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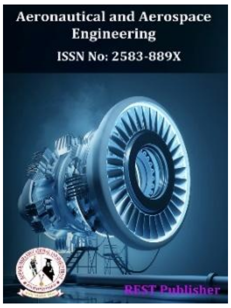

Biomaterial Selection for Knee Prosthesis Using the TOPSIS Multi-Criteria Decision-Making Method

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***Abstract**: The choice of biomaterial for the knee prosthesis is an important consideration when creating artificial knee joints for patients who require knee replacement surgery. The longevity, biocompatibility, and long-term success of knee prosthesis are significantly influenced by the biomaterials chosen. Several essential qualities should be present in the optimum biomaterial for knee prosthesis. First and foremost, it needs to be extremely strong mechanically so that it can support and stabilise the knee joint while withstanding the loads and forces involved in regular activities. The second requirement is that it be biocompatible, which means that the immune system won't reject it or have any negative reactions to it. This guarantees that the implant will blend in without causing irritation or discomfort to the surrounding tissues. Metals, ceramics, and polymers are often utilised biomaterials in knee prostheses. Research on the choice of biomaterial for knee prostheses is important because it enhances patient outcomes, lengthens implant life, assures biocompatibility and safety, propels material science developments, allows for individualised treatment plans, and fosters cost-effectiveness. Research on knee prosthesis biomaterial selection is essential for optimising biocompatibility and safety, enhancing patient outcomes, advancing material science, enabling individualised treatment plans, and enhancing cost-effectiveness. These studies advance orthopaedic science and help people with knee joint problems and the development of improved knee prostheses. Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%).*

***Keywords:** MCDM, Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%).*

1. INTRODUCTION

The issue of selecting materials is handled by engineers and manufacturers in design engineering. Several materials are now available as a result of advancements in manufacturing and material science. As a result, selecting the right materials might be challenging. A mathematical framework for the material selection process can be derived from the multiple criteria decision making (MCDM) approach. When selection criteria include intended objective values, target-based MCDM techniques may be important. Target-based MCDM can be an extensive version of conventional decision-making (DM) with many criteria when all types of criteria are taken into account red. There is now a collection of materials that could be used for the femoral component of knee joint replacements. The purpose of this study is to describe a way to choose an appropriate material for the femoral component of a knee prosthesis based on a recently proposed MCDM method, namely complete VIKOR [24], in order to prolong and improve human life. A case study is presented in Section 3 after Section 2's theoretical discussions of the understand save VIKOR methodology and a suggested method for sensitivity analysis of subjective weights. A broad overview of TKR components and the qualities of implant materials needed for femoral competence are included in this case study. Following a thorough understanding of the technique in Section 2 and the prerequisites in Section 3, Section 4 presents the solution process and covers the choice of the best biomaterials. Conclusions and reflections are included in Section 5 of the essay. The 1967-introduced cemented Charley prosthesis is still the gold Standard in hip surgery, despite commendable efforts to enhance prosthetic designs. Since then, no other technology has emerged that has brought about a comparable revolution in joint replacement surgery. This could be as a result of the general focus on a single issue while ignoring other factors. While ignoring biomechanical issues like stress shielding or micro motion, some biomaterials scientists tend to place a lot of attention on creating new, bioactive materials to address the issue of prosthesis attachment. The only approach to improve the long-term performance of implants is to integrate biomechanics and biomaterials. sufficient strength Material strength is crucial in a prosthetic knee joint to prevent joint breakage. Bone-implant articular joint dysfunction during loading produces in the growth of soft fibrous tissue, which then results This study simultaneously takes into account the impacts of stress protective coverings, durability to wear, and bioactivity to suggest two types of ceramic-based prosthetic systems using three-phase operationally graded nanomaterials. In order to eliminate pain and other drawbacks, the TKR elements may have to get replaced by an artificial organ during revision surgery. Investigated is also the necessary toughness and strength. The behaviour and effectiveness of the suggested prosthetic systems and those frequently employed in earlier publications are contrasted. A recommended material combination is needed for a certain design to proportionately achieve optimal biocompatibility and constant performance, depending on the lifestyle and age of the patient. In the world of materials and orthopaedic biomechanics, there is growing interest in facilitating the appropriate selection of a successful model and preferable material for the creation of patient-specific prostheses using the finite element method (FEM). The rigid-body biomechanics of the bone structure experience both static and dynamic movement; they were static motion is defined as rest or uniform motion, whereas dynamic motion is acceleration brought on by the application of forces with a subdivision of kinematics associated with motion definition and kinetic, the causes of motion. When constructing such a design, it is challenging to predict an efficient model with the best combination of materials while maximising the strain, stress, and deform ability for certain articulating components. Mesh creation is the key step in the geometric division of a certain model.

2. METERIALS AND METHOD

Tensile Strength (MPa): Hydropower is a well-known technique that uses water to generate electricity, while biomass uses organic waste to generate both heat and energy. Geothermal energy is dependable and consistent because it draws heat from the Earth's core. Tidal and wave energy hold great potential since they can harness ocean energy to create electricity. Utilising renewable energy sources helps create a durable and effective energy system for a better and cleaner future.

Corrosion resistance: It is possible to define corrosion resistance as the ability to shield the substrate from corrosion. In this case, the internal structure of the coating, specifically the apparent presence of open gaps and gaps, may be greater in significance than the chemical composition of the coating.

Wear resistance*:* The ability of stone to withstand various external forces, including abrasion, edge cutting, and impact while in use is known as wear resistance.

Osseo integration: Possum "bone" and integrate mean "to make whole" in osseo integration. It is "the formation of a direct interface between an implant and bone, without intervening soft tissue" according to dental terminology.

Cost (Mg/m^ {3}): One microgram per litter (up/L), or around 1 ppb, is equal to one milligramme per cubic metre (mg/m3) in water.

Density(g/cc): The mass (or weight) of a material per unit volume at a specific temperature is known as density (D). Grammes per cubic centimetre (g/cc or g/cm3) are typical quantities.

Elasticity (in GPA): resistance of a material to elastic (temporary) deformation when under stress along a specific axis is measured by its modulus of elasticity. The "stiffness" of a material may also be considered in this context.

Elongation (%): **"**Elongation at Break" is a measurement that identifies the maximum amount of stretching that a material can withstand before snapping. The percentage of elongation, which is a measurement of the, is another name for this.

TOPSIS Method: One of the numerical techniques used in multi-criteria decision making is the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. It is a technique with many practical applications and a straightforward mathematical basis. Utilising computers in this way is also highly useful. utilising the TOPSIS supplier evaluation process. The following are the primary benefits of the TOPSIS strategy: 1. It is easy to operate. 2. It considers every factor, both subjective and objective. 3. It is logical and makes sense. 4. The computing methods are straightforward. 5. The concept enables the pursuit of the best options as determined by a simple mathematical computation The TOPSIS technique was first introduced by Yoon and Hwang and evaluated by surveyors and a number of operators. TOPSIS is a technique for making judgements. A goal-based method is used to identify the alternative that is most similar to the ideal response. This method assigns a grade to solutions based on how closely they match the ideal answer. If a choice is more similar to the best course of action, it will score higher. We try to approximate a solution that is perfect from any point of view but does not truly exist. We mainly consider the design's distance from ideal and non-ideal solutions to assess how closely a design (or alternative) resembles ideal and non-ideal levels. The best option from a list of possibilities is chosen using multi-criteria decision-making (MCDM) approach termed TOPSIS (tactic for Order of Preference by Similarity to Ideal Solution). It comprises comparing alternatives to the best and worst possibilities and evaluating alternatives in relation to a set of standards. The TOPSIS method functions as follows: Criteria Identification Establish the relevant for instance, while comparing several car models, considerations can include price, fuel efficiency, safety rating, and interior space. Normalise the criteria values to make them fit on a single scale. In this stage, each requirement is given the attention it deserves. The decision matrix should be built with the normalised values for each choice and criterion. The dimensions of the decision matrix will be Add up the normalised numbers for each criterion to determine the best solution and worst solution. For each criterion, the best performance is represented by the ideal solution, whilst the poorest performance is represented by the worst solution. This is accomplished by choosing, for each criterion, option using the performance of each in relation to the best and worst solutions. The data must be normalised after the criteria have been developed in order to place all of the criteria on a common scale. This is carried out to guarantee that evaluation criteria with different measurement scales or units are appraised equally. Two examples of normalisation methods are min-max normalisation and linear normalisation. Weighting: Based on each criterion's relative importance or priority, decision-makers must assign weights various techniques, such as expert opinion, the analytical hierarchy process (AHP), or individual preferences The performance of the options in comparison to the criteria is numerically represented in the decision matrix. Making the Perfect two categories of ideal solutions that are taken into account by the TOPSIS approach. The PIS and NIS represent the best and worst possible results for each criterion, respectively. These perfect solutions are constructed by either maximising or decreasing each criterion. calculating a proximity coefficient estimate The proximity coefficient is used to determine the separation between each alternative and the optimal solutions. It is determined by comparing the separations between each alternative and the PIS and NIS. The distances can be calculated using a Sorting through the Alternatives The options are ranked in accordance with their closeness coefficients as the last stage. The optimum choice is one which, as determined by the proximity coefficient, is most similar to the ideal answer. The TOPSIS technique is a useful tool for making decisions when presented with a variety of criteria and possibilities. It offers a methodical and organised methodology for assessing alternatives and ranking them according to how well they perform in comparison to the optimal solutions. Identification of Criteria: List the standards by which the alternatives will be judged. These standards ought to be pertinent, quantifiable, and directly tied to the decision-making issue. Give each criterion a weight to represent their relative relevance or order of importance. The decision-maker's subjective preferences are reflected in the weights, which can be established using a variety of techniques, including surveys, expert judgement, and analytical procedures.

3. RESULT AND DISCUSSION

TABLE 1. Knee Prosthesis Biomaterial Selection

	Tensile Strength(MPa)	**Corrosion resistance**	**Wear resistance**	**Osseo integration**	**Cost(Mg/m ^{3})**	**Density(g /cc)**	**Elastic Modulus(GA)**	**Elongation (%)**
Ti-5Al-2.5Fe	862	6	7	5	31	8	200	12
Ti-6Al-4V	550	9	5	7	105	4.5	100	54
Ti-6Al-7Nb	900	9	6	7	145	4.45	112	6
L316(annealed)	985	9	6	7	191	4.43	112	12
L316(cold worked)	1000	9	6	7	165	4.52	110	12
Zr-2.5Nb	510	7	7	7	216	6.44	98	20

Table 1 shows the Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^{3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) and alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb

TABLE 2. Normalized Data

	Tensile Strength(MPa)	Corrosion resistance	Wear resistance	Osseo integration	Cost(Mg/m^{3})	Density(g/cc)	Elastic Modulus(GA)	Elongation (%)
Ti-5Al-2.5Fe	0.426446983	0.296680906	56.71543611	52.4596494	2.276531057	63.27614936	2.770687427	14.01301871
Ti-6Al-4V	0.272094943	0.445021359	36.18734322	33.47193407	1.452543018	40.37341316	1.767840006	8.94102122
Ti-6Al-7Nb	0.44524627	0.445021359	59.21565255	54.77225575	2.376888575	66.06558518	2.8928291	14.630762
L316(annealed)	0.487297307	0.445021359	64.80824195	59.94519102	2.601372496	72.30511267	3.166040738	16.01255619
L316(cold worked)	0.494718078	0.445021359	65.7951695	60.85806195	2.640987305	73.40620575	3.214254556	16.25640222
Zr-2.5Nb	0.25230622	0.346127724	33.55553644	31.03761159	1.346903526	37.43716493	1.639269823	8.290765132

Table 2 shows the Normalized Data information of Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) and alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb.

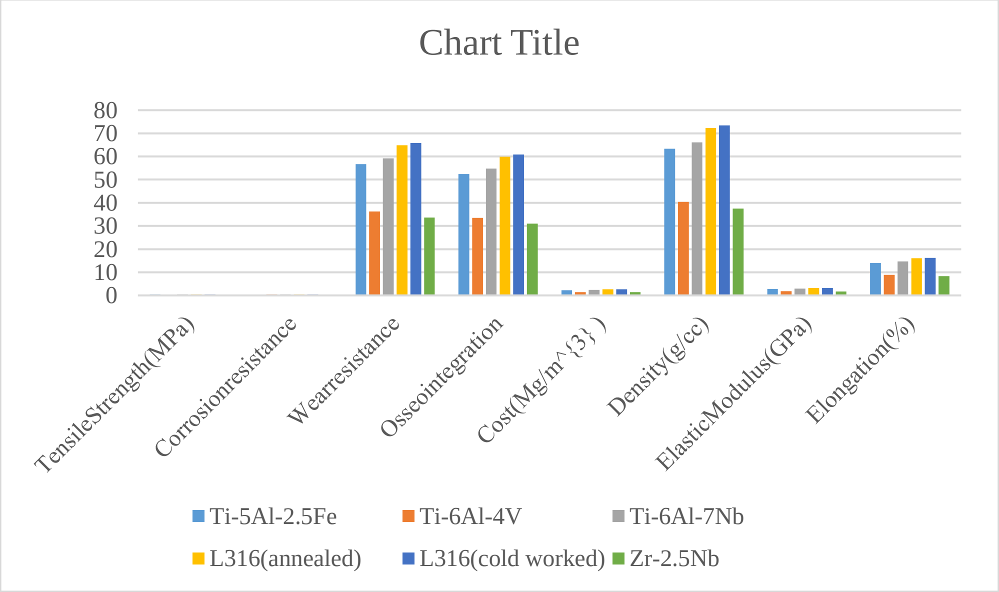

FIGURE 2. Normalized Data

Figure 2 shows the Normalized Data information set of alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb and Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) Normalized Data value.

TABLE 3. Weightages

	Tensile Strength(MPa)	Corrosion resistance	Wear resistance	Osseo integration	Cost(Mg/m^{3})	Density(g/cc)	Elastic Modulus(GA)	Elongation(%)
Ti-5Al-2.5Fe	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Ti-6Al-4V	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Ti-6Al-7Nb	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
L316(annealed)	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
L316(cold worked)	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Zr-2.5Nb	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125

Table 3 shows the Weightages of all are same value 0.125.

TABLE 4. Weighted Normalized Decision Matrix

	Tensile Strength(MPa)	Corrosion resistance	Wear resistance	Osseo integration	Cost(Mg/m^{3})	Density(g/cc)	Elastic Modulus (GA)	Elongation(%)
Ti-5Al-2.5Fe	0.053305873	0.037085113	7.089429513	6.557456175	0.284566382	7.90951867	0.346335928	1.751627339
Ti-6Al-4V	0.034011868	0.05562767	4.523417903	4.183991759	0.181567877	5.046676645	0.220980001	1.117627653
Ti-6Al-7Nb	0.055655784	0.05562767	7.401956568	6.846531969	0.297111072	8.258198147	0.361603638	1.82884525
L316(annealed)	0.060912163	0.05562767	8.101030244	7.493148877	0.325171562	9.038139083	0.395755092	2.001569523
L316(cold worked)	0.06183976	0.05562767	8.224396187	7.607257743	0.330123413	9.175775719	0.401781819	2.032050277
Zr-2.5Nb	0.031538277	0.043265965	4.194442055	3.879701449	0.168362941	4.679645617	0.204908728	1.036345641

Table 4 shows the Weighted Normalized Decision Matrix information set of alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb and Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) Weighted Normalized Decision Matrix value.

TABLE 5. Positive matrix

	TensileStrength(MPa)	Corrosionresistance	Wearresistance	Osseointegration	Cost(Mg/m^{3})	Density (g/cc)	ElasticModulus(GPa)	Elongation(%)
Ti-5Al-2.5Fe	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277
Ti-6Al-4V	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277
Ti-6Al-7Nb	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277
L316(annealed)	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277
L316(cold worked)	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277
Zr-2.5Nb	0.031538277	0.037085113	4.194442055	3.879701449	0.330123413	9.175775719	0.401781819	2.032050277

Table 5 shows the Positive matrix information set of alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb and Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) Weighted Normalized Decision Matrix value.

TABLE 6. Negative Matrix

	Tensile Strength(MPa)	Corrosion resistance	Wear resistance	Osseo integration	Cost(Mg/m^{3})	Density(g/cc)	Elastic Modulus(GA)	Elongation(%)
Ti-5Al-2.5Fe	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641
Ti-6Al-4V	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641
Ti-6Al-7Nb	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641
L316(annealed)	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641
L316(cold worked)	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641
Zr-2.5Nb	0.06183976	0.05562767	8.224396187	7.607257743	0.168362941	4.679645617	0.204908728	1.036345641

Table 6 shows the Negative matrix information set of alternative Ti-5Al-2.5Fe, Ti-6Al-4V, Ti-6Al-7Nb, L316(annealed), L316(cold worked), Zr-2.5Nb and Tensile Strength (MPa), Corrosion resistance, Wear resistance, Osseo integration, Cost (Mg/m^ {3}), Density(g/cc), Elastic Modulus (GPA), Elongation (%) Weighted Normalized Decision Matrix value.

TABLE 7. Final Result of Knee Prosthesis Biomaterial Selection

	Si plus	Si negative	Ci	Rank
Ti-5Al-2.5Fe	3.65621	4.1519863	0.5317473	4
Ti-6Al-4V	5.05554	4.2592903	0.4572589	5
Ti-6Al-7Nb	3.83802	4.4695753	0.5380109	3
L316(annealed)	4.47408	5.3234927	0.5433482	2
L316(cold worked)	4.61211	5.4896692	0.543436	1
Zr-2.5Nb	5.48965	4.612112	0.456565	6

Table 7 shows the final result of TOPSIS for Knee Prosthesis Biomaterial Selection. Figure 3 shows the TOPSIS Analysis Result of Knee Prosthesis Biomaterial Selection. In Table 6, Si positive is calculated using the formula (3). From figure 3, In Si positive, Zr-2.5Nb is having is Higher Value and Ti-5Al-2.5Fe is having Lower value. Si Negative is calculated using the formula (4). In Si Negative, L316(cold worked) is having is Higher Value Ti-5Al-2.5Fe is having Lower value. Ci is calculated using the formula (5). In Ci, L316(cold worked) is having is Higher Value and Zr-2.5Nb is having Lower value.

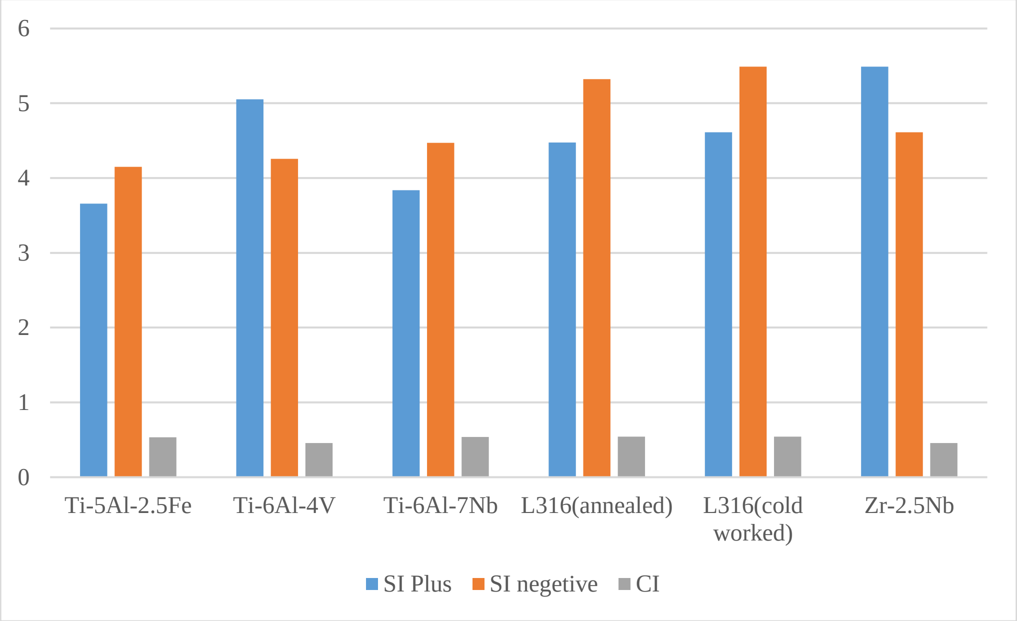

FIGURE 3. SI Plus, SI Negative, Ci Value

Figure 3 shows the final result of TOPSIS for Knee Prosthesis Biomaterial Selection. Figure 3 shows the TOPSIS Analysis Result of Knee Prosthesis Biomaterial Selection. In Table 6, Si positive is calculated using the formula (3). From figure 3, In Si positive, Zr-2.5Nb is having is Higher Value and Ti-5Al-2.5Fe is having Lower value. Si Negative is calculated using the formula (4). In Si Negative, L316(cold worked) is having is Higher Value Ti-5Al-2.5Fe is having Lower value. Ci is calculated using the formula (5). In Ci, L316(cold worked) is having is Higher Value and Zr-2.5Nb is having Lower value.

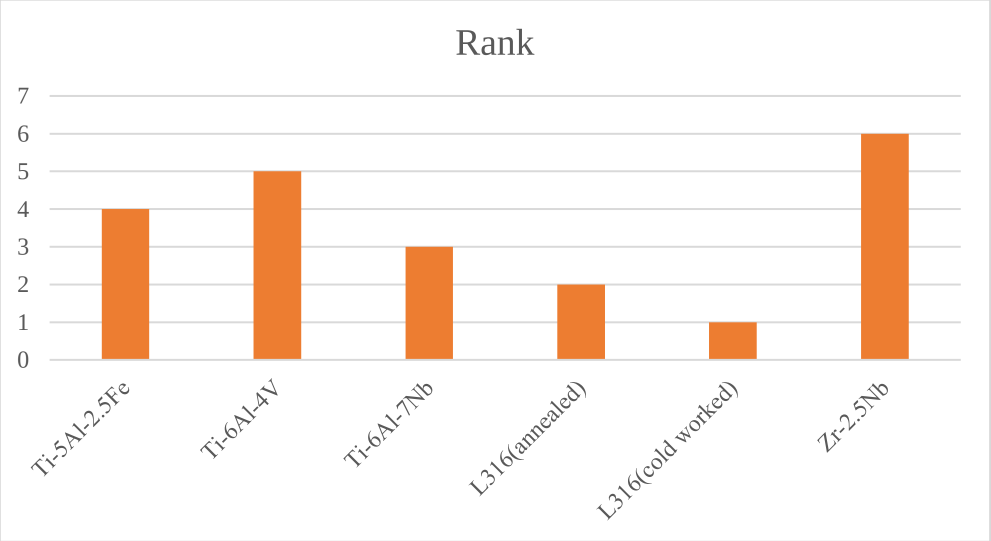

FIGURE 4. Rank

Figure 4 shown the Rank final result of TOPSIS for Knee Prosthesis Biomaterial Selection. L316(cold worked) is having is Highest Rank and Zr-2.5Nb is showing the Lowest Rank.

4. CONCLUSION

In this study, the choice of biomaterial was decided utilising the cutting-edge MCDM method known as RIM. The method was assessed using two separate biomaterial selection issues that were taken from the literature. The results were compared to those of the research that were published. Co-Cr alloys-wrought alloy and Ti6Al4V are the two most recommended alternatives for hip prosthesis materials. The comprehensive VIKOR technique was successfully used to rank the femoral component of the TKR candidate materials, and weight sensitivity analysis was conducted to produce more precise results. Perfect geometric symmetry between the implant and bone surfaces is necessary due to the sensitivity of the strains that develop in the bone to the precise nature of the contact between the implant and the bone and the requirement for enough initial stability of fixation. The selection of biomaterials and the utilised in TDR were the main topics of this investigation. Long-term use of metal alloys and polymeric materials has mostly unknown local, systemic, and physiological impacts. UHMWPE, stainless steels, cobalt alloys, and titanium alloys are the four main materials having a track record of more than 50 years that are employed in TDR. The critical environment of the TDR demands the reliability of past performance, as proven by current TDR designs, even though newer alloys (such as oxidised zirconium) may be better suited to fulfil some design criteria and may represent biomaterial upgrade to TJA design. The selection of biomaterials and the utilised in TDR were the main topics of this investigation.

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