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Triadic dynamics of clinical decisions in apical surgery based on Neutrosophic N- Alectic

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Abstract. This study explored the creation of a clinical decision-making model in apical surgery via Neutrosophic N-Alectic, blending affirmative (operate), negative (observe), and neutral (retry conventional endodontics) based on equivocal findings to offer potential solutions to the presentation of periapical lesions. The methodology consisted of dialectic considerations of previous surgeries retrospectively, meaning attributable elements such as lesion severity and response to previous treatment were assessed via a neutrosophic approach to assess the degree of truth, degree of falsity and degree of indeterminacy across all treatment options. The main findings are the neutrosophic model assists in determining the best decisions based on a conglomeration of clinical perspectives simultaneously, when a traditional yes/no determination can lead to unnecessary procedures and less effective diagnosis. Findings are applicable that Neutrosophic N-Alectic is a successful strategy for navigating complexity and equivocation of the decision-making arena, which fosters a more individualized approach to endodontics with potential for further interdisciplinary application.

Keywords: Apical surgery, N-Alectic Neutrosophic, Decision making, Endodontics, Uncertainty, Clinical dialectics, Periapical lesions.

1. Introduction

Apical surgery, an endodontic procedure for treating persistent periapical lesions, poses a significant clinical challenge due to the difficulty in deciding between surgery, observation, or reattempting conventional endodontic treatment. This decision is complicated by diagnostic uncertainty, variability in treatment responses, and patient preferences, which can lead to unnecessary interventions or delays in appropriate treatment. The lack of a structured framework for integrating these options into a clear decision-making process represents a critical problem in clinical practice, as traditional approaches are often binary and fail to consider the inherent ambiguity of these cases.

Several studies have explored decision-making in endodontics, focusing on clinical criteria such as the extent of periapical lesions and response to previous treatments [1]. For example, research has shown that apical surgery is effective in resolving persistent infections, but its indication depends on factors such as lesion size and the quality of the coronal seal [2]. However, these studies often adopt linear approaches that do not address uncertainty or the contradictions between operating and observing [3]. Furthermore, the literature highlights that repeating conventional endodontics may be a viable alternative in certain cases, although the criteria for its selection are not well defined [4]. The limitations of traditional approaches lie in their inability to model the complexity of clinical decisions under uncertainty. Binary models, which prioritize whether to operate or not to operate, ignore the possibility of an intermediate option, such as retrying endodontics, which can lead to suboptimal decisions [5]. This gap in the literature suggests the need for a framework that integrates multiple perspectives and manages the ambiguity inherent in these cases, allowing for a more holistic assessment of available options.

N- Alectic , developed as an approach to modeling decisions under uncertainty, offers a promising solution by integrating three components: affirmation, contradiction, and neutrality. This framework allows for simultaneous consideration of decisions to operate (affirmation), observe (contradiction), and retry endodontics (neutrality), assigning truth, falsity, and indeterminacy values to each option. Unlike traditional models, neutrosophy provides a dialectical structure that captures the complexity of clinical decisions, which is particularly useful in contexts where the evidence is inconclusive. The relevance of this study lies in its ability to address an unmet clinical need: improving the accuracy and personalization of decision-making in apical surgery. In a context where medical resources are limited and patient expectations are high, an approach that optimizes clinical decisions can reduce unnecessary interventions, improve therapeutic outcomes, and increase patient satisfaction. Furthermore, the application of Neutrosophic N- Alectic could set a precedent for its use in other areas of medicine where uncertainty is a critical factor.

Modern endodontics is facing increasing case complexity due to factors such as an aging population and the rising prevalence of systemic diseases that affect treatment response [6]. These challenges underscore the need for innovative approaches that go beInd traditional clinical guidelines, which do not always consider individual patient variability. The integration of advanced theoretical tools, such as neutrosophy, may provide a practical and theoretically sound solution to this problem.

Neutrosophic N- Alectic clinical decision-making model in apical surgery , which facilitates the choice between operating, observing, or reattempting conventional endodontic treatment. A secondary objective is to evaluate the applicability of this model to real-life clinical cases by analyzing how the integration of affirmation, contradiction, and neutrality improves diagnostic and therapeutic accuracy. No specific hypotheses are put forward, as the study adopts an exploratory approach to model the triadic dynamics of clinical decisions. The implicit hypothesis is that the use of Neutrosophic N- Alectic will allow a more complete evaluation of clinical options by considering uncertainty as a central component of the decision-making process. This approach could overcome the limitations of binary models, which fail to capture the complexity of periapical cases , and offer an alternative that balances the risks and benefits of each treatment option [7].

This study is justified by its potential to transform clinical practice in endodontics, providing a framework that not only improves decision-making but also encourages a more personalized and patient-centered approach. By addressing the limitations of traditional approaches and proposing an innovative solution, this research contributes to the advancement of knowledge in endodontics and the application of neutrosophic theories in clinical contexts. In summary, the introduction of Neutrosophic N- Alectic into clinical decision-making in apical surgery represents a significant advance toward the management of uncertainty and complexity in endodontics. By integrating affirmation, contradiction, and neutrality, this study seeks to establish a model that not only optimizes clinical decisions but also lays the foundation for future research in other areas of medicine.

2. Preliminaries

2.1. N - Alectic Neutrosophic as a theoretical framework.

N- alectic constitutes an advanced evolution of neutrosophy, developed by Smarandache (2002), which expands the scope of conventional dialectical thought. While classical dialectic is based on the confrontation between two opposing poles—truth (T) and falsehood (F) —neutrosophy incorporates a third key element: indeterminacy or neutrality (I). This component represents a midpoint that expresses ambiguity, doubt, or even the simultaneity of opposites. According to Smarandache, it is an "interaction between truth, falsehood and neutrality", which allows us to address more complex realities, where binary oppositions are insufficient to explain the totality of the phenomena or relationships present. This approach evolves further towards N-Alectic, a general model that refines the basic components T (Truth), I (Indeterminacy) and F (Falsehood) into n interdependent subcomponents: $(T_1, T_2, \ldots, T_p;\ I_1, I_2, \ldots, I_r;\ F_1, F_2, \ldots, F_s)$, where p, r and s are positive integers and $p + r + s =$

$n$physical logic allows multidimensional phenomena to be decomposed into specific elements, modeling their dynamic relationships more accurately.

The foundation of N- alectic finds its roots in the indigenous worldviews of pre-Columbian times, such as those of the Mesoamerican, Andean, and Amazonian, which have historically been characterized by structuring their thinking beInd binary logic. [8].

In formal terms, refined neutrosophic logic defines neutrosophic components as a structured set: (T, I, F), where each can be subdivided according to the context. For example, in fourfold neutrosophic logic, an intermediate case between trialectic and n- alectic, a refinement of (T, F) into (T, I_1, I_2, F) is proposed, as in the case of man (T), woman (F), complementarity (I_1), and contradiction (I_2).

In its most general form, N-Alecticsi expressed as: $(T_1, T_2, \dots, Tp; I_1, I_2, \dots, Ir; F_1, F_2, \dots, Fs)$ where the total number of subcomponents $(n = p + r + s)$depends on the granularity required for the analysis. This flexibility makes it possible to capture the richness of dynamic systems, where interactions are not reduced to simple polarities. Furthermore, N-Alectic is applied in practice through quantitative metrics, as in the ethical decision-making described in the base article. In this case, weights (w_i) are assigned to each subcomponent; for example, w_T = 0.33 for T, w_I = 0.165 for pure I, w_F = 0.175 for F, and the neutrosophic distance to an ideal solution is calculated using the formula:

$$\boldsymbol{d_i}^+ = \sum_{i=1}^{n} \left(w_T \left| T_{A(x_i)} - T_{B(x_i)} \right|^{\lambda} + w_{IT} \left| IT_{A(x_i)} - IT_{B(x_i)} \right|^{\lambda} + w_I \left| I_{A(x_i)} - I_{B(x_i)} \right|^{\lambda} + w_{IF} \left| IF_{A(x_i)} - IF_{B(x_i)} \right|^{\lambda} + w_F \left| F_{A(x_i)} - F_{B(x_i)} \right|^{\lambda} \right) \quad \textbf{(1)}$$

where λ determines the type of distance (λ = 1 for Hamming, λ = 2 for Euclidean), x_i are the observed values and y_i the ideal ones [9]. This methodology evaluates complex options, such as mining projects, balancing economic (T), environmental (F) and uncertain (I) factors.

This type of analysis, based on the trialectic logic of N-alectic, transcends previous approaches that have addressed these constructs as if they were static or independent entities. Instead, it proposes a relational and integrative view, capable of representing the dynamic interaction between multiple factors.

From this perspective, the ideal configuration can be represented through a harmonious combination of T values, which allows for the modeling of more realistic and complete scenarios. For example, the ideal solution could be defined as::

$$I = \left(max(T_x), max(IT_x), min(I_x), min(IF_x), min(F_x) \right) \quad (2)$$

Where:

- T_x: Truth associated with option x.
- IT_x: Indeterminacy that tends towards the truth associated with option x.
- I_x: Pure indeterminacy associated with option x.
- IF_x: Indeterminacy that tends to falsehood associated with option x.
- F_x: Minimum falsehood associated with option x.

The relevance of N-Alectic in this context lies in its ability to model the dynamic interaction between these elements, aligning with principles of complementarity and balance present in Andean philosophies such as Yanantin, which resonate with teacher training in a culturally diverse environment [11]. Furthermore, its practical application, inspired by the ethical decision-making model of the base article, allows for the quantification these relationships through weights assigned to each subcomponent and neutrosophic distance calculations, providing a robust methodological tool.

3. Case Study

The present analysis aims to apply a clinical decision-making model in apical surgery using Neutrosophic N- Alectic . The purpose is to structure the choice between **operating** (apical surgery),

reattempting conventional endodontics or simply **observing** , addressing the uncertainty inherent in the treatment of persistent periapical lesions . To this end, a clinical case is presented, where prognostic factors are evaluated by decomposing the decision into subcomponents of truth (treatment success), falsity (failure or complication) and indeterminacy (diagnostic or prognostic uncertainty).

This approach, based on refined neutrosophic logic, enables a quantitative and multidimensional assessment that overcomes the limitations of traditional binary decision models (e.g., operate vs. do not operate), offering a structured basis for personalizing treatment and optimizing clinical outcomes.

Step 1: Definition of Neutrosophic Subcomponents

To model the clinical decision in the treatment of a periapical lesion , the following subcomponents are established based on the principles of Neutrosophic N- Alectic , adapted to the endodontic context :

Truth (T) - Factors that favor successful treatment and dental preservation:

- **T_1 : High probability of elimination of** periapical pathology and effective apical sealing.
- **T_2** : High probability of bone regeneration and complete resolution of symptoms in the long term.

Indeterminacy (I) - Factors of clinical ambiguity and uncertain prognosis:

- **IT (Indeterminacy towards the Truth)** : Ambiguous radiographic or clinical findings, but with a favorable overall prognosis (e.g., small lesion, asymptomatic patient with previous treatment of apparently good quality) .
- **I (Pure Indeterminacy)** : Contradictory clinical information (e.g., asymptomatic patient but with a large, slow-growing radiographic lesion; complex root anatomy making outcome difficult to predict).
- **IF (Indeterminacy towards Falsehood)** : Factors that introduce uncertainty with negative bias (e.g., suspicion of an unconfirmed vertical root fracture; limited access that compromises visibility) .

Falsehood (F) - Factors that indicate a risk of failure or complications:

- **F_1** : High risk of complications during or after the procedure (e.g. damage to adjacent anatomical structures, extrusion of material).
- **F_2** : High probability of persistence of the pathology, treatment failure or need for future tooth extraction.

The decision scenario is therefore structured as the following n- alectic set :

Clinical Decision= $\{\boldsymbol{T}_1, \boldsymbol{T}_2, \boldsymbol{I\_T}, \boldsymbol{I}, \boldsymbol{I\_F}, \boldsymbol{F}_1, \boldsymbol{F}_2\}$

Step 2: Assigning Weights to Components

To reflect the relative importance of each factor in clinical decision-making, the following weights are assigned. The highest priority is given to eliminating pathology (T_1) and minimizing failures (F_2).

Table 1. Weight Assignment by Component

Component	Description	Weight (w_i)
T_1	Elimination of pathology	0.25
T_2	Regeneration and resolution	0.15
I_M	Uncertainty with a favorable forecast	0.10
I	Pure uncertainty	0.10
I_F	Uncertainty with unfavorable prognosis	0.15
F_1	Risk of complications	0.10
F_2	Long-term risk of failure	0.15
Total		**1.00**

The total sum of the weights is: $\Sigma wi = 0.25 + 0.15 + 0.10 + 0.10 + 0.15 + 0.10 + 0.15 = 1.00$

Step 3: Identifying the Ideal Profile and Evaluating Clinical Options

The ideal profile (Ideal) for any treatment represents the greatest possible success with minimal uncertainty and risk. Using the defined structure, the ideal profile is established as follows:

$\mathbf{Ideal} = \{\boldsymbol{T_1 = 1.0, T_2 = 0.9, I\_T = 0.1, I = 0.0, I\_F = 0.1, F_1 = 0.0, F_2 = 0.1}\}$

This profile represents the total elimination of the pathology, almost complete regeneration, minimal uncertainty and practically zero risks.

Clinical Case

Patient : A 45-year-old man presents with a maxillary first molar that had undergone root canal treatment 8 years earlier and a well-fitting zirconium crown. The patient is asymptomatic, but a follow-up x-ray shows a periapical lesion. Persistent radiolucent lesion of moderate size (~5 mm in diameter) associated with the mesiobuccal root . The quality of the existing root canal treatment is acceptable but not optimal; no clear cause of failure is observed.

Evaluation of Treatment Options

Table 2. Neutrosophic Assessment of Treatment Options

Component	Apical Surgery	Endodontic Re-treatment	Observation
T_1	0.9	0.6	0.1
T_2	0.8	0.5	0.1
I_T	0.2	0.4	0.2
I	0.1	0.6	0.5
I_F	0.2	0.5	0.7
F_1	0.3	0.4	0.1
F_2	0.2	0.5	0.8

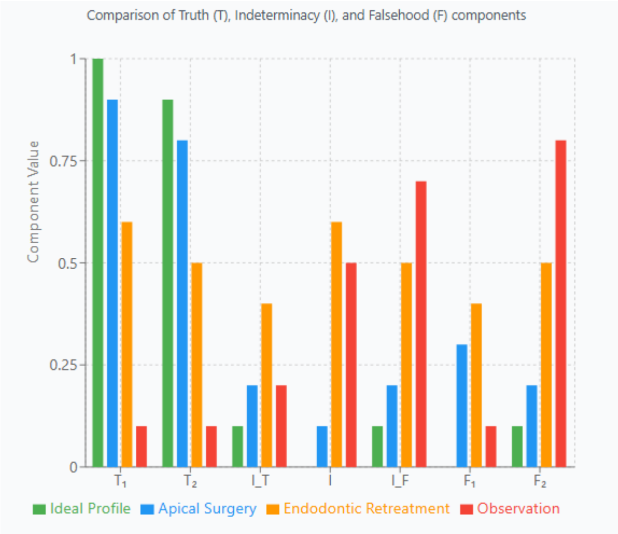

Figure 1: Evaluation of Neutrosophic Components by Treatment

Justification of the Evaluations:

Option A: Apical Surgery (Operate)

- T_1=0.9: High probability of removing the lesion directly and achieving an apical seal
- T_2=0.8: Good probability of bone regeneration
- I_T=0.2: Surgery resolves uncertainty about the cause of failure by allowing direct inspection
- I=0.1: Minimum uncertainty, related to the patient's biological response
- I_F=0.2: Risk of not being able to locate or completely seal an accessory duct
- F_1=0.3: Risk of complication due to the proximity of the maxillary sinus
- F_2=0.2: Low risk of failure if the surgery is performed correctly

Option B: Retry Conventional Endodontics (Re-treatment)

- T_1=0.6: Moderate probability of success, since it requires removing a zirconium crown and the result is uncertain.
- T_2=0.5: Regeneration depends on the success of disinfection, which is uncertain
- I_T=0.4: If a better seal is achieved, the prognosis is good
- I=0.6: High uncertainty about whether pretreatment can be improved or whether there are untreated channels
- I_F=0.5: High risk of not being able to negotiate the canals or of the cause being extra-radicular
- F_1=0.4: Risk of tooth fracture when removing the crown and post, if present
- F_2=0.5: Moderate probability that treatment will fail and surgery will still be required

Option C: Observation (Wait and Monitor)

- T_1=0.1: Very low probability of spontaneous resolution
- T_2=0.1: Bone regeneration is very unlikely without intervention
- I_T=0.2: The only positive aspect is that treatment is avoided for now
- I=0.5: Uncertainty about the evolution of the injury: it could remain stable
- I_F=0.7: High probability that the lesion will grow or become symptomatic over time

- F_1=0.1: There is no risk of immediate iatrogenic complication
- F_2=0.8: Very high probability of long-term failure, resulting in a worse prognosis or tooth loss

Quantitative analysis

Step 4: Calculating the Neutrosophic Distance

Hamming distance formula (λ=1):

$$\textbf{d(Ideal Option)} = \sum_1^7 w_i \cdot |x_i - y_i|$$

Where :

- w $_i$ = weight of component i
- x $_i$ = value of component i for the option evaluated
- and $_i$ = value of component i in the ideal profile

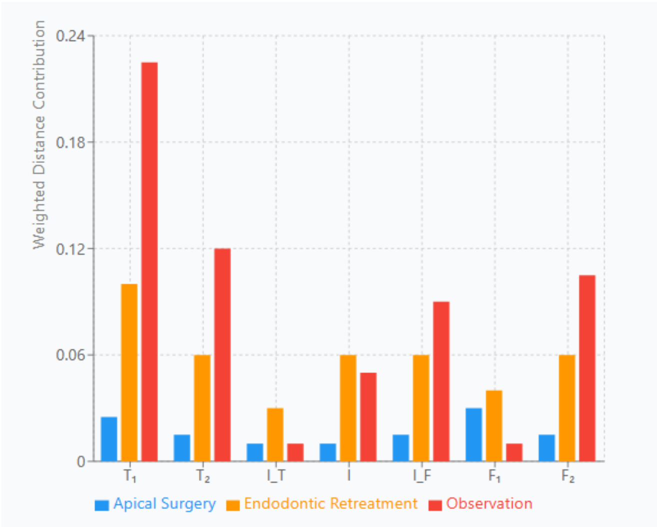

Figure 2: Weighted Contribution to Neutrosophic Distance

Qualifying Results

When comparing the calculated neutrosophic distances:

Table 3. Ranking of Options by Neutrosophic Distance

Option	Distance to the Ideal	Ranking
Apical Surgery	0.120	1st (Best)
Endodontic Re-treatment	0.410	2nd
Observation	0.610	3rd (Worst)

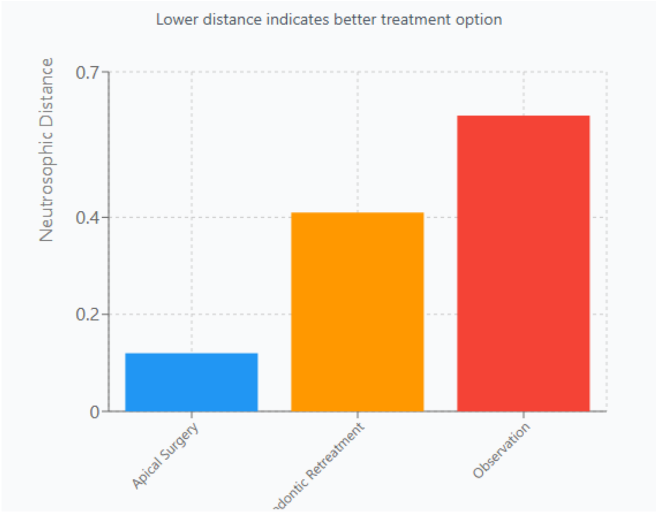

Figure 3: Neutrosophic Distance to the Ideal Profile

Option **A (Apical Surgery)** presents the smallest neutrosophic distance from the ideal profile. Therefore, according to this model, it is the most robust and recommendable clinical decision for the case presented.

4. Discussion

N-Alectic Neutrosophic analysis not only provides a recommendation but also illuminates the decision structure. The result indicates that **Apical Surgery** ($\boldsymbol{d = 0.120}$) is significantly superior to the other two options for this specific clinical case [13, 14].

The key differentiator is how each option handles **uncertainty** and **risk of failure** [15]. **Retrying Root Canal Treatment** ($\boldsymbol{d = 0.410}$) , although a more conservative approach, was heavily penalized by its high uncertainty (I=0.6, I_F=0.5) and the risk that the treatment will not resolve the problem (F_2=0.5). The model quantifies the clinical disadvantage of performing an invasive procedure (removing a crown) with such an uncertain prognosis [16].

Observation **(d=0.610)** turned out to be the worst choice, as expected. Its high distance score was due to its near-zero probability of success (T_1=0.1, T_2=0.1) and a high long-term probability of failure (F_2=0.8), encapsulated in a falsifiable indeterminacy (I_F=0.7). The model formalizes why "inaction" is a high-risk decision in this context.

In contrast, **apical surgery [17]** , despite having an inherent complication risk (F_1=0.3), offers the highest probability of definitive success (T_1=0.9) and the greatest reduction in diagnostic uncertainty (I=0.1). The model demonstrates that accepting a known and manageable complication risk (F_1) is preferable to accepting high uncertainty about treatment efficacy (I, I_F) or almost certain failure (F_2).

N-alectis's ability to go beyond a simple comparison of success rates. By explicitly incorporating and weighing ambiguity and multifactorial risks , the model offers a more accurate reflection of complex clinical reasoning, where decisions are often made by balancing not only what is true and false, but also what is uncertain [18,19].

5. Conclusions

The neutrosophic N-Alectic-based clinical decision-making model proves to be a powerful and effective tool for addressing complexity in apical surgery. The model optimizes the clinical decision by identifying Apical Surgery as the superior option for the presented case, not only due to its high probability of success but also its ability to resolve uncertainty more effectively than the alternatives. By quantifying the distance to an "ideal" solution, the method provides a clear and hierarchical ranking of treatment options, facilitating an informed choice.

The main contribution of the neutrosophic framework is its ability to manage uncertainty by formally integrating it as a core component of the analysis. This reflects clinical reality, where information is often incomplete, and allows for differentiation between a predictable though risky option (surgery) and one with an uncertain prognosis (retreatment). In turn, the methodology offers a transparent and reproducible process that, through the explicit definition of subcomponents (Truth, Indeterminacy, Falsity) and the assignment of weights, compels the clinician to systematically reflect on all relevant factors, reducing cognitive biases.

Ultimately, the application of Neutrosophic N-Alectic in endodontics not only validates its utility as an analytical tool but also paves the way for its use in other areas of medicine where complex decisions under uncertainty are the norm. This approach fosters a paradigm that values clarity, manages ambiguity, and quantitatively balances risks, thereby improving the quality and consistency of clinical judgment.

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