Identifying and Ranking the Factors Impacting the Utilization of Nanotechnology in Dentistry using the MCDM Fuzzy Approach

Original Article

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Abstract

Introdouction:

One of the existing problems in the field of dentistry is the use of utilizing materials. Utilizing materials in dentistry must have high rigidity and resistance and a beautiful appearance. The weak formulation of dentistry materials causes irritation, side effects, and increases the cost of healthcare. Therefore, farms and organizations related to dentistry care are trying to produce highly efficient products. Therefore, in the current research, we attempted to recognize and rank the factors that impact on the utilization of nanotechnology in dentistry by an MCDM Fuzzy approach. The statistical community of the present research includes dentists and university experts, who are active in the field of Nano-Dentistry in Mazandaran, Dentist College in Sari . They are selected by the consensus of two groups. The first group included managers and superordinate experts of the organization with 32 people for localizing the modeling. In the second group, five experts as the statistical sample were selected.

Materials and methods:

The descriptive method and descriptive survey were used. Therefore, by exploring the scientific texts, the criteria were recognized, and their reliability then proved by experts.

Results:

By using the screening (decimal-fuzzy), 21 factors were recognized as important and effective in the use of nanotechnology in dentistry. To determine the impact and influence of these factors, the DEMATEL technique was used.

Conclusion:

According to the results, decreasing dental plaque had the most impact, and the cost of technology was the most influential factor..

Key words:

•Nanotechnology •Nano-Dentistry, •Multiple-Criteria Decision Analysis, •DEMATEL Technics

Introduction

In the last few years, nanotechnology has emerged as a novel approach which has triggered a new industrial revolution due to its wide range of practical applications.[1] In terms of vocabulary, nano means one billionth[9,10] and was taken from the Greek word meaning dwarf.[2] The field of dentistry has been involved in the introduction of nanotechnology to human life in the environmental and medical sciences sector. Materials in dentistry must have rigidity, resistance, and a beautiful appearance. Weak dentistry materials cause inconvenience, side effects, and increase healthcare costs. Recent improvements in the field of nanotechnology field have been given this field an even higher profile.[2] Therefore, in the present research, we seek to identify the important factors that influence the use of nanotechnology in dentistry and their relative impacts.

In dentistry, nanotechnology is primarily applicable in the areas of teeth health (toothpaste and brush) and dentistry equipment.[3] The application of nanotechnology can be used to control the recurrence of caries, combat enamel demineralization, control hypersensitivity in teeth, produce a vaccination against teeth caries, control the oral biofilm, disinfect the root channel, generate new local torpidity ways, and so on.[4] Some of the applications of nanotechnology in dentistry that have been presented in medical fields are:

1-Tooth polishing powder
2-Nano-bleach toothpaste
3-Composite resins and nano-composites
4-Producing self-cleaning dental plaques with silver nanoparticles
5-Nano-metric dental adhesives
6-Nanoscale glass powder for dental fillers
7-Using nanoparticles in tooth restoration
8-Usi ng nanoparticles with plasma lasers
9-Oral-local anesthesia
10-Nano-robotic mouthwash
11-Hydroxyapatite nanopowder
12-Decreasing endodontic therapy by using nanofilms
13-Making sensitive teeth durable by use of gold nanoparticles[5-7]

Nanotechnology has made possible the generation of nano-fillers and nanocomposites. These materials have different light, mechanical, and chemical characteristics to the old microcomposites. Nanotechnology in dental restorations causes to increase the adversity, the beauty of the amended part, rather than the old materials.[2] Different researches have been conducted to study the utilization of nanotechnology in dentistry. Hushmand et al. reported on a nanocomposite synthesized using a cell-gel method, which was found to have better biocompatibility than hydroxyapatite powder. They were then able to produce a porous nanocomposite structure from hydroxyapatite and loggias carbonic nanopipes by the same method. This material could be used to facilitate the rebuilding and fixing of damaged bones.[8] Fat'hi et al. used nano-fluorapatite in cobalt-based alloys for applications in dentistry.[9] In their research, Farzanegan explored the orthodontic use of nanoparticles including silver, copper, and zinc to prevent white enamel lesions around braces, They added nanoparticles to mouthwash to prevent the formation of caries around the braces, and used molybdenum disulfide nanoparticles to decrease friction between the wire and braces.[1] They also showed that in all designs, the lack of appropriate tools, technologies, and experts in the field of nanotechnology was acutely felt.[1] Kasraei et al. found that the addition of silver nanoparticles can reduce wetting of silver composites and methacrylate.[4] Saadat et al. utilized nano-hydroxyapatite to improve dental adhesives.[10] Sivaramakeshnan et al. explored applications of nanotechnology in dentistry, such as in the determination of the conditions for local anesthesia and orthodontic and periodontic motions.[11]

Materials and Methods

The present research is counted as the research-application from goal points of view, and from gathering the information perspective, it is survey descriptive. In the present research, sampling is counting and statistical community of experts, dentists and university experts who are active in Nano-dentistry field, in Sari dentistry collage. The information was gathered by documents, interviews, and surveys with direct reference to different and effective parts. It is important to mention that because of the specialty of this research topic and the need to overcome on different dimensions of the research topic, there are two groups of experts in the present research

in time and place territory. The first group included the managers and superordinate experts, numbering about 32 people, who were used to localize the model and explore the conceptual validity of the model and factors by using the screening math model. Because of the use of these research techniques, the second group were society experts who in base of Acording to Saati of view (2002) five experts were considered as the people who were related to the organization. Also, these people had the relevant expert and specialty education and more than 10 years of experience. To gather the necessary data through the research, two kinds of questionnaires (screening and couple comparing questionnaires) were used.

Results

To realize the goals of this research in terms of recognizing nanotechnological applications in dentistry and to determine the weight of the criteria and sub-criteria in the related selection process and their impact and influence on each other, multi-indexes and group decision making techniques, such as screening (decimal-fuzzy), DEMATEL, were used as models. By determining the main criteria of nanotechnology by using the expert's justices, which were received by using the screening (decimal-fuzzy) criteria, sub-criteria, which included the more relative importance for next steps, were selected. Then, by using the DETMEL technique, the intensity of impact and the influence of the criteria and sub-criteria were explored. In the following, we describe how the abovementioned methods were used.

Screening method (decimal-fuzzy)

A questionnaire to determine the relative importance of the various criteria and sub-criteria was supplied. After determining the effective factors, this questionnaire was then provided to experts to allow them to determine the relative importance of the various criteria and sub-criteria using the 5-point Likert scale. After determining their relative importance, they would be questioned among the experts. For accurate determination, criteria, sub-criteria, and fuzzy and normal weights of criteria and sub-criteria were counted. A comparison was then made to see whether the indexes had more of a normal or fuzzy weight? The quality weights that were used in the line scale are based on a distance scale and determined by selecting the decimal weight. (12)

$$N=a_{ij}/max_{ij}$$

It should be noted that to avoid complications, the responses of each questionnaire were supplied as a 5-point Likert scale. Then, after gathering the questionnaires from there where the answers on the questions had been mentioned from most important to less important, for changing these numbers to certain quantity numbers, each option was specified a fuzzy-triangle number, as shown below.

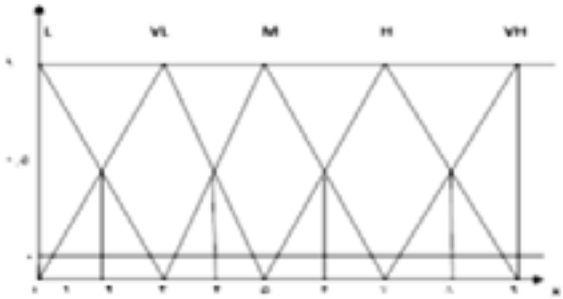

Figure 1. Different Scales for Changing the Language Texts to Fuzzy Numbers

Then, by using the fuzzy rational concepts and fuzzy numbers' changing formulation to certain numbers (Minkowski Formula) X=M+((β-α)/4), the mentioned fuzzy numbers would be equal to the numbers that can be seen in Table (1).

Table 1. Changing the Fuzzy-Triangle Numbers to Certain Numbers

Option	Quality Number	Triangle Fuzzy Number(α,β,m)	Certain Fuzzy Number
A	So Important	(0,0.3,1)	0.925
B	Important	(0.25,0.25,0.75)	0.75
C	Average	(0.2,0.2,0.5)	0.5
D	Less Important	(0.25,0.25,0.25)	0.25
E	So Less Important	(0,0,0.3)	0.075

DEMATEL Technique

The DETMEL Technique is used to structure the imagined information so that the strictness of the connections is explored as the scoring, and the feedbacks among the elements (risks) were looked for with their importance and the connectable relations would be accepted.[13] Through the current technique, the interconnection measures in each level are counted.[14] The steps of DETMEL are as shown below.

Step 1: Determine the exploring forming elements of the system

Step 2: Put the imaginative elements in the angles of a diagraph and determine the relations that should be ruled on the connections between the stations (angles).

Step 3: Determine the group decision making rules for the collective agreement of the experts for a possible relation between two A,B elements.

Step 4: Ask the final relations' strict (and the collective agreement) from experts, and then specify the scores' median (or geometric mean in using the percent) and count the A,B for each two elements and specify on the diagraph.

Step 5: Show the final scores, for existing relations, from the diagraph set in the 4th step as a Mˆmatrix.

Step 6: Multiply the entrance of the matrix Mˆ on the reverse of the most collective row (α) of that matrix m=α.Mˆ.

Step 7: Count the unlimited trail sum from direct and indirect works from elements as the geometric progress, based on the existing rules of the graphs.

The progress of a geometric sum:=

$$S_{t\to\infty}=m+m^2+m^3+m^4+...+m^t=(m(I-m^t))/(I-m);$$

$$\lim_{t\to} m^t_{\infty} \Rightarrow =m/(I-m)=m(I-m)^{-1}$$

Step 8: Calculate the possible strict of the indirect relations (of the existing elements with each other): $s_{t\to\infty}=m^2+m^3+m^4+...+m^t=m^2(I-m)^{-1}$

Step 9: Determine the possible hierarchy or structure of the elements.

The most sum of row(R) will show the order of elements which penetrate 2 the other elements so strictly. The most jamb sum(J) will show the order of the elements that are penetrated. Therefore, the order of Row(R) will show the hierarchy from penetrating elements, and the order of the elements from Jamb (J) will show the hierarchy from the penetrated elements.[3]

After interviewing experts and studying the existing literature on the topic of nanotechnology in dentistry, we also explored different articles on the factors affecting the use of nanotechnology in dentistry, the greatest number of factors were extracted.

Since the number of criteria and sub-criteria that were determined were greater to localize the indexes, decrease the entrances, and determine their importance to each other, and explore their validity, a weight limitation was applied to the model. To do this, a questionnaire was designed with 50 questions and based on a 5-point Likert scale from Extraordinarily Important to Not Important, and 32 questionnaires were distributed among the first group, who had all comprehensively responded to the first questionnaires. Then, to determine the important factors, a screening method (decimal-fuzzy) was used. The studying nano-dentistry sub-criteria was introduced in Table 3 for scoring and prioritizing.

Table 2. Matrix, the Penetration Order of the Elements on Each other

In base of R-J	Order of the elements' happening	In base of R+j	Order of the elements' happening	In base of j Jamb's most sum	Order of the elements' happening	In base of R row's most sum	Order of the elements' happening

Table 3. Normalized Weight's, Geometric Mean, and Fuzzy Normalized of the sub-criteria of nanotechnology

Ranking	Sub-Index	Abbreviation	Geometric Mean
1	Technology Risk	C (5 6)	0.028549729
2	Business Model	C (4 9)	0.028490014
3	High Stain	C (11 5)	0.028445596
4	Financial Resources	C (4 5)	0.028357709
5	Increased Bending Power	C (9 6)	0.028253601
6	Dental Oral Treatment	C (14 1)	0.027737257
7	Reducing the Aggregation of the Dental Plaque	C (11 2)	0.02752341
8	Decreasing the Side Effects	C (10 2)	0.027236447
9	Anti- Caries and Treating the Caries	C (9 1)	0.027199081
10	Less Fragility	C (4 10)	0.027073159
11	Margin of Technology Profitability	C (5 10)	0.026947126
12	Payback Period	C (4 1)	0.026852456
13	Technology's Attractiveness	C (5 11)	0.026807078
14	Experts Force	C (4 2)	0.02671735
15	High Involvement with Resins with High Quality	C (10 4)	0.026710714
16	Price of Technology	C (5 7)	0.02648107
17	Increasing the Accuracy	C (13 2)	0.026364311
18	Cutting the Soft Tissue without Anesthesia	C (14 3)	0.026170854
19	Increasing the Speed	C (13 1)	0.026018226
20	Cutting the Enamel and Cutting the Dentin	C (14 4)	0.025885917
21	Reconstructing the Minerals Materials Lost from Teeth	C (9 3)	0.024591795
22	Removing the Melanin of Gum	C (14 2)	0.024563399
23	Technology's Cycles	C (5 9)	0.022285447
24	The Lowest Adhesion to Tools	C (11 3)	0.020618174
25	Commercialization Mechanism	C (4 11)	0.020393982
26	Validating the Technology Cost	C (5 3)	0.019627835
27	High Quality	C (12 1)	0.019135073
28	High Transparency	C (12 2)	0.018411046
29	Less Using of these Materials to Create Similar Impact	C (9 4)	0.018017156
30	Strategy (Commercializing the Technology) Company	C (4 4)	0.016647572
31	Personalizing the Technology Applications	C (5 5)	0.015805226
32	Preventing any Cracks, Cuts and Creating the Free Space	C (11 6)	0.015601592
33	Research and Development	C (4 3)	0.015494153
34	Excellent Formulation of Dental Materials	C (10 1)	0.015170503
35	The Economic Justification Technology	C (5 8)	0.0150066
36	Complications and Sensitivity of Technology	C (5 1)	0.014854308
37	The Company's Technology	C (4 6)	0.014336189
38	Easy Job	C (12 5)	0.013481367
39	Material Stability and Resistance to Mechanical Impacts	C (9 5)	0.013079936
40	Management Approach	C (4 8)	0.012761841
41	The Internal Rules of the Organization	C (4 12)	0.012152365
42	Protecting the Produced Acid by bacteria	C (9 2)	0.011764979
43	The Level of Complexity OF Technology	C (5 2)	0.011150761
44	Prioritizing the Technology	C (5 4)	0.010688432
45	Company's Stability	C (4 7)	0.010516719

Ranking	Sub-Index	Abbreviation	Geometric Mean
46	Less Dissolution Rate	C (10 3)	0.010481136
47	Diagonal Tension and More Compression Force	C (12 4)	0.010456565
48	Less Fragile	C (12 3)	0.010453492
49	Allowing Accurate Color Matching	C (11 4)	0.010225619
50	Decreasing the Abrasion	C (11 1)	0.008386719

As can be seen, the Technology Risk, Marketing Model, High Stain, Financial Resources, Increased Bending Power, Dental Oral Treatment, Decreasing Dental Plaques, Decreasing Side Effects, Anti Caries and Treating Caries, Less Breaking, Technology Profit Margin, Returning the Capital Period, Attractiveness of the Technol ogy, Expertise, High Involvement with Resins of High Quality, Price of Technology, Increasing Accuracy, Cutting Soft Tissue without Anesthesia, Increasing Speed, Cutting Tooth Enamel and Dentin, Rebuilding Lost Mineral Materials of the Tooth were studied as the nanotechnology using sub-criteria included the high importance and regeneration of lost tooth minerals.

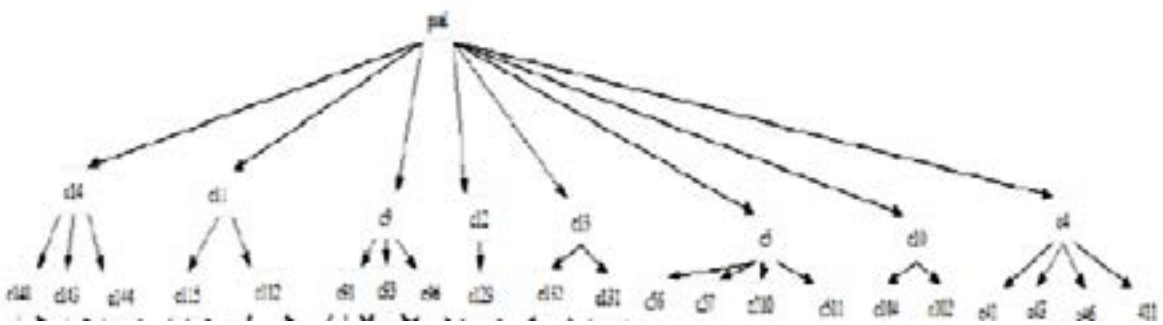

Figure 3. The Model with Research Network Structure

DEMATEL Solution

The sum of the elements of jambs and lines of the matrix $\tilde{T}$ was counted for its main factors and sub-factors and named as the $\tilde{R}$ vectors (impact) and $\tilde{D}$ (influence), for which all calculations are shown in Table 4:

Table 4. Values of (J)،(R)، (R+J) and (R-J)

Sub-Criteria	R	J	R+J	R_J
C (5 6)	4.56712701	3.665888625	8.233015635	0.901238385
C (4 11)	4.419001225	4.220982135	8.63998336	0.19801909
C (11 5)	4.834023011	5.630795178	10.46481819	−0.796772167
C (4 6)	4.697498085	5.523945083	10.22144317	−0.826446998
C (9 6)	5.140107989	5.758866862	10.89897485	−0.618758873
C (14 1)	4.289790198	4.584390106	8.874180305	−0.294599908
C (11 2)	5.493029924	5.624885297	11.11791522	−0.131855374
C (10 2)	4.178514518	3.94235158	8.120866099	0.236162938
C (9 1)	4.650250117	4.465592765	9.115842882	0.184657353
C (12 3)	4.256826012	4.546840041	8.803666053	−0.290014029
C (5 10)	4.127619128	4.000013297	8.127632424	0.127605831
C (4 1)	4.438992615	4.629360755	9.06835337	−0.19036814
C (5 11)	4.801837867	4.952496595	9.754334462	−0.150658728
C (4 3)	4.240970352	4.143615892	8.384586244	0.097354461
C (10 4)	4.577797265	3.95825031	8.536047575	0.619546955
C (5 7)	4.000970508	3.57394713	7.574917638	0.427023378
C (13 2)	5.130332653	5.554334295	10.68466695	−0.424001642
C (14 3)	5.268729624	5.305310123	10.57403975	−0.036580499
C (13 1)	3.957756708	3.798887778	7.756644486	0.15886893
C (14 4)	5.253098765	4.875257703	10.12835647	0.377841062
C (9 3)	4.471559205	4.03982123	8.511380435	0.431737975

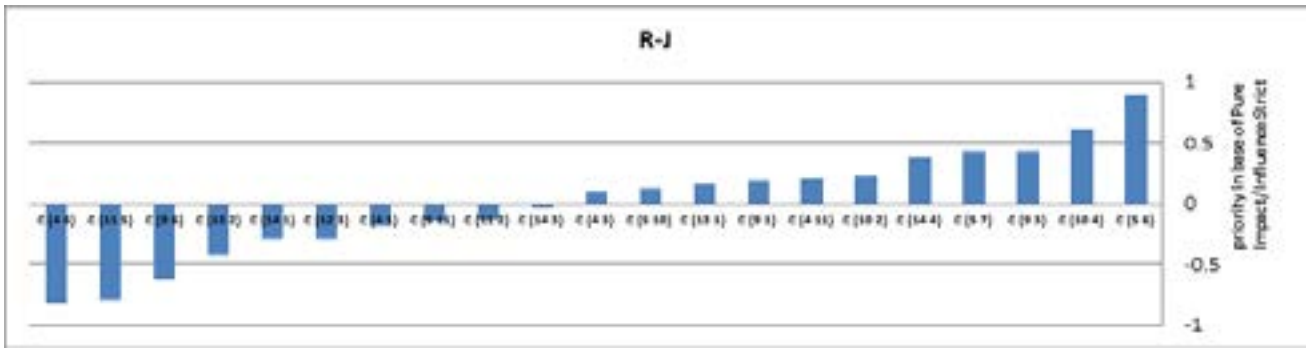

Figure 4. The Weight Priority with respect to Interaction

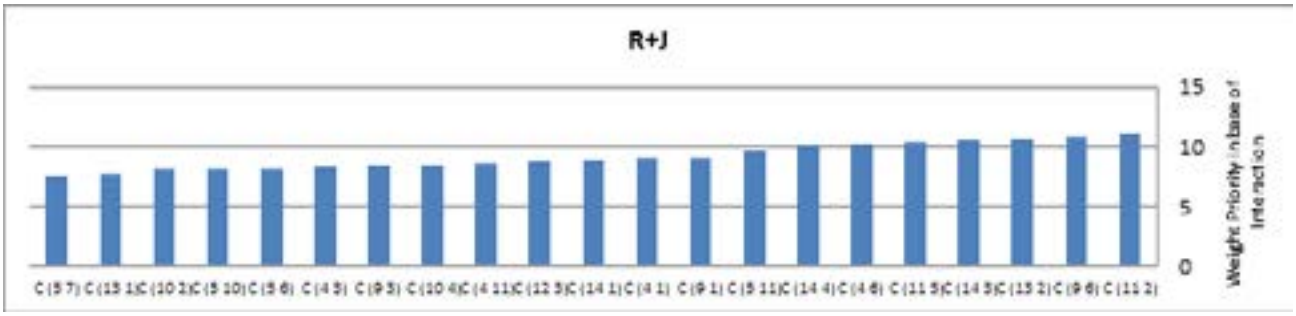

Figure 5. Priority with respect to Pure Impact/Influence Strict

Discussion

On the basis of the accessed results, in the first step, reviewing the literature, 14 main criteria, with associated sub-criteria, were determined. Then, by using the screening method (Fuzzy-Decimal), 8 main criteria and 21 sub-criteria that included the more important factors were identified. By attention to the analyses and determination of the factors affecting the utilization of nanotechnology in dentistry and researches that were performed in the research topic and after screening, 21 main factors, whose main criteria were as below, were determined: (Flexible Application, Dental Restoration, Rigidity and Resistance, Quality, Speed, Technology, Formulation, and Organizational Factors). Through the determination of the effectiveness and influencing power and the method of interactions of the criteria and sub-criteria, the following conclusions can be drawn.

Decreasing the dental plaques' aggregation, these sub-criteria have the highest impact on other criteria. The result is that this sub-criterion has is ranked first in terms of impact and interaction with other sub-criteria, showing that it is of the highest importance. It is noticeable that in light of teria of the bending power were increased, and the sub-criteria decrease of the aggregation of the dental plaques among the other sub-criteria included the highest importance (weight), while the results accessed from the experts, the sub-crithe technology price sub-criterion is ranked last and has the least influence. Also, this sub-criterion is also ranked last in terms of its interaction with the system. From the results of our research, we suggest the following solutions. By considering the results of the application of nanotechnology in dentistry and determining the effective sub-indexes and also their relative degrees of importance, it is suggested that experts must attend to factors such as Reflexive Application, Teeth Restoration, Rigidity and Resistance, Quality, Speed, Technology, Formulation, and an organization for using nanotechnology in dentistry. Also, it is suggested that experts ought to pay attention to the Technology Price Sub-Criterion, as this is the criterion that has the least interaction with other factors, and consider the Decreasing the Dental Plaques' Aggregation sub-criterion as the more important sub-index and the Bending Power Sub-Criterion and high stain as the most influential sub-criteria of nanotechnology in dentistry.

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