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Neutrosophic Statistics to Analyze Prevalence of Dental Fluorosis

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Abstract. Fluorine is a mineral that has been worldwide used for treating teeth, as it is effective in preventing dental cavities. That is why fluorine has been incorporated into toothpastes, as well as in some foods. However, excessive consumption of this mineral constitutes a serious oral health problem. This paper analyzes the occurrence of fluorosis, which is the disease caused by excessive consumption of fluorine, in children belonging to El Oro Educational Unit, located in the Central Ecuadorian Sierra. The study was carried out by means of a survey applied to the children's parents, and the direct study of the infants' teeth. Data is statistically processed, however, during the analysis of the data some of them had indeterminacies, so we decided that the best tool to use is Neutrosophic Statistics, because this theory studies statistics techniques in situations where there is indeterminacy in the data, in the population size, or in the parameters of the hypothesis tests. Moreover, this study has an important impact on the knowledge about the oral health of the children who attend this educational unit. In addition, it is a precedent for improving oral hygiene habits in infants.

Keywords: Neutrosophic Statistics, dental fluorosis, fluorine, survey.

1 Introduction

During the 1940s, the discovery that high amounts of fluorine in water causes abnormal discoloration of the tooth enamel, led to carefully find out how it affects the general health of an individual, thus, it was necessary to investigate how fluorine inserts in hard tissues and in human metabolism, as well as its presence in nature, [1].

In the 1950s, a research on fluorides was conducted in the United States, which have been very useful today to prevent and reduce dental caries. Therefore, the Pan-American Health Organization (PAHO) recommends artificial fluoridation of water supplies as a preventive measure for caries, for the structuring and mineralization of the dental follicle in the first years of life. Since 1962, it has been established in the United States that optimal doses are between 0.7 and 1.2 parts per million (ppm) per day, according to World Health Organization's recommendations (WHO), [2].

Currently, studies of fluorides have led many countries to implement fluorine in water, salt or milk, in addition to the natural sources from which it comes. Today, there are many products enriched with fluorides that can be found in the market, such as mouthwashes, toothpastes, food and materials for dental use, [3].

The excessive intake of fluorine and its indiscriminate use, due to the availability of fluorides that exist in different sources, may cause harmful effects on temporary and permanent dentition such as dental fluorosis. This alteration has been increasing every day. It is mostly due to the summation effect at the systemic level caused by the large amount of fluorine that is daily consumed and that can be found in different sources, [3].

Dental fluorosis, according to the scientific literature, is described as a serious pathology, which is characterized by abnormalities in the dental pieces. This pathology is caused by the existence of an interaction between the fluorine molecules present in the body, at the moment they enter in contact with dental tissues during the mineralization process, thus causing hypo-mineralization, specifically on the enamel surface. Its characteristics are manifested with a considerable increase in the porosity of the enamel, showing an opaque coloration that also affects the dentin. In Ecuador, according to the Ecuadorian Institute for Standardization (INEN 1108-2004), the limit of fluorine molecules present in water for human consumption is 1.5 ppm, which is high if compared to the recommendations of WHO, [4].

Dental fluorosis is an endemic public health problem described by causing alteration in the process of formation of dental organs, causing enamel defects, which can vary from whitish spots to the presence of craters, which are related to the severity degree and the period of formation of the dental organs. This pathology affects a large percentage of the population worldwide and as well as in the Ecuadorian Central Sierra. Taking into account this background, the purpose of this research is to determine the prevalence of dental fluorosis in schoolchildren from 8 to 12 years old from the Educational Unit El Oro. We also analyzed its relationship with triggers, in a population of 138 schoolchildren whose tutors or parents, through a validated survey attached to an informed consent, were evaluated in terms of diet and oral hygiene habits, [5].

This study is carried out because of the presence of dental fluorosis is suspected in the schoolchildren of El Oro Educational Unit, in Totoras parish, due to the fact that the drinking water is not treated or purified. Added to this background, is the ignorance of parents, educators and schoolchildren about the correct use and concentrations of fluoride toothpastes and mouthwashes. Therefore, it is necessary to carry out a study in which the prevalence of dental fluorosis will be determined.

A teeth frontal view of each of the participants is photographed; each photograph was analyzed by two evaluators specialized in the detection of fluorosis using the Thylstrup and Fejerskov Index to determine the degree of fluorosis, [6]. Each participant was asked to dose a portion of commercialized toothpaste, simulating what is performed on a daily basis, the dosages were weighed using a precision balance. Finally, the water sample that was taken from the Educational Unit was chemically analyzed for fluorine concentration.

We decided to carry out this study with the help of Neutrosophic Statistics ([7-14]). This theory generalizes classical statistics to the framework of Neutrosophy. This generalization consists in statistically processing data with a certain degree of indeterminacy; this indeterminacy can be present in the sample size, in some data, or in the estimated parameters of the statistical tests.

In this case study, when carrying out the statistical processing of the survey data, we found that there are some imprecise answers, while others do not include precisely a particular answer among the proposals. For this reason, it was determined that Neutrosophic Statistics is more appropriate than classical statistics.

This paper is split into the following sections. Section 2 contains the initial concepts of Neutrosophy and Neutrosophic Statistics. Next, section 3 is presents the results of applying Neutrosophic Statistics in schoolchildren who are being studied. The article ends with the conclusions.

2 Materials and Methods

Neutrosophic Statistics extends classical statistics, such that crisp values are replaced by sets [7, 15, 16]. This section describes the main concepts of Neutrosophy and Neutrosophic Statistics that will be used in this paper to process the data.

In this new statistics, the population size, the parameters used for the calculations, as well as the data may contain indeterminacies, due to the researcher's lack of knowledge, lack of information, contradictory information, or any other reasons.

Neutrosophic Statistics is essentially concerned with indeterminacy as well as randomness, while classical statistics studies only random phenomena.

Neutrosophic Descriptive Statistics comprises all the techniques that describe the characteristics of numerical data.

Neutrosophic Inferential Statistics consists of inference methods from a random sample of neutrosophic elements.

Neutrosophic Data is the data set, such that at least one of them contains some indeterminacy. These are classified into *discrete neutrosophic data* if the data are isolated points, e.g., $5 + i_1$, where $i_1 \in [1, 4]$ or *continuous neutrosophic data*, if the data comprise one or more intervals, e.g., [6, 9], see [17-20].

Quantitative (numerical) neutrosophic data are those represented by numerical ranges. *Qualitative (categorical) neutrosophic data* are those categorical data with indeterminacy, e.g., blue or red (we do not know exactly).

Univariate neutrosophic data consists of the observed data on a neutrosophic single attribute. A *multivariate neutrosophic data* consists of observations of two or more attributes.

A *Neutrosophic Statistical Number* N has the following form [7]:

$$N = d + i \qquad (1)$$

Where d is the *determinate part* and i is the *indeterminate part*.

A *Neutrosophic Population* is a population not well determined at the level of membership.

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

Neutrosophic Numbers are those satisfying Equation 2 [17-20]:

$$a + bI \qquad (2)$$

Where a, b are real numbers, and I is indeterminacy, such that $I^2 = I$ and $0 \cdot I = 0$.

If the coefficients a and b are real, then a + bI is called *Neutrosophic Real Number*.

Given $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$ two neutrosophic numbers, some operations between them are defined as follows:

1. $N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition);
2. $N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),
3. $N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Multiplication),
4. $\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division).

Additionally, given $I_1 = [a_1, b_1]$ and $I_2 = [a_2, b_2]$ we have the following operations between them (see [7, 21]):

1. $I_1 \leq I_2$ if and only if $a_1 \leq a_2$ and $b_1 \leq b_2$.
2. $I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition);
3. $I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction),
4. $I_1 \cdot I_2 = [\min\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}, \max\{a_1{\cdot}b_1, a_1{\cdot}b_2, a_2{\cdot}b_1, a_2{\cdot}b_2\}]$ (Multiplication),
5. $I_1/I_2 = I_1{\cdot}(1/I_2) = \{a/b\colon a{\in}I_1, b{\in}I_2\}$, always that $0 \notin I_2$ (Division).

3 Results

The study consists of a survey to the parents of schoolchildren from 8 to 12 years of age from El Oro Educational Unit in Totoras parish, to determine their knowledge about dental fluorosis, the triggers and the appropriate concentrations to maintain optimal oral health. Additionally, the photographic technique was used to determine the degree of fluorosis using the TF technique in schoolchildren.

The call for survey was made to hold a meeting of parents where it was explained as an informative talk about the purpose of the investigation, then, each parent gave its informed consent. Emphasis is placed on three important points: purpose, benefits and risks of the study[22, 23]. It is also explained that with the signature of this document the parent or tutor authorizes the child to participate in the course of the investigation. Along with the consent, a survey is delivered to be completed by the parents or tutors of the examined children. This survey has a total of 17 closed questions to obtain information on the possible risk factors for the presence of dental fluorosis. The document contained questions such as the type of water consumed, packaged beverages, type of salt, type of food diet and oral hygiene conditions. To guarantee patient confidentiality, the surveys were managed with numerical codes.

Photographs were taken with a smartphone's high-resolution camera under natural light conditions. The photographic record was made requesting each participant to remain seated in a chair. The mouth gag was placed according to the age of the patient. The food residues, plate or substance existing on the vestibular surface that interfered with the correct visualization of the teeth were removed with sterile gauze. Each photograph was adequately identified and subsequently analyzed by the researcher and the tutor-teacher, duly prepared and trained to detect fluorosis using the TF index. The values that each researcher will grant to each photograph were saved to tables in Microsoft Excel with the identification data of each participant. In case of discrepancy in the degree of fluorosis according to the analysis of the evaluators, it was decided to choose the most severe degree.

The photographs were accordingly identified by codes to preserve the anonymity of the participant, they were analyzed by two people trained and specialized in the detection and definition of the Fluorosis Index according to the TF index (Thylstrup and Fejerskov), due to their high command of the subject. Using statistically validated unified criteria, we used the aforementioned index, obtaining a value of 95% agreement. In each photograph, the vestibular surfaces of the teeth were analyzed, considering healthy teeth as the tooth with no signs of fluorosis.

From a statistical point of view, the entire population of the educational center was studied, therefore descriptive statistics is applied. When the survey was applied, we detected that there were questions having answers with a certain degree of indeterminacy. For example, in some cases, parents did not remember exactly the brand of toothpaste used by children, or even the brand could be more than one. For this reason, it was determined to use neutrosophic statistics, where these indeterminacies were included. In these cases $I = [0, 1]$ was used as notation to represent indeterminacies.

The population is made up of 79 boys and 59 girls. The recommended toothbrush dimensions by age are specified in Table 1.

	Width of the brushing (Maximum in mm)	**Head length (mm)**	**Height of the filaments (mm)**
Children	9	15-25	9-12
Teenagers	11	17-30	9-13

Table 1: Recommended dimensions of the toothbrush by groups of age.

The highest percentages with respect to the origin of the evaluated people were that 87.0% lives in H. Totoras parish, 82.6% are from Tungurahua province, whereas in relation to the canton, 80.4% are from Ambato. The target of this investigation are children, from whom 20.3% are 8 years old, 24.6% are 9 years old, 26.10% are 10 years old, 18.1% are 11 years old and 10.9% are 12 years old.

In relation to mothers' instruction, educational level is none in 6.5% of them, 62.3% of them has a primary level, 26.8% are in secondary, 1.4% of them are technical and 2.9% of them are professionals. Mothers employed in the informal sector are 23.2%, 32.6% of them are workers and craftswomen, 21.0% are farmers, 6.5% are public employees, 15.2% are private employees, and 1.4% of them are professionals.

In relation to fathers' educational level, 3.6% have none, 58.7% have a primary level, 29.0% have a secondary, 2.9% are technicians, and 5.8% are professionals. Fathers whom are employed in the informal sector constitute 8.0%, workers and craftsmen are 42.8%, 13.8% of them are farmers, 10.1% are public employees, 22.5% are private employees, and 2.9% are professionals.

According to economic income, the majority, 75.4%, receive a salary of 1 and 2 Universal Basic Income (UBI), 23.2% have a salary of 3 and 4 UBI and only 1.4% have a salary of more than 4 UBI.

These data are important because the educational level of the parents directly influences in the health education of the children. In addition, the parents with the highest purchasing power financially guarantee the use of dental products suitable for their children, as well as the best nutrition.

Table 2 summarizes the results of the survey on questions asked to parents about their children's eating habits. Some data contain symbol I, because of the parents were not able to give an answer to the asked questions, or because of there are several possible answers to the same question. Therefore, to maintain the accuracy of the calculations, we decided to include indeterminacy.

Question	**Answer**	**Number of children**	**Percent**
Q1: The water your child consumed in his/her first 4 years of life was:	Drinking water without boiling	78+19I	[56.5, 70.3]
	Boiled drinking water	11+12I	[8.00, 21.7]
	Bottled water	5+2I	[3.6, 5.1]
	Well water	1	0.7
	Filtered water	2	1.4
	River or gap	1	0.7
Q2: The type of milk your child drank during the first 4 years of life, in addition to breast milk was:	Powdered	9+10I	[6.52, 13.8]
	Delivery truck	22+4I	[15.9, 18.8]
	Cover	86+6I	[62.3, 66.7]
	Soy milk	1	0.7
Q3: Your child consumes packaged beverages (juices, soda, soft drinks, iced tea, etc.)	Before the age of three	62	44.9
	After three years old	76	55.1
Q4: The bottled drink your child usually prefers is:	Soda	20+14I	[14.5, 24.6]
	Juices	66+12I	[47.8, 56.5]
	Soft drinks	16+14I	[1.4, 11.6]
	Tea	10	7.2
Q5: The times a week that your child consumes packaged drinks (juices, sodas, tea) is:	Once	45+32I	[32.6, 55.8]
	Three times	23+32I	[16.7, 39.9]
	More than three times	4+2I	[2.9, 4.3]
Q6: The diet your child usually consumes is:	General diet	75+35I	[54.3, 79.7]
	Hypercaloric/Hyperprotein Diet	8+8I	[5.8, 11.6]
	Hypo fat soft diet	6	4.3
	Astringent diet	6	4.3
Q7: The type of salt your child consumes is:	Refined salt	114+9I	[82.6, 89.1]
	Sea salt	10+3I	[7.2, 9.4]
	Grain salt	1	0.7
	None	1	0.7

Table 2: Results of the survey applied to the parents.

Table 3 summarizes the dental hygiene habits of children, according to the survey conducted with their parents.

Question	Answer	Number of children	Percent
Q1: Brand of the toothpaste with which your child regularly brushes	Colgate	121+7I	[87.7, 92.8]
	Oral-B	2	1.4
	Fortident	2	1.4
	Polar	3	2.2
	Blendy	3	2.2
Q2: Your child's tooth brushing starting age was:	He/she has never done it	6	4.3
	Before three years old	83	60.1
	At three years old or later	49	35.5
Q3: The age at which your child started brushing his/her teeth unaccompanied by an adult was:	He/she has never done it	2	1.4
	Before three years old	32	23.2
	At three years old or later	104	75.4
Q4: When you started brushing your child's teeth, did you use the same tooth-paste as adults?	Yes	67	48.6
	No	71	51.4
Q5: When your child started brushing his/her teeth, he/she swallowed the tooth-paste during brushing	Yes	119	86.2
	No	19	13.8
Q6: The times a day your child brushes his/her teeth is:	Once	27+7I	[19.6, 24.6]
	Twice	63+7I	[45.7, 50.7]
	Three times	27+7I	[19.6, 24.6]
Q7: The amount of toothpaste your child uses to brush his/her teeth is:	One drop	6+8I	[4.3, 10.1]
	Brush half	73+8I	[52.9, 58.7]
	All brush	35+8I	[25.4, 31.2]
Q8: Does your child use mouthwash?	Yes	17+2I	[12.3, 13.8]
	No	117+2I	[84.8, 86.2]
Q9: The age at which your child uses mouthwash is:	He/she has never done that	119	86.2
	Before three years old	6	4.3
	At three years old or later	13	9.4
Q10: The mouthwash brand used by your child is:	Colgate	14	10.1
	Listerine	5	3.6
	Others, parent does not indicate	119	86.2

Table 3: Results of the survey on the use of oral hygiene products

Table 4 summarizes the percentages of the TF index, according to the photographs taken of the children.

Index	Level	Number of children	Percent
TF Index	TF 0	24	17.4
	TF 1	21	15.2
	TF 2	28	20.3
	TF 3	23	16.7
	TF 4	18	13.0
	TF 5	11	8.0
	TF 6	5	3.6
	TF 7	4	2.9
	TF 8	3	2.2
	TF 9	1	0.7
	Total	138	100

Table 4: Level of Fluorosis in number of children and percent

The analysis of data about TF index in Table 4 and their relationship with the data in Tables 2 and 3, have yielded that p-values are bigger than 0.05, thus null-hypothesis is not rejected, which means there is not a significant relationship between these variables and the fluorosis. However, one variable is the exception: "the child uses mouthwash".

The result of the relationship between TF index and this variable is analyzed with a contingency table, see Table 5. Let us note that between parentheses are the values of de-neutrosophication ([24]) according to formula 3, a de-neutrosophication process gives an interval number $I = [a_1, a_2]$ [25].

$$\lambda([a_1, a_2]) = \frac{a_1+a_2}{2} \qquad (3)$$

	TF 0 (Healthy tooth)	**TF1-TF9 (Ill tooth)**	**Total**
Yes	[6, 7] (6.5)	[11, 12] (11.5)	[17, 19](18)
No	17(17)	[100, 102] (101)	[117, 119] (118)
Total	[23, 24] (23.5)	[111, 114] (112.5)	[134, 138] (136)

Table 5: Contingency table between TF index and the use of mouthwash by the child. Between parentheses, are the de-neutrosophied values.

For processing the data in Table 5, the Chi-square test is applied, [26], then, the obtained p-value is 0.023285<0.05, therefore, the null-hypothesis of independence is not accepted with 95% of significance level. Figure 1 is the bar graph, which depicts the values in Table 5. Note that there are portions of bars in yellow, representing indeterminacy.

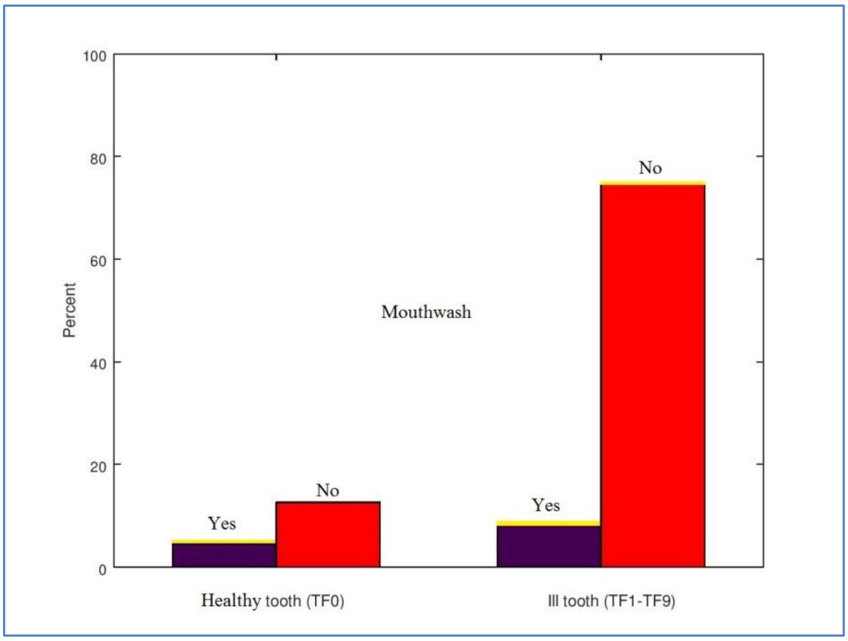

Figure 1: Bar graph representing the values in Table 5.

Let us note that most of the children which do not use mouthwash have some tooth problems.

Conclusion

This paper studies the incidence of fluorosis in El Oro Educational Unit. The population consists of 138 children of ages from 8 to 12 years old. Fluorosis is a severe disease that deserves the attention of specialists. We statistically processed the survey applied to the children's parents about their nutritional habits and their use of the oral hygiene products. We also studied the TF index for each of them and the correlation between TF level and the others variables. We preferred to use the neutrosophic statistics instead the classical statistics, because of the ambiguity and duplicity of some answers, thus, including indeterminacy guarantees more accuracy in the results. After applying the chi-square test in the contingency table, the obtained result was that there is a relationship between to have a healthy tooth (child with TF 0 level) and to use mouthwash. The more the child uses mouthwash, the less he/she will suffer of fluorosis. The possible reason is that not all mouthwashes contain fluorine, or its content is minimal, containing other substances like alcohol, nonetheless specialists need to analyze the cause of this result. There is independence among TF index and the other variables.

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