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Artificial Intelligence Based Decision Making on Biocompatible Material Selection in Dental Implant by MATLAB

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Abstract

In present era, biomaterial selection, design & development are changing dramatically and drastically. Automated Selection and decision approaches are an important key issue in upcoming near future. In this new era of technology, it is an essential requirement to choose a potential dental implant material which proves in terms of good mechanical properties, biocompatibility and good optical properties and aesthetics in dental implantology. In several studies, conventional based dental implants and their fabrication techniques have not proven higher success rates in terms of the onset hypersensitivity reactions, biocompatibility issues, aesthetics, manufacturing time and cost, human errors, and defects during prosthetic rehabilitation in dentistry. The purpose of this literature review is to suggest a suitable dental implant material and appropriate additive manufacturing technique as a viable alternative for the conventional methods used in dentistry.

Keywords: Biocompatibility, Material Selection, MCDM, SAW, TOPSIS, Sensitivity Analysis, Health Sector.

Introduction

In this new era of technology, it is an essential requirement to choose a potential dental implant material which proves in terms of good mechanical properties, biocompatibility and good optical properties and aesthetics in dental implantology. In several studies, conventional based dental implants and their fabrication techniques have not proven higher success rates in terms of the onset hypersensitivity reactions, biocompatibility issues, aesthetics, manufacturing time and cost, human errors, and defects during prosthetic rehabilitation in dentistry [Fig:1].

Fig.1: Osseointegration of Dental Implant

This research ventures one of the major concerns in the field of strategy to select suitable material forfemoral component of knee prosthesis based on a entropy method, namely SAW, TOPSIS, in orderto improve the longevity and quality of human life.

In this article, a novel MCDM method have been used for dentistry/practitioners and implant manufacturers. This project addresses modelling an automated selection methodology for dental implant research.

Literature Review

The purpose of this literature review is to suggest a suitable dental implant material and appropriate additive manufacturing technique as a viable alternative for the conventional methods used in dentistry.

Len Tolstunov (2006) This article shows the factors of importance in the long-term success and failure of oral implants based on literature review. Dental Implant Success-Failure Analysis-A Concept of Implant Vulnerability was proposed.

Łodygowski T. et al. (2009) did a study using genetic algorithm in dental implant. The subject of the present work is optimization of the modern implant system Osteoplant.

Ikebe K. et al. (2009) try to described the old age factor of dental implants. Patient's condition is distinctly different among individuals especially in the elderly.Dental implant failure seems to be a multi-factorial problem; therefore, it is unclear that aging itself is a risk factor for the placement of implants. This review reorders and discusses age-related risk factors for the success of dental implants.

Lee S. et al (2012) have developed a decision-making system for selection of dental implant abutments based on the fuzzy cognitive map.

Dmitriy V. Ivanov, Aleksandr V. Dol and Dmitriy A. Smirnov (2016) This work is devoted to the "bone-implant" system investigation aiming on the optimization of dental prostheses installation. The objective of this study was to develop the implant treatment planning technique. Modern non-invasive methods such as computer tomography (CT) and 3D-scanning as well as numerical calculations and 3D-prototyping allow optimizing all of dental prosthetics stages.

Gatto A. et al.(2017) try to find out the failure analysis of Dental implant. For more than thirty percent of patients with implant-supported fixed dental prosthesis, various complications can be observed over five-years of function. In some cases, failure can be ascribed to mechanical reasons such as loosening of the retaining screws or fracture of the implant components.

Ercan ŞENYİĞİT and Bilal DEMİREL (2018) proposed a model of the selection of material in dental implant with entropy based simple additive weighting and analytic hierarchy process methods.

Chang Cheng Y. et al (2018) This study presents an optimization procedure for the design of a one-piece zirconia ceramic dental implant that uses finite element simulation with dynamic loads and experimental validation using a fatigue test.

Ivvala J. et al (2019) have described a review on the selection of dental implant material and suitable additive manufacturing technique in dentistry.

Hemalatha B and Rajkumar N (2020) Proposed a versatile approach for dental age estimation using fuzzy neural network with teaching learning - based optimization classification.

Staedt H. et al (2020) This study represents that Potential risk factors for early and late dental implant failure: a retrospective clinical study on 9080 implants.

Pradhan M. et al (2020) in this paper an effort is taken to priortize the best dental implant material by Fuzzy Ahp method on the basis of characteristics of dental implant.

Nancy Abdelhay et al (2021) The purpose of this systematic review and meta-analysis was to evaluate implant failure rates and their association with guided and free-hand implant placement techniques.

Methodology

Multi Criteria Decision Making (MCDM)

Considering multiple conflicting criteria, selecting the best path from a set of feasible alternatives known as Multiple criteria decision making (MCDM). This process always goes through at least two alternatives and two conflicting criteria. MCDM are divided two broad categories: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). Several useful tools for solving of MCDM problems are

- Simple Additive Weighting method (SAW)
- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
- Multi Objective Optimization Ratio Analysis (MOORA)
- Analytical Hierarchy Method (AHP)
- Analytical Network Method ANP etc.

Entropy Method

Entropy was originally a thermodynamic concept, first introduced into information theory by Shannon. It has been widely used in the engineering, socioeconomic and other fields. According to the basic principles of information theory, information is a measure of system's ordered degree, and the entropy is a measure of system's disorder degree [Table 2].

Sensitivity Analysis

In actual situation decision-making is rather dynamic not static process. Changing with environment it varies in the continuously. In reality the value of decision-making attitude depends upon decision maker's personal choice but now a days the artificial intelligence remove the personal biases. Keeping it in mind, the proposed model for the selection of femur material has been enhanced by sensitivity analysis [Fig:4] to provide a readymade solution of the current problem under variable decision-making attitude[Table:6].The governing equation of the material measure (AM) is given by

$$\mathbf{AM_i} = \alpha(\mathbf{OFM_i} - \mathbf{SFM_i}) + \mathbf{SFM_i}$$

Where, i = 1, 2…m.

OFM_i = Objective factor measure for the alternative i

SFM_i = Subjective factor measure for the alternative i

α = Objective factor decision weight/Coefficient of attitude.

The Flowchart of the Proposed Methods

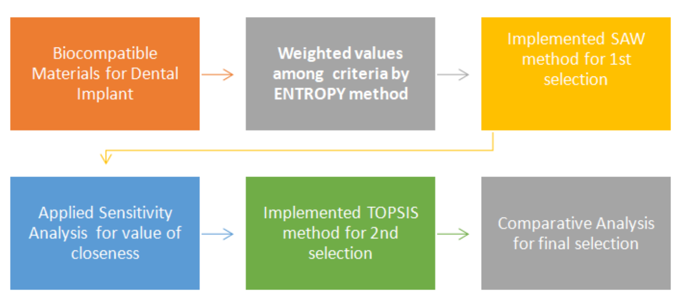

Fig. 2: Flowchart of Methodology

Material

The selection of dental implant materials in health sector considering technical, economic aspects. The paper involves identification of different material [Table:1] that are used in the manufacturing of bio-material and to give a best result. Ten materials with four important propertiesare considered. The decision maker has to compare all the materials regarding each aspect and has to judge the best one, and this is difficult decision-making problem. So, these MCDM methods is applied to select optimal material in this section.

Criteria / Material	Young's modulus (C1)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
Chromium cobalt (M1)	225	450	370	4700
Nickel (M2)	205	485	190	1500
Nickel Titanium (M3)	82	443	160	1000
Titanium (M4)	103	283	200	5500
Stainless Steel (M5)	200	205	195	130

Table 1: Dental implant material selection matrix [8]

Research Gap

Selection and proper decision making brings success in any operation. When a problem arise for dental implant material selection then proper decision approach is needed for human body system. Maximum biomaterial industry is spent their money to developed an efficient decision-making system. This paper is projected to improve this system in normal and emergency environment. According to literature review, biomaterial selection of femoral component in medical industry some piecemeal work has been done. Comparative analysis by various MCDM methods on Material selection process and Sensitivity analysis are implemented first to know the best material as well as the value of closeness.

Problem Formulation

In dental implant, biomaterials are made of various materials. Among these four criteria [C]-Young's modulus (C1), Yield strength (C2), Hardness (C3) is beneficiary and rest of criteria (Cost) are non-beneficiary. Find out the optimum result among alternatives [M] are difficult task. In the matter of total Dental implant, the proper material selection is challenging task to a decision maker. This paper involved to find out the best result among the alternatives considering criteria.

Experiment and Result

Criteria	Young's modulus (C1)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
weighted values	0.2060	0.2350	0.1793	0.3797

Table 2

In the SAW method

The weighted values got from entropy method

Step 1: Determination of normalized decision matrix

Material	Young's modulus (C1) (MPa)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
Chromium cobalt (M1)	1.0000	0.9278	1.0000	0.0277
Nickel (M2)	0.9111	1.0000	0.5135	0.0867
Nickel Titanium(M3)	0.3644	0.9134	0.4324	0.1300
Titanium (M4)	0.4578	0.5835	0.5405	0.0236
Stainless Steel (M5)	0.8889	0.4227	0.5270	1.0000

Table 3

Step 2: Determination of weighted normalized decision matrix

Material	Young's modulus (C1) (MPa)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
Chromium cobalt (M1)	0.2060	0.2181	0.1793	0.0105
Nickel (M2)	0.1877	0.2350	0.0921	0.0329
Nickel Titanium (M3)	0.0751	0.2147	0.0775	0.0494
Titanium (M4)	0.0943	0.1372	0.0969	0.0090
Stainless Steel (M5)	0.1831	0.0994	0.0945	0.3797

Table 4

Step 3: Computation of composite score s......by sum of all weighted normalized rows

The values of (s) are:

Material	Chromium cobalt	Nickel	Nickel Titanium	Titanium	Stainless Steel
	.6139	0.5477	0.4167	0.3373	0.7566

Table 5

Step 4:

Arranging the final value (s) in descending order: ---------->>>M5 > M1 > M2 > M3 > M4 ....in SAW method

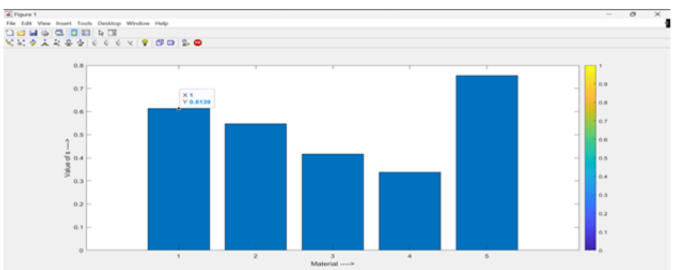

Fig. 3

Sensitivity Analysis

The value of closeness co-efficient in SAW method

Material	when alpha=0	when alpha=1
M1	0.0105	0.6034
M2	0.0329	0.5148
M3	0.0494	0.3673
M4	0.0090	0.3284
M5	0.3797	0.3769

Table 6

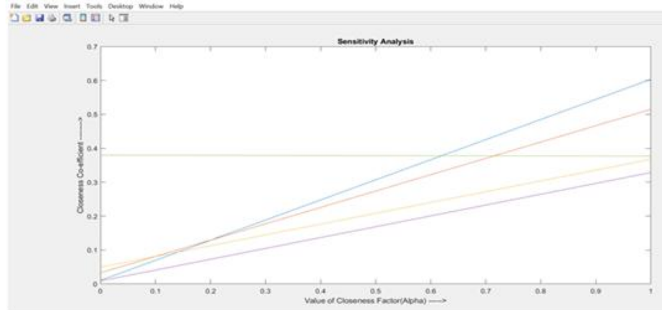

Fig. 4

In the TOPSIS method

The weighted values got from entropy method

Step 1: Determination of normalized decision matrix

Material	Young's modulus (C1) (MPa)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
Chromium cobalt (M1)	1.0000	0.9278	1.0000	0.0277
Nickel (M2)	0.9111	1.0000	0.5135	0.0867
Nickel Titanium(M3)	0.3644	0.9134	0.4324	0.1300
Titanium(M4)	0.4578	0.5835	0.5405	0.0236
Stainless Steel (M5)	0.8889	0.4227	0.5270	1.0000

Table 7

Step 2:

Determination of positive ideal solution: taking the maximum values of each column from the normalized decision matrix

Criteria	Young's modulus (C1) (MPa)	Yield strength(C2)	Hardness (C3)	Cost (INR) (C4)
	1	1	1	1

Table 8

Determination of negative ideal solution: taking the minimum values of each column from the normalized decision matrix

Criteria	Young's modulus (C1) (MPa)	Yield strength (C2)	Hardness (C3)	Cost (INR) (C4)
	0.3644	0.4227	0.4324	0.0236

Table 9

Step 3:

Calculation of the separation measure from the positive ideal solution (di_Plus)

Material	Chromium cobalt	Nickel	Nickel Titanium	Titanium	Stainless Steel
	0.6002	0.6007	0.6558	0.7079	0.3478

Table 10:

Calculation of the separation measure from the negative ideal solution (di_Minus)

Material	Chromium cobalt	Nickel	Nickel Titanium	Titanium	Stainless Steel
	0.4483	0.3776	0.2468	0.0998	0.6482

Table 11:

Step 3: Calculation of R_i

Material	Chromium cobalt	Nickel	Nickel Titanium	Titanium	Stainless Steel
	0.4276	0.3860	0.2734	0.1236	0.6508

Table 12

Step 4:

Arranging the final value in descending order: --------->>>M5 > M1 > M2 > M3> M4 >>

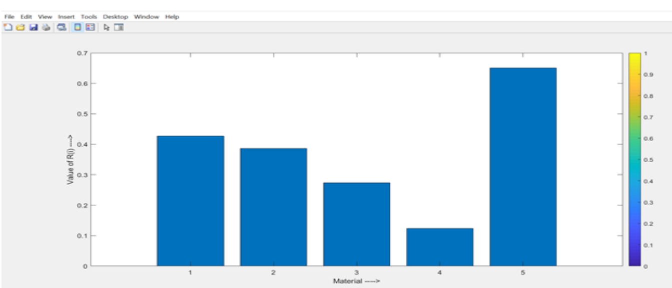

Figure 5

Comparative Analysis of MCDM Methods

Material	Saw (Rank)	Tops is (Rank)
(M1)	2	2
(M2)	3	3
(M3)	4	4
(M4)	5	5
(M5)	1	1

Table 13

Discussion

From this experiment, result,the two different processes of MCDM, the result is same. The ranking of all choices is same for thosedifferent processes. In SAW and TOPSIS methods, ranks of alternatives are given in descending order of their respective composite score. So, the ranking of alternatives of materials are as follows:Stainless Steel >Chromium cobalt >Nickel> Nickel Titanium>Titanium.It means that the choices are the best as it maximizes the benefit criteria respectively.

We have also made the sensitivity analysis with graphical representation in which we see that inSAWmethod. From the sensitivity analysis graph, we also get the rank of the lathes for any alpha value by drawing a vertical line from that alpha value to the straight line of the lathe in the graph. That’s why for doing the sensitivity analysis our result does not depends any different decision makers with their different weighted values.

Conclusions

SAW and TOPSIS methods are observed to be quite capable and computationally easy to evaluate and select the proper material in dental implantfrom a given set of alternatives. These methods use the measures of the considered criteria with their relative importance in order to arrive at the final ranking of the alternative material. Comparing the SAW and TOPSIS in regard to four criteria involves for selection of the optimal material for dental implant design and operation.

As a future scope, a fuzzy TOPSIS, fuzzy SAW based methodology may be developed to aid the decision makers to take decisions in dentistry. The proposed future research work is planned into different stages: Objective setup, analysis of parameter and design of experiments, experimentation and validation of results, alternative solution search. In second phase the project research can be taken to the next level by designing in CATIA and finding the stress analysis by ANSYS and implementation of Finite Element Analysis (FEA) and henceforth comparing the life cycles. Application of software like Delcam would convert this theoretical approach to the final product, which in turn, would be of great help in dental sector.

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