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Research Article

THE SELECTION OF MATERIAL IN DENTAL IMPLANT WITH ENTROPY BASED SIMPLE ADDITIVE WEIGHTING AND ANALYTIC HIERARCHY PROCESS METHODS

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ABSTRACT

The aim of our study is the determination of the most suitable material to be used as a dental implant with the help of Entropy based Simple Additive Weighting and Analytical Hierarchy Process which are the two from multi-criteria decision making methods. Three important criteria in fulfilling this purpose have been chosen: young's modulus, yield strength and hardness criteria. Materials alternatives are chrome cobalt, nickel, nickel titanium, titanium, and stainless steel. Of these alternatives, it has been tried to be determined the most suitable one for the sake of both health and transactional characteristics. At the end of our analysis, it was determined that the best material to be used in implant design is chromium cobalt according to the Entropy based Simple Additive Weighting and Analytic Hierarchy Process methods.
Keywords: Multi-criteria decision making, entropy based simple additive weighting method, analytic hierarchy process, material selection, dental implant.

1. INTRODUCTION

The human being, as a biological entity, has to make decision at every stage of its life. Accurate decision making will help humans to achieve the right results. The multi-criteria decision-making problem is the name given to the problem of determining the best alternative to more than one criterion from more than one alternative. The selection of material being an important problem is a multi-criteria decision-making problem. The material selection problem is an important problem. There are currently over 100,000 materials in the World. The right material determination from within the large number of materials is a crucial decision and is a process that takes a lot of time and experience. It has highlighted the importance of the developing field of multi-criteria decision-making (MCDM) to the material selection process [19]. Health-related decisions are the most important decisions in human life. Teeth are vital organs that directly affect the quality of life and health. Dental implant treatment is one of the basic treatments that have been used if teeth are lost because of some reasons. Today, the use of dental implants has become widespread. The material used for dental implant affects the quality and product life of the dental implant. Therefore, there is a need for medical, dental and engineering researches that focuses on

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the selection of the most appropriate material for dental implant. This study was carried out to satisfy this need. The design and analysis results related to the dental implant that was analysed by the ANSYS program are shown in figure 1. Dental implant image is shown in figure 2.

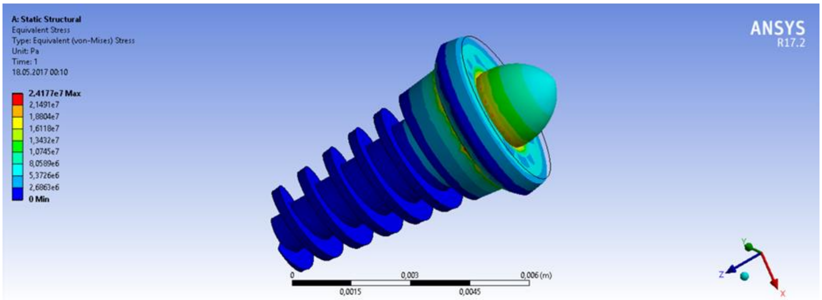

Figure 1. Design and static structural analysis of the dental implant used in this study

Figure 2. Dental Implant

Material selection that is a critical decision is one of the most important factors to consider in design. Selection of the right material, which is a problem type that mechanical and material engineers frequently encounter, ensures that the design in question has the optimum performance [17]. In the literature, the problem which one or more decision maker take the best decision by considering more than one criterion from among more than one alternative. That is called the multi-criteria decision-making problem. Many MCDM methods are used to solve MCDM problems. The Entropy based Simple Additive Weighting method was used in our study as a new method and the Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), and TOPSIS (The Technique for Order Preference by Similarity to Ideal Solution) methods are also from the other extensively used methods. For this reason, the determination of the criteria weights in the solution of the MCDM problem is one of the most important steps. The criterion weighting method must be determined before this process. The reason for criterion weights being taken into consideration is to determine the importance of each criterion according to the others. The weights defined by the assessment criterion and their importance ensure the changes of various values, which each criterion has, as to these weights and their having different numerical values based on these changes [1]. Many weighting methods are reported in the literature. This method is an example of pairwise comparison methods [1]. The entropy method is a criterion weighting method that can be used when the values of a multi-criteria decision-making matrix are known or given. This method focuses on the intensity of oppositions. The AHP method is a subjective weighting method while the Entropy weighting method, which takes entropy weights into account, is an objective method. Our aim in using ESAW method in this study is to compare the results obtained with AHP, which is a subjective method, with ESAW method, which is an objective method. In cases, where experts can provide subjective weights on quantitative criteria, it is better to derive objective weights with Entropy weighting method [21]. Thus, a robust evaluation is made and the best decision is determined as a result.

2. LITERATURE REVIEW

Multi-criteria decision-making problems (MCDM) describe the process of making a decision from a number of alternatives and taking into consideration important criteria bearing in mind that these may change according to the decision maker. In the literature, there are a great number of multi-criteria decision-making methods. The most known and frequently used method among these is the AHP method. This method is mostly preferred due to its being both a multi-criteria decision-making and a weighting method. In addition, the usability of the other multi-criteria decision-making methods which use weights was obtained by this method.

Dağdeviren and Eren [2] used the AHP and 0-1 target programming methods to solve a supplier selection problem. Kahraman and Çerçioğlu tried to solve the problem with a method based on the AHP in a hospital investment selection problem [3]. Üstün and Anagün studied the determining of weighting importance concerning disaster management for Istanbul by using the AHP method [4]. Yerlikaya and Arıkan determined the importance weights of criteria in the performance efficiency ranking of consolidations, which is provided to KOBIs, by the AHP method [5]. Şenyiğit and Demirel chose the AHP method from among the multi-criteria decision-making methods in material selection [6]. Apart from these studies, there are many other studies using the AHP in the literature [7, 8].

One of the other basic methods used in multi-criteria decision-making in the literature is the SAW method. This method is also called the Weighted Sum Model. This is mathematically a very easy method. For the first time, Ömürbek et al. used the Entropy based Simple Additive Weighting method to assess the performance of automotive companies [9]. Urmak, Çatal and Karaatlı, in their study, studied forestry activities of cities and used the SAW model [10].Chu et al. compared the SAW, TOPSIS and VIKOR methods in group decision analysis [11]. Kaliszewski and Podkopaev studied the SAW method in detail and examined the effects of the ordering of criteria weights in other multi-criteria decision-making methods [12]. Other works on the SAW method can be obtained from the review studies [13, 14,15].

In addition to these methods, different multi-criteria decision-making methods have been applied in the literature to solve the problem of material selection [17]. Çalışkan et al. solved the material selection problem for the tool holder working under hard milling conditions [16]. Şenyiğit and Demirel considered the selection of material to be used in the packaging of carbonated soft drinks [6]. Mousavi-Nasab and Sotoudeh-Anvari reviewed the literature for material selection with MCDM methods [17]. Bhosale et al. reported the procedure for selection of material composition for powder metallurgy process [18]. Jahan and Edwards worked on amalgam tooth filling and a hip joint prosthesis material selection problem [19]. This study is the first study on material selection for dental implant with MCDM.

3. MULTI-CRITERIA DECISION MAKING

The decision making problem is very general; it can be defined as the selection of the most appropriate option from a certain set of options for at least one purpose or measure. Accordingly, the elements of a decision problem constitute the priorities of the decision makers, options, criteria, outcomes, environment and the decision maker [2].Multi-criteria decision making (MCDM), one of the most well-known branches of decision making, can be described as a decision-making problem under the existence of a set of decision criteria [3]. The authors of the manuscript are used as decision maker in this study.

3.1. Analytic Hierarchy Process method (AHP)

This method can handle both qualitative and quantitative data. It is based on pairwise comparisons. The four basic steps of the AHP method are described below [5]. For a detailed description of this method, various studies [2-8, 15] can be examined.

Step 1: The multi-criteria decision-making problem is defined. A decision hierarchy is set up that shows the purpose, criteria and alternatives.

Step 2: Pairwise comparisons of alternatives with criteria are made. Pairwise comparisons of criteria are made with each other. The weight values of the criteria are determined.

Step 3: The consistency ratios are calculated.

Step 4: The best alternative is determined [15].

3.2. Entropy Based Simple Additive Weighting Method (ESAW)

Entropy is a commonly used method in the physics and information sciences. The entropy method is used to measure the amount of useful information provided by the current data [9, 10]. ESAW is a method that considers the criteria separately as benefit and cost criteria. It considers the criteria weights determined by entropy weighting method. This method has 5 basic steps [9, 15]. These are mentioned as below.

Step 1: The decision matrix is normalized by using Equation-1. In this equation, m denotes the alternatives, n the criteria, R_{mn} the normalized values and K_{mn} the decision matrix values.

$$R_{mn} = \frac{K_{mn}}{\sum_{m=1}^{A} K_{mn}} \tag{1}$$

Step 2: Entropy values are calculated using Equation-2 for the relevant criteria. In this equation, C denotes the number of criteria.

$$E_n = -\big(ln(C)\big)^{-1} \sum_{n=1}^{C} R_{mn} \, lnR_{mn} \tag{2}$$

Step 3: The weight values of each criterion are determined using Equation 3 [9,15].

$$w_n = \frac{1-E_n}{\sum_{m=1}^{A}(1-E_n)} \tag{3}$$

Step 4: Each alternative (E_{ij}) is normalized according to the benefit (Equation 4) or cost (Equation 5) criterion.

$$A_{ij} = \frac{E_{ij}}{Max\, E_{ij}} \tag{4}$$

$$A_{ij} = \frac{Min\, E_{ij}}{E_{ij}} \tag{5}$$

Step 5: The weighted values of the criterion are multiplied by the normalized values of each criterion value of each alternative. The total values (T_i) of each alternative are found by Equation (6). The sum of these values for each alternative is calculated. The alternative with the highest overall value is the best alternative [9, 15].

$$T_i = \sum_{j=1}^{N} w_n A_{ij} \tag{6}$$

4. APPLICATION AND RESULTS

The aim of this study is to determine the best material for use in dental implant design. The young's modulus (C1), yield strength (C2) and hardness (C3) criteria are considered to achieve this goal. Because the most important criteria in dental implant design are these criteria. Criteria are divided into two classes. These are benefit and cost criteria classes. The basic reason of this classification is that while benefit criteria are being maximized, cost criteria are being minimized [20]. These three criteria are benefit criteria in this study. For a better implant design, the values of these criteria must be high. The best alternatives are expected to reach the maximum of these benchmark values. The decision matrix is shown in Table-1. The 5 alternative materials are chromium cobalt (M1), nickel (M2), nickel titanium (M3), titanium (M4), and stainless steel (M5). In this study, AHP and ESAW multi-criteria decision-making methods are taken into consideration for the best material selection.

Table 1. Decision matrix

	Criterions		
Materials	Young's modulus (C1)	Yield strength (C2)	Hardness (C3)
Chromium cobalt (M1)	**225**	450	**370**
Nickel (M2)	205	**485**	190
Nickel titanium (M3)	82	443	160
Titanium (M4)	103	283	200
Stainless steel(M5)	200	205	195

Table-1 is a decision matrix showing the relevant criterion value of each material. When table-1 is reviewed, it is seen that M1 has the highest values according to C1 and C3 criteria. It is also seen that it has the second highest value according to C2 criterion. As a result, it is understood from the decision matrix that M1 is a good material alternative. The Pairwise comparison matrices of the material alternatives according to criteria C1, C2 and C3 are shown in Table 2-4, respectively. Table-5 shows the priorities and consistency ratios of the alternatives according to the criteria. Consistency ratios must be less than 0.1.

Table 2. Pairwise comparison matrix of material alternatives according to the criterion C1

C1	**M1**	**M2**	**M3**	**M4**	**M5**
M1	1	1	3	5	5
M2	1/3	1	2	3	5
M3	¼	1/5	1	1/9	1/5
M4	1/7	1/5	7	1	1/3
M5	1/9	1/7	5	2	1

Table 3. Pairwise comparison matrix of material alternatives according to criterion C2

C2	**M1**	**M2**	**M3**	**M4**	**M5**
M1	1	7	5	3	2
M2	1/7	1	1/5	1/7	1/3
M3	1/5	5	1	1/7	1/5
M4	1/3	5	7	1	3
M5	1/2	3	1/7	1/3	1

Table 4. Pairwise comparison matrix of material alternatives according to criterion C3

C3	M1	M2	M3	M4	M5
M1	1	3	4	2	2
M2	1/7	1	3	2	1
M3	1/9	1/7	1	2	3
M4	1/3	1/3	1/5	1	1/3
M5	1/5	1/3	3	2	1

Table 5. Priorities and consistency ratios (CR) of alternatives according to criteria

	C1	C2	C3
M1	0.40	0.42	0.41
M2	0.28	0.04	0.18
M3	0.06	0.09	0.16
M4	0.13	0.32	0.09
M5	0.13	0.12	0.16
CR	0.08	0.02	0.08

Table-6 shows the pairwise comparison of the criteria. The consistency ratios of the pairwise comparison matrix of the criteria are shown in Table-7.

Table 6. The pairwise comparison of the criteria

	C1	C2	C3
C1	1	1/3	½
C2	3	1	2
C3	2	½	1

Table 7. The consistency ratios of the pairwise comparison matrix of the criteria

	C1	C2	C3
C1	0.17	0.18	0.14
C2	0.50	0.55	0.57
C3	0.33	0.27	0.29
CR	0.01		

The criteria weights determined by considering the AHP method according to experts are shown in Table-8. The most important criterion according to the decision makers is criterion C2, while the criterion with the least importance is criterion C1.

Table 8. Criteria weights according to the AHP method

C1	C2	C3
0.16	**0.54**	0.30

Table 9 shows the results obtained by following the steps of the AHP method. According to these results, the best material alternative is M1. The second best alternative is M4.

Table 9. The results of the AHP method

M1	**0.41**
M2	0.12
M3	0.11
M4	0.22
M5	0.14

Table-10 shows the criteria weights determined by the Entropy method for ESAW. When these values are examined, it is seen that the criteria weights are very close to each other. The most important criterion is the criterion C2 while the criterion of least importance is criterion C1.

Table 10. The criteria weights determined by the entropy method

C1	C2	C3
0.323	**0.340**	0.337

Since the criterion considered in Table-11 is the benefit criterion, the normalization matrix obtained using Equation-4 is shown in this table.

Table 11. Normalization matrix by the ESAW method

	C1	C2	C3
M1	1.00	0.93	1.00
M2	0.91	1.00	0.51
M3	0.36	0.91	0.43
M4	0.46	0.58	0.54
M5	0.89	0.42	0.53

Table-12 shows the results obtained by the ESAW method. The best material alternative according to the ESAW method is M1.

Table 12. The results of the ESAW method

M1	**0.98**
M2	0.81
M3	0.57
M4	0.53
M5	0.61

Table 13. The comparison of ESAW and AHP results

	ESAW	AHP
1	**M1**	**M1**
2	M2	M4
3	M5	M5
4	M3	M2
5	M4	M3

Finally, Table 13 compares the order of alternative materials obtained by the ESAW and AHP methods. The Spearman's rank correlation coefficient between ESAW and AHP methods was obtained as 0.7 in our study. It can be concluded that the correlations acquired between these methods are generally in acceptable range. According to the comparison, the M1 (chrome cobalt) material is determined as the best material alternative in both methods. The ESAW method determines the M2 material as the second best material because the best material according to the C2 criterion is M2 (see Table-1). In the AHP method, the second best material alternative is M4. In the pairwise comparison of alternative materials made according to C2 criterion. It is determined that the M4 alternative is the best material alternative while M2 material is the worst material alternative (see Table-3). Here we are confronted with a disadvantage of the AHP method. The AHP method is a subjective method while the ESAW method, which takes entropy weights into account, is an objective method [19, 21].

5. CONCLUSION AND FUTURE STUDIES

This paper presents a new study, comparing the AHP and ESAW in regard to three criteria employed for selection of the optimal material for dental implant design. The AHP and ESAW methods were used, first time in the literature, as multi-criteria decision-making methods in dental implant design. The entropy weighting and AHP methods were used to determine the weights of the criteria. The Young's modulus, yield strength and hardness criteria were specified as material selection criteria. Chrome cobalt, nickel, nickel titanium, titanium and stainless steel were the material alternatives. Among these alternatives, chromium cobalt was found to be best alternative according to the AHP and ESAW methods.

The number of mathematical operations in many of the methods used to solve multi-criteria decision-making problems (TOPSIS, ELECTRE, PROMETHEE, etc.) is too high. For this reason, these methods are not widely used by business owners, managers and engineers. In conclusion, we believe that there is a clear need for new multi-criteria decision-making methods with a low number of easy-to-understand and easy-to-apply mathematical operations. Our next study aim will be upon development of a new multi-criteria decision making method which will meet this requirement. Since the material selection problem is an important problem, we will continue to work on new solutions to solve this problem using new multi-criteria decision making methods with our future studies.

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