853 & 0.5000 & 0.6833 & 0.2853 & 0.5000 & 0.5710 & 0.0000 \end{bmatrix}$$

From this, the normalized initial direct relationship matrix D is obtained by using equations (14) and (15), as well as the total direct relationship matrix T, which can be calculated by using equation (16). as shown in Figure 2:

Figure 2: Total direct relationship matrix. Source: Own elaboration

$$T = \begin{bmatrix} 0.290 & 0.271 & 0.410 & 0.387 & 0.452 & 0.326 & 0.425 & 0.411 & 0.441 \\ 0.244 & 0.120 & 0.212 & 0.178 & 0.272 & 0.267 & 0.272 & 0.214 & 0.236 \\ 0.351 & 0.293 & 0.272 & 0.377 & 0.459 & 0.330 & 0.450 & 0.402 & 0.443 \\ 0.290 & 0.174 & 0.253 & 0.186 & 0.361 & 0.262 & 0.367 & 0.276 & 0.370 \\ 0.324 & 0.171 & 0.321 & 0.235 & 0.238 & 0.208 & 0.308 & 0.281 & 0.309 \\ 0.360 & 0.274 & 0.291 & 0.230 & 0.351 & 0.203 & 0.385 & 0.252 & 0.341 \\ 0.209 & 0.148 & 0.201 & 0.167 & 0.212 & 0.253 & 0.178 & 0.192 & 0.274 \\ 0.244 & 0.164 & 0.305 & 0.280 & 0.341 & 0.213 & 0.283 & 0.191 & 0.289 \\ 0.338 & 0.168 & 0.249 & 0.262 & 0.340 & 0.220 & 0.306 & 0.287 & 0.230 \end{bmatrix}$$

After obtaining the total direct relationship matrix, the direct and indirect effects of the indicated elements are determined by analyzing the axes of prominence and relationship for the cause-and-effect group, as shown in Table 8.

Table 8: Analysis of the axes of prominence and relationship for the cause-and-effect group. Source: Own elaboration

Elements to evaluate	Ri	Ci	Ri+Ci	Ri-Ci
Patient needs	3,414	2.65	6,064	0.764
Costs and budget	2015	1,784	3,799	0.231
Techniques and materials	3,377	2,514	5,891	0.863
Clinical nuances	2,539	2,302	4,841	0.237
Medical history	2,395	3,026	5,421	-0.631
Psychosocial factors	2,687	2,282	4,969	0.405
Treatment time	1,834	2,974	4,808	-1.14
Ethics and informed consent	2.31	2,506	4,816	-0.196
Long-term results evaluation	2.4	2,933	5,333	-0.533

Based on the analysis, it is evident that patient needs and techniques and materials are the most prominent elements in the system. Interestingly, these two elements also have a higher level in the relationship indicator, indicating that they have the greatest causality over the other analyzed elements. The analysis indicates that the primary focus for implementing the proposed actions and developing neutrosophic orthodontic treatment planning should be directed towards this direction.

Conclusion

Neutrosophy emerges as a relevant philosophy for decision making and planning in the dental field. Its focus on the search for balance and understanding in a world characterized by polarization and complexity proves to be a valuable perspective for dental professionals. In a context where patient needs, costs, ethics and other factors must be balanced, Neutrosophy provides a philosophical framework that promotes informed and equitable decision making.

Orthodontic treatment planning from a neutrosophic perspective focuses on the holistic consideration of multiple factors. It recognizes the importance of balancing patient needs with clinical considerations, costs, sustainability of materials and techniques, as well as ethical and psychosocial issues. This comprehensive approach results in more personalized and satisfying orthodontic care.

The involvement of dental professionals in the evaluation of key aspects of neutrosophic treatment planning is essential. The weighting of criteria and the evaluation of complex variables such as clinical effectiveness, long-term stability, and impact on quality of life require the expertise and judgment of qualified professionals. As a result of the study, it was possible to highlight that the most notable elements in neutrosophic dental treatment planning are patient needs, costs and budgets, techniques and materials, and clinical nuances. In this sense, planning actions should be strengthened for the attractiveness and quality of life of patients.

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