AMAR SAAD ZINELABDIN MOHAMED DENTAL FILLINGS MATERIALS AND THEIR EVALUATION BY USING FUZZY PROMETHEE METHOD AND CLARIFYING THE RISK FACTORS OF AMALGAM NEU 2023

DENTAL FILLINGS MATERIALS AND THEIR EVALUATION BY USING FUZZY PROMETHEE METHOD AND CLARIFYING THE RISK FACTORS OF AMALGAM.

A THESIS SUBMITTED TO INSTITUTE OF GRADUATE STUDIES DEPARTMENT OF ENGINEERING NEAR EAST UNIVERSITY

BY
AMAR SAAD ZINELABDIN MOHAMED

PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BIOMEDICAL ENGINEERING

NICOSIA, 2023

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Approval

We certify that we have read the thesis submitted by **Amar Saad Zinelabdin Mohamed** titled "**DENTAL FILLINGS MATERIALS AND THEIR EVALUATION BY USING FUZZY PROMETHEE METHOD AND CLARIFYING THE RISK FACTORS OF AMALGAM.**" and that in our combined opinion it is fully adequate, in scope, and quality, as a thesis for the degree of Master of Sciences in Biomedical Engineering.

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Amar Saad Mohamed

Abstract

"Dental Fillings Materials and Their Evaluation by Using Fuzzy PROMETHEE Method and Clarifying the Risk Factors Of Amalgam."

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June 2023,

Background of Study: The pain resulting from tooth decay and the damage it causes in the basic structure of the tooth makes it necessary to find a solution for the parts affected by tooth decay, which is why dental fillings were invented. Dental fillings are materials that are used to repair teeth affected by decay and necrosis, where the affected tooth is cleaned and the area affected by decay is removed from it, then the space is filled using one of the types of dental fillings. Dental fillings vary according to use, some are temporary and others are permanent.

Permanent dental fillings also differ in materials, and each has certain uses according to the affected tooth. The front teeth have fillings different from the back teeth, and nerve fillings are different from cosmetic fillings, some dental fillings are used in implants, and they differ in materials, strength, period, etc. Also, each type of dental filling has its advantages, and each of them also has disadvantages. Composite fillings, for example, are tooth-colored and blend in with the surrounding teeth, making them a popular choice for front teeth or other visible areas. Amalgam fillings, on the other hand, are made of a mixture of metals and are often used for back teeth due to their durability and strength. Recent studies have shown that most people prefer the color of the filling to be similar to their teeth, and this is what makes composite fillings the best options available for use. While amalgam fillings have been used for many years, concerns have been raised about their safety due to the presence of mercury in the filling material. However, the American Dental Association (ADA) and other major health organizations maintain that amalgam fillings are safe and effective when used properly.

Objective/Method: This research aims to evaluate and compare the materials used in dental fillings and to clarify the importance of each of them in use in different cases. Also, after clarifying the negative and positive effects of the dental filling materials, using one of the multi-criteria decision-making (MCDM) techniques called, the fuzzy preference ranking organization

method for enrichment of evaluations (PROMETHEE), we have provided the ranking result of these materials based on their selected features.

Result: The cost, life length, strength, patient satisfaction, aesthetics, number of sessions, and allergy risk were considered in the first scenario for the evaluation of the dental filling materials. Amalgam ranked as the first alternative, and gutta-percha ranked as the second alternative. The cost and the life length are eliminated in the second scenario. The resin composite ranked as the first alternative, and gutta-percha ranked second. The results were obtained based on the weights assigned to the criteria selected. The results can simply be updated based on the condition and the preferences of the patients or dental doctors.

Conclusion: As a result of this decision-making approach, the important factors of the materials used in new dental filling materials and the most commonly used dental filling materials were analyzed. The difference between the new materials used in dental fillings and the most commonly used materials was analytically revealed. The results can also contribute to the development of educational initiatives and awareness programs aimed at promoting alternative treatment options and minimizing the potential harm associated with dental amalgam.

Keywords: Dental fillings, Amalgam fillings, Composite fillings, Dental materials, Dental clinics, tooth decay, awareness, fuzzy PROMETHEE.

Özet

"Dental Dolgu Malzemeleri ve Fuzzy PROMETHEE Yöntemi Kullanarak Değerlendirilmeleri ve Amalgamın Risk Faktörlerinin Açıklanması"

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Yüksek Lisans, Biyomedikal Mühendislik Bölümü

Haziran 2023,

Araştırmanın Arka Planı: Diş çürüğünden kaynaklanan ağrı ve dişin temel yapısına verdiği zarar, diş çürüğünden etkilenen bölgeler için bir çözüm bulmayı gerektirir. İşte bu nedenle diş dolguları icat edilmiştir. Diş dolguları, çürük ve nekroz etkilenen dişleri onarmak için kullanılan malzemelerdir. Etkilenen diş temizlenir, çürüğün etkilediği bölge çıkarılır ve ardından boşluk bir tür diş dolgusu kullanılarak doldurulur. Diş dolguları kullanıma göre farklılık gösterir; bazıları geçici, bazıları ise kalıcıdır.

Kalıcı diş dolguları aynı zamanda malzemelere göre de farklılık gösterir ve her biri etkilenen dişe göre belirli kullanımlara sahiptir. Ön dişler, arka dişlerden farklı dolgulara sahip olup sinir dolguları kozmetik dolgulardan farklıdır. Bazı diş dolguları implantlarda kullanılır ve malzeme, dayanıklılık, süre vb. açısından farklılık gösterir. Ayrıca, her bir diş dolgu türünün avantajları ve dezavantajları vardır. Örneğin, kompozit dolgular diş renginde olup çevreleyen dişlerle uyum sağlar, bu nedenle ön dişler veya diğer görünür bölgeler için popüler bir seçenektir. Öte yandan, amalgam dolguları metal karışımından yapılmış olup dayanıklılık ve sertliği nedeniyle genellikle arka dişler için tercih edilir. Son çalışmalar, çoğu insanın dolgunun renginin dişlerine benzer olmasını tercih ettiğini göstermiştir ve bu, kompozit dolguların kullanılabilirlik açısından en iyi seçenekler olduğunu ortaya koymaktadır. Amalgam dolguları uzun yıllardır kullanılmaktadır, ancak dolgu malzemesinde civa bulunması nedeniyle güvenlik konusunda endişeler ortaya çıkmıştır. Bununla birlikte, Amerikan Dişhekimleri Derneği (ADA) ve diğer önemli sağlık kuruluşları, amalgam dolguların uygun şekilde kullanıldığında güvenli ve etkili olduğunu belirtmektedir.

Amaç/Yöntem: Bu araştırma, diş dolgularında kullanılan malzemeleri değerlendirmeyi ve farklı durumlarda her birinin önemini açıklamayı amaçlamaktadır. Ayrıca, diş dolgusu malzemelerinin olumlu ve olumsuz etkilerini açıkladıktan sonra çok kriterli karar verme (MCDM) tekniklerinden biri olan bulanık tercih sıralama organizasyonu yöntemi (PROMETHEE) kullanılarak bu malzemelerin seçilmiş özelliklerine dayalı sıralama sonuçlarını sunmaktayız.
Sonuç: Diş dolgusu malzemelerinin değerlendirilmesi için ilk senaryoda maliyet, kullanim süresi, dayanıklılık, hasta memnuniyeti, estetik, tedavide gereken seans sayısı ve alerji riski dikkate alındı. Amalgam birinci sırada, gutta-perka ise ikinci sırada yer aldı. İkinci senaryoda maliyet ve kullanim süresi değerlendirmeye katılmadı. Rezin kompozit birinci sırada, gutta-perka ise ikinci sırada yer aldı. Sonuçlar, seçilen kriterlere atanan ağırlıklara dayanarak elde edildi. Sonuçlar, hastaların veya diş hekimlerinin durumlarına ve tercihlerine göre basitçe güncellenebilir.
Sonuç: Bu karar verme yaklaşımının sonucu olarak, diş dolgusu malzemelerinde kullanılan malzemelerin önemli faktörleri ve en yaygın kullanılan ve yeni diş dolgusu malzemeleri analiz edildi. Diş dolgularında kullanılan yeni malzemeler ile en yaygın kullanılan malzemeler arasındaki fark analitik olarak ortaya konuldu. Sonuçlar ayrıca alternatif tedavi seçeneklerini teşvik etmeyi ve dolguda kullanılan amalgama bağlı potansiyel zararı en aza indirmeyi amaçlayan eğitim girişimlerinin ve farkındalık programlarının geliştirilmesine katkıda bulunabilir.

Anahtar Kelimeler: diş dolguları, amalgam dolguları, kompozit dolgular, diş malzemeleri, diş klinikleri, diş çürüğü, farkındalık, bulanık PROMETHEE.

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LIST OF ABBREVIATIONS

BPA	**Bisphenol A**
ADA	**American Dental Association**
UNEP	**United Nations World Environment Program**
WHO	**World Health Organization**
MCDM	**Multicriteria Decision Making**
NKUA	**National and Kapodistrian University of Athens**
NEU	**Near East University**
Bis-GMA	**Bisphenol A-glycidyl methacrylate**
UDMA	**Urethane dimethacrylate**
TEGDMA	**Triethylene glycol dimethacrylate**
S-PRG	**Surface pre-reacted glass-ionomer**
F	**fluoride**
B	**Borate**
Al	**Aluminum**
Na	**Sodium**
Si	**Silicate**
Sr	**Strontium**
MH	**Micro-hardness**
WS	**Water sorption**
SL	**Solubility**
HA	**Hydroxyapatite**
SiO2-CaO-Na2O-P2O5-MgO	**Bioglass**
GICs	**Glass ionomer cement**
GP	**Gutta-percha**
PROMETHEE	**Preference ranking organization method for enrichment of evaluations**

CHAPTER I

- **1- Introduction**

1.1. Background of Study:

Teeth are exposed to many problems that may cause great pain to the patient. Tooth decay is the most prominent of these problems, which may lead to tooth damage or tooth extraction if the tooth decay reaches the nerves. On the other hand, tooth discoloration is a common problem for many patients as a result of smoking and other problems and causes.

Tooth decay is damage that leads to the erosion of the enamel layer that contains calcium and phosphate. Therefore, we must know what are the main causes of these dental problems:

First, an unhealthy diet: Eating unhealthy foods that contain high levels of starches and sugars is one of the reasons that increases the risk of tooth decay. These foods are a perfect environment for bacteria that live in the mouth, as they work on the bacteria to break down starches and sugars into Acids contributing to enamel damage, and leading to tooth decay [1, 2, 3, 4].

Secondly, plaque accumulation: Plaque is known as a sticky layer that is formed as a result of the accumulation of bacteria and nutrients, which leads to the plaque hardening over time and turning into tartar, which makes the gums sensitive and more irritated, thus increasing the chances of infection. Over time, this leads to the collapse of the enamel layer, which is known as the hard outer layer of the teeth, causing tooth decay [1].

Third: Fluoride deficiency: It is a mineral that helps increase the efficiency of tooth enamel and strengthen it against decay. Fluoride is found in water, some foods, and toothpaste [5].

Fourth, chronic diseases: Chronic diseases are one of the causes of tooth decay, such as diabetes and thyroid diseases, as these diseases cause a lack of saliva secretion, which helps get rid of leftover food and bacteria. When the production of saliva in the mouth decreases, the accumulation of plaque on the teeth increases, which increases the incidence of tooth decay [6, 7, 8].

Fifth, poor personal care: Not paying attention to cleaning the teeth with brush, paste, and floss increases the possibility of cavities occurring. Brushing the teeth removes tartar and plaque from the teeth.

Tooth decay causes many health problems that generally affect the health of the mouth and the body. The most prominent of these problems are tooth decay, gingivitis, infection, digestive problems, and other problems. Toothache is one of the most prominent of these problems, as it spreads to the entire mouth and causes problems in the rest of the teeth due to enamel erosion [9, 10]. On the other hand, tooth erosion is defined as the erosion of the outer enamel layer of the teeth and occurs as a result of excessive brushing or acid reflux [11]. In addition, gingivitis is a common problem among smokers due to the accumulation of plaque and tartar, which causes bleeding gums and bad breath. Add to this the loss of teeth [11, 12, 13, 14]. Tooth infection is a problem that occurs as a result of serious complications of tooth decay and neglecting to visit the doctor, as it causes inflammation of the nerves and tissues and even leads to sepsis [12, 13, 14]. Other problems that may occur as a result of tooth decay include problems in the digestive system as a result of not chewing food well, which affects the absorption of food and nutrients [13, 14]. Speech problems can also be caused by tooth decay as teeth can be lost or eroded, changing the shape of the mouth and making it difficult to speak clearly [9, 10].

In general, caries can lead to serious health and physical problems if they are not treated properly and on time. Therefore, it is recommended to visit the dentist periodically, follow a healthy diet, and practice good personal dental care to maintain oral and dental health.

1.2. Thesis Problems:

Knowing and increasing the awareness of dentists, students, and patients and reducing the use of amalgam is an important challenge at present, and we may encounter some problems during this process, and these problems include:

Technical Performance: Some people may find it difficult to use amalgam substitutes, especially if they have been using amalgam for a long time. Switching to amalgam substitutes may require learning new techniques and practicing proper use.

Technical Challenges: Alternative amalgam fillings require sophisticated technology to manufacture and develop them effectively, and this poses a challenge for scientists and engineers.

Cost: Some amalgam substitutes may be more expensive than traditional amalgams. Some individuals may have difficulty affording these alternatives.

Technological capabilities: Some amalgam alternatives may not be available in all places, especially in remote areas or developing countries, where access to modern technology is not available.

Effectiveness of alternatives: Some alternatives to amalgam may not provide the same level of effectiveness as traditional amalgam. Switching to the use of amalgam alternatives may require careful evaluation of their effectiveness and comparison with traditional amalgam. The difficulty of extracting amalgam from the mouth is because it requires a specific device and a special doctor to remove the amalgam so that mercury vapor does not reach the patient and the doctor. This device is considered to be very expensive and is not found in poor and developing countries in general. The amalgam is extracted directly from the teeth, which affects the health of the patient, the doctor, and the physician’s assistant.

Clinical Outcomes: Newer alternatives to amalgam fillings need large-scale clinical studies to evaluate their long-term safety and efficacy.

Cultural awareness: There may be challenges in switching from the use of traditional amalgam fillings to alternative alternatives in some societies and cultures, and this requires awareness and continuous education.

Legal and regulatory challenges: Regulations and legislation related to dental fillings and the chemicals used in them differ between countries, and this presents a challenge for developing new alternatives and adopting them at the global level.

1.3. Aims of the research:

- The main aim is to analyze, compare and rank dental filling using a mathematical approach.

- Also, increasing the awareness of dental students who are still in the early stages of study so that they can rely on the available alternatives to dental fillings.

- Providing more detail information about the dental filling materials.

1.4. Significance of the research:

No applications of the fuzzy preference ranking organization method for enrichment of evaluations (PROMETHEE) methodology for determining the best types of dental fillings and when to use them.

- This research will give a clear understanding of dental fillings and dental implants to solve dental problems.

- The results of this research will aid or help or support dentists and patients in choosing or selecting the appropriate dental filling.

- The analytical results of this research are considered a reference for doctors and students so that they can test the best materials in filling cases, whether in the front teeth or the back teeth, in addition to knowing the best implants and their components.

Maintaining public health: Amalgam contains harmful chemicals that may affect public health and cause long-term health risks, such as hormonal disorders and problems in the nervous and immune systems. Thus, public health can be maintained by reducing the use of amalgam and relying on alternative dental fillings with healthy and environmental qualities.

Preserving the environment: Amalgam is a product that is largely disposed of in landfills and incinerators, and this leads to the production of greenhouse gases and the addition of harmful chemicals to the environment. Therefore, the environment can be preserved by reducing the use of amalgam and relying on alternative dental fillings with healthy and environmental qualities.

Preserving Teeth: Dental fillings help maintain dental health and prevent tooth decay and tooth erosion, while amalgam can erode teeth and cause ulcers in the mouth and gums.

Economical: Dental fillings are considered a more economical and effective alternative to amalgam, as they cost less in the long run, retain teeth and reduce the need for expensive dental treatments.

Social: Dental fillings can contribute to improving oral health and self-confidence, thus, helping to enhance social and work relationships.

1.5 Limitations of the Research:

- The used data as is collected from literature.
- If there is an addition or removal of any alternative or criteria, the results of the study are likely to change.
- The adjustment of the selected importance weights for the criteria can also be modified by the decision maker, potentially leading to changes in the ranking results of the alternatives.

CHAPTER II

- **2. Literature Review**

2.1. Amalgam risks.

The problems caused by amalgam are many, as they are not limited to environmental pollution only, as other problems that differ with the aesthetic shape of the teeth are also one of the reasons that limit and reduce the use of amalgam. Also, some diseases may be caused to the patient because of inhaling mercury and other diseases. All these problems will be mentioned in detail below.

- **Amalgam and the environment:**

Eight closely linked issues make up the substantial subject of academic research on sustainability in dentistry [15]. The "four Rs" philosophy of reducing, reusing, recycling, and rethinking, policy and guideline issues, biomedical waste management, decreased plastic usage, procurement, research and education, and the use of biodegradable and biomimetic materials for oral health are a few of the themes covered here [16]. On a national or worldwide level, there are now challenges to enacting the necessary regulations to support sustainable dentistry practices. The biggest obstacles are a lack of knowledge among professionals and the general public, carbon emissions from the transportation of patients and staff, problems with recycling and recovering biomedical waste, a lack of knowledge and education about sustainable healthcare, difficulties with manufacturing, and the use and disposal of dental materials like amalgam. In order to address these issues, more study and instruction are needed on sustainable dental practices, as well as global policy reforms to support them. In the end, encouraging environmentally friendly dental procedures can develop a more environmentally friendly sector that benefits both people and the environment [16, 17, 18, 19].

- **Amalgam and health and dental problems:**

Dental amalgam has benefited the dental profession for a long time by repairing missing dental tissues on anterior and posterior teeth as well as filling cavities of different shapes, sizes, and sorts. However, opponents of dental amalgam have periodically questioned the material's widespread use because of worries about human health and the environment, as well as because it doesn't match the esthetic and functional requirements of modern dentistry [20, 21]. Mercury (Hg), a prominent amalgam component with a body weight ratio of nearly 50%, is the main source of worry over its use. Amalgam that has crystallized in the form of Hg vapors seems to produce poisonous Hg ions. The scientific community is concerned about its impact on the health of both patients with amalgam fillings and dentists and dental assistants who are exposed to it at work [22, 23]. Dental amalgam has also been accused of releasing Hg into the environment by numerous pathways (such as water and air) from the time it is generated until it is removed from the oral cavity, even years later [23,24,25]. Even with posterior deciduous or permanent teeth, this is true. In order to lessen the exposure of patients (especially children) and personnel to Hg vapors, other materials and repair types, such as composite resins, glass ionomer materials, or ceramics, have been suggested thus far [23,24,25,26].

- **Amalgam and global consumption of mercury:**

Even though dentistry is not the main source of mercury, the United Nations Environment Program (UNEP) Global Mercury Assessment 2013 reports that dental amalgam represents for 21% of the world's consumption of mercury in products [27]. Mercury is one of the top 10 compounds that represent a substantial risk to human health, according to the World Health Organization (WHO) [28]. Volcanoes are one example of a man-made source that emits into the environment. When Hg is released into the environment, it moves through the air, soil, and water, the three primary environmental compartments, before being subsequently eliminated from the system by being buried in coastal and deep-water sediments, as well as subterranean soils [29, 30]. Since Hg does not break down in the environment, it is believed that its concentrations in the world's water supplies and land with little vegetation impair human health through the animal and plant food chain [27, 28, 31].

The major way that humans are exposed to Hg is through seafood. The chain of survival tends to accumulate higher levels of mercury when larger predatory fish, such as tuna or swordfish, enter the human food chain, predisposing individuals to higher mercury intake. The dosage of Hg has an impact on health. The effects of mercury on growing fetuses and young children are currently the largest cause for concern. In addition to procedures like applying or removing dental amalgam fillings, a mother's seafood consumption might result in Hg exposure during pregnancy [32]. A baby's growing brain and nerve system may be severely and permanently disrupted by this, resulting in impairments to memory, language, attention, and other skills. More than 1.8 million kids are thought to be born every year in Europe alone with Hg levels that are higher than what is considered safe [33].

- **Global agreements to reduce the use of mercury (amalgam):**

The Minamata Convention on Mercury was founded in 2013 to protect human health and the environment from mercury's harmful effects [34]. Realistic initiatives were taken to phase out amalgam's use in dentistry because of the Hg content of the material. Even its use has been made illegal in many countries. The first country to forbid the use of mercury in any form, including dental amalgam, was Norway in 2008. Denmark and Sweden soon after [35]. As of July 1, 2018, all children under the age of 15 and pregnant or nursing women must not use dental amalgam as a result of the European Union's adoption of the 2017/852 rule [36]. The Minamata Convention has been ratified by 128 countries, but unhappily, the bulk of them have not made any significant advancements in this field [37, 38]. In low- and middle-income countries, discontinuing amalgam use may be extremely challenging [35, 36, 37, 38]. There are also EU countries like Greece where using dental amalgam is not only acceptable but also on the decline.
Many of the older dental clinics still lack amalgam separators, despite the fact that European law and professional bodies mandate them for new dental clinics.
Even though the use of amalgam in restorations is now prohibited, concerns concerning the environmental and public health safety of new restorations continue to be a focus of discussion at the European and global levels. As a result, dental amalgam was assessed and compared to other materials that are used in dental fillings in this research utilizing one of the Multicriteria

Decision Making (MCDM) Models that has been proven to be useful, specifically the fuzzy PROMETHEE approach.

- **2.1.2. Summary of the most prominent negative effects of amalgam.**

Risk of usage of the difficulty of extracting it from the teeth and the high cost of extracting it correctly is one of the negative effects of the amalgam, as shown in Figure 1 and Figure 2. In Figure 1, the X-ray shows the amount of toxic vapor that the patient inhales when extracting amalgam fillings from the teeth.

Figure 2 shows the special device that is used in cases of extracting amalgam fillings from the teeth. It also shows that the doctor and his assistant take all preventive measures, and the patient also has special pipettes for removing saliva and steam from the mouth.

Water pollution: Amalgam is a major source of water pollution, as it contains harmful chemicals that seep into and pollute ground and surface water.

Health Effects: Amalgam contains chemicals known as Bisphenol a (BPA), which is a toxic substance that may cause long-term health damage, such as hormonal disturbances and problems with the nervous and immune systems. Also bad in terms of aesthetics, as shown in Figure (3).

Environmental pollution: Amalgam is largely disposed of in landfills and incinerators, and this leads to the production of greenhouse gases and the addition of harmful chemicals to the environment.

Excessive consumption of resources: The production, storage, distribution, and disposal of amalgam require a lot of energy and material resources, and this leads to the consumption of more energy and natural resources.

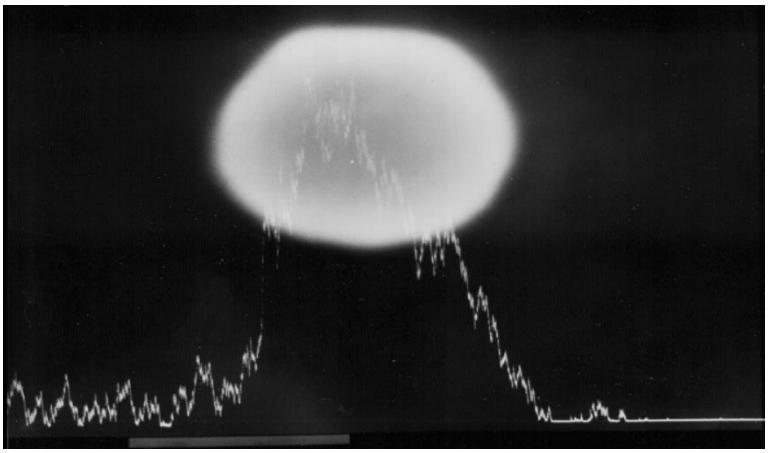

Figure (1). Amalgam gas in x-rays [25]

Figure 1 shows the amount of toxic vapor inhaled by the patient, the doctor, and the physician's assistant. It also spreads in the atmosphere, which affects the increase in the percentage of carbon in the atmosphere and increases air pollutants directly [16, 17, 18, 19].

Figure (2) Amalgam filling removal device[26]

Figure 2 shows the extent of the commitments taken by the doctor, his assistant, and the patient regarding the toxic emissions that come out of amalgam fillings, and the existing device is specially designed to withdraw all the vapor that comes out of the mouth and the remnants of saliva in the patient's mouth so that it does not cause any future problems for the patient.

Therefore, reducing the use of amalgam aims to stimulate the use of healthy and environmental friendly alternatives, and to reduce pollution and negative impacts on health and the environment [23, 24, 25, 26].

In the Figure 3, it is shown that the color of the amalgam differs from the color of the teeth, which gives a bad appearance to the teeth, and this shows the magnificence of the other modern fillings in the aesthetic form of the dental fillings, as it is shown in Figure 4.

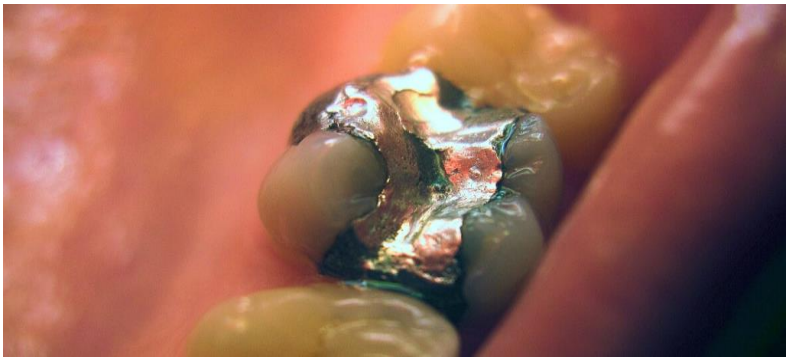

Figure (3) Amalgam filling color [20]

In Figure 3 an amalgam filling was used and the effect of amalgam on the aesthetic shape of the teeth is shown. Also, the rest of the healthy part of the tooth was affected by pigmentation significantly affected the change in the color of the tooth [20, 21].

Figure (4) The color of the composite filling [20]

In Figure 4, the color between composite fillings and the teeth is not clear, and this is what distinguishes composite fillings from amalgam. In addition, composite fillings have the same strength characteristics largely [20, 21].

- **2.2. Amalgam and its alternatives**

- **2.2.1 Filling alternatives**

A. Resin composite

A common restorative material used in routine dental procedures to replace decayed or missing tooth structures is resin composite [38, 39]. Compared to traditional dental amalgam, resin composite restorative materials are more aesthetically pleasing and functionally superior. The ability of resin composite to mimic the natural color of teeth is one of its key benefits. It is therefore the best option for filling cavities in parts of the mouth that are visible. The substance can be specially blended to match the color of the patient's real teeth and is offered in several hues. Further enhancing the look of a patient's smile, resin composite can also be utilized to reshape teeth or close spaces between them [40].

Another desirable feature that resin composite offers is bonding to tooth structure. As opposed to conventional metal fillings, which are held in place by mechanical retention, resin composites create a micromechanical and chemical link with the tooth, strengthening it and lowering the likelihood of additional decay or injury. Resin composite is a strong substance that can bear chewing and biting pressure. Resin composite is robust enough to withstand the typical forces exerted on teeth during regular use, although not as strong as metal fillings. Additionally, the material is easily replaceable or simply repaired intraorally. Their physical and visual qualities have advanced quickly since they were first introduced to the market [41]. In the past, amalgam was the material of choice for places that experienced significant occlusal stresses, and the use of resin composite was restricted to anterior teeth to satisfy cosmetic requirements. Resin composite is now consistently employed for direct and indirect restorative purposes on anterior and posterior teeth [42, 43].

A matrix of organic resin, usually bisphenol A-glycidyl methacrylate (Bis-GMA) or urethane dimethacrylate (UDMA), with inorganic fillers like silica, zirconia, or glass ceramics makes up resin composite materials. Typically, monomers, oligomers, and initiators make up the organic matrix of resin composites. While oligomers act as binders to keep the filler particles together, monomers are the components that make up the resin matrix. The three monomers bis-GMA, UDMA, and trimethylene glycol dimethacrylate (TEGDMA) are the most frequently used ones in resin composites. Being one of the most hydrophobic monomers and having a high molecular weight, bis-GMA is a great option for resin composite matrices. Since UDMA is less viscous than Bis-GMA, it is simpler to handle, and TEGDMA is frequently employed as a diluent to lessen the matrix's viscosity. To improve the mechanical properties of resin composites, inorganic fillers are commonly used. These fillers can have a spherical or asymmetrical shape and range in size from nanometers to micrometers. The most common filler in resin composites, silica, is usually coated with a silane coupling agent to improve the binding between the filler and the resin matrix. Additional fillers are used in resin composites. include zirconia, glass ceramics, and barium aluminate [44].

Many properties of these materials, including strength, wear resistance, and color stability, are largely determined by their composition. Fillers can be added to the resin matrix to increase the material's strength, stiffness, and wear resistance. On the other hand, too much filler makes the material less transparent and more opaque, which could detract from its attractiveness. The size, shape, and the distribution of the fillers can also affect the material's properties. For example, it has been shown that Nano-fillers, with their vast surface area and tiny size, improve the mechanical properties of resin composite [45].

The primary matrix elements in resin composites that have been utilized from the start and have not altered over time are BIS-GMA, TEGDEMA, and UDMA. To satisfy the specified qualities and enhance resin composite materials, filler particle technology has undergone extensive research and development. The main topics of research over the previous years were the size, type, volume, weight, polymerization, and optical characteristics of the filler particles [46].

Nano-hybrid resin composites are currently the most widely used resin-based restorative material because of their physical characteristics. The addition of various-sized filler particles increased the filler percentage in a nano-hybrid resin composite [47]. Flowable composite, on the other hand, has a lower filler percentage to promote fluidity and make it easier to penetrate deep and small sections of prepared cavities. The lower filler percentage of flowable composite sacrifices other qualities despite having improved flowability. Surface pre-reacted glass-ionomer (S-PRG) filler is another recently developed technology that has the capacity to release a variety of ions, including fluoride (F), borate (B), aluminum (Al), sodium (Na), silicate (Si), and strontium (Sr) ions, which have bioactive properties like promoting remineralization, halting demineralization, acid buffering, and anti-biofilm properties [48].

Resin composites can produce an outstanding cosmetic result, but maintaining the optical and physical stability of these materials continues to be a major difficulty in restorative dentistry [49]. The aesthetic evolution over time has been cited in various research studies as a serious worry. After being submerged in various liquids for 1, 14, or 30 days, resin composites from various manufacturers were examined for color changes, and the results of this retrospective investigation by Zdaş D et al. revealed significant color changes in all tested materials [50]. According to a distinct study by El-Rashidy AA et al., single-shade and multi-shade resin composites have color alterations following artificial aging and storage in a variety of media, such as artificial saliva, red wine, tea, and red wine [51].

The physical characteristics of resin composite are deteriorating, which jeopardizes the long-term success of fillings in restored teeth. Resin composite is intrinsically prone to absorbing water and dissolving over time in oral fluid. After being stored in water and synthetic saliva for a year, Alshali et al. examined the water sorption and solubility of both the traditional and bulk-fill resin composites; their results revealed that both tested materials exhibited these properties [52]. A universal resin composite and a silorane-based resin composite were found to be soluble in artificial saliva or mouthwash by Ozer et al. [53]. In addition to resins and fillers, composite materials also contain several other ingredients, such as pigments, silane coupling agents, initiators, and accelerators that may have an impact on the materials' physical and optical characteristics [54].

There is a constant need to assess and contrast the properties of new items because the market for dental materials is always changing and seeing the introduction of new materials [55]. These studies[55] included micro-hardness (MH), water sorption (WS), solubility (SL), color stability, and aging tests to assess the physical and optical stability of resin composite materials with various filler characteristics. The study's null hypothesis was that the investigated materials did not differ in terms of mass stability, color characteristics, or micro-hardness.

B. Gold fillings

Gold fillings are sometimes used as a substitute for traditional dental fillings made of other materials such as cement or amalgam. Gold fillings are distinguished by durability and long-term durability, and they resemble natural teeth more than other fillings, and they do not change over time and are not affected by external factors such as eating and drinking [56, 57]. However, placing gold fillings requires more treatment sessions and is more costly than placing regular dental fillings. Before applying gold fillings, the damaged portion of the tooth must be extracted, and any remaining decay must be completely cleansed out of the tooth. Next, a filling made of gold or an alloy containing gold is inserted into the damaged tooth. To fit the tooth's shape and keep food and bacteria out, the filling is bonded to the tooth using a unique adhesive [58, 59]. Although they are not the sole choice, gold fillings are a common treatment for teeth with significant deterioration. As an alternative to gold fillings, cement or resin fillings might be utilized. The patient's needs and the state of the damaged tooth will determine which filling is best. As with teeth filled with any other material, dental hygiene is crucial for teeth filled with gold. In addition to seeing the dentist on a regular basis to have the filling examined, its integrity confirmed, and any possible issues identified, you should clean your teeth thoroughly using toothpaste, dental floss, and brushing [60].

- **Gold fillings provide several benefits, such as:**

Durability and Long-Term Durability: If properly cared for, gold fillings are more durable and can last a very long time in good condition [56, 57].

Natural Response: The body naturally accepts gold fillings and does not react negatively to them [56–57].
Color harmony: Gold fillings look more natural than some other fillings because they closely match the color of the tooth [56–57].

Unaffected by outside influences: gold fillings do not deteriorate over time and can tolerate heat, cold, eating, and drinking better than some other fillings [56–57].

Extra Strength: Gold fillings for teeth with damage help make them stronger and less prone to cracking or crumbling [56–57].

Extreme precision: Gold fillings can be crafted with extreme precision and tailored to precisely match the contours of the tooth [56–57].

Endurance: Gold fillings are resilient enough to endure the continuous pressure that teeth experience when speaking and chewing [61, 62].

Gold fillings are a good option for people looking for a long-term solution to treat an infected tooth. But it is important to note that they are more expensive than some other fillings and require additional treatment sessions.
One of the earliest and most widely used treatments for dental decay is the use of gold fillings. Still, it has:

- **Some potential drawbacks include:**

Cost: Gold is one of the most expensive materials in the manufacture of fillings, and therefore the cost of filling is high compared to other alternatives [58].

Color: Gold fillings are distinguished by their bright golden color, which means that they may be clear and eye-catching in the front teeth, and therefore they are not desirable in some cases [58 ،59].

Allergies: Gold fillings may cause sensitivity in some people due to the interaction of gold with saliva, and this can cause irritation and pain in the teeth, and this happens in very few cases [61, 62, 63].

C. Glass Ionomer Cements

Glass ionomer cement (GICs) are aesthetically pleasing dental products with special qualities that make them effective as luting and restorative materials.

Dental materials called glass ionomer cement (GICs) are cosmetically appealing and have special qualities that make them effective luting and restorative materials [64,65]. This comprises biocompatibility, low toxicity, adherence to wet dental structures and base metals, anti-cariogenic qualities from fluoride release, thermal compatibility with tooth enamel, andante-cariogenic capabilities due to fluoride release. However, due to their poor mechanical performance, GICs have not been widely used in mechanically demanding situations. Their extensive usage in dentistry as a filler material in stress-bearing applications is constrained by poor mechanical qualities, including low fracture strength, toughness, and wear. Glass ionomer cement is frequently utilized as temporary filling materials in the posterior dental region. The need to fortify that cement has prompted an increase in research into approaches for strengthening or reinforcing [64, 65, 66].

Dental restorative materials have dominated the market over the past few decades in an ever-growing diversity. Up until the late 1970s, amalgam was employed for direct restorations, but today the primary standard materials for indirect restorations are gold and ceramics [64]. Due to its potential for allergic and hazardous reactions when mercury is released, amalgam use has been hotly debated [65]. Today's strong demand for tooth-colored and biocompatible restorations has had an impact on the decline in the use of amalgam fillings [64]. There are now many amalgam substitutes thanks to significant advancements in dentistry science [66]. The need for direct filling materials increased as a result of changes in restoration methods. The development

of adhesive techniques preserves sound tooth structure and is consistent with prophylactics' main tenets. In contrast to harmful, micromechanical constructed preparations with indirect restorative materials, direct filling methods are increasingly used to stabilize and protect tooth-hard structures [67].

In everyday dental practice, various direct restorative materials are used. In addition to amalgam, resin composites and glass-ionomer cement (GICs) are the most widely used. With a lengthy therapeutic history, amalgam is affordable and simple to use. However, there are drawbacks, including potential mercury toxicity and subpar aesthetics [65]. The substance with the most aesthetically pleasing physical qualities is resin composite [68]. They demonstrate their shortcomings by being a very expensive, time-consuming, and technique-dependent adhesive approach [69, 70]. Due to their capacity to alter their physical properties by modifying the powder/liquid ratio or chemical formulation, glass-ionomer cement can be used in a variety of clinical applications [71]. In terms of aesthetics, glass-ionomer cements are preferable to metallic restorations [72]. They also have strong biocompatibility and chemical adherence to mineralized tissue, and by containing fluorine, they offer an anti-cariogenic potential [73]. On the other hand, its extensive usage in dentistry as a filler material in stress-bearing areas is constrained by poor mechanical qualities, such as low fracture strength, toughness, and wear [74, 75]. Glass-ionomer cements are frequently employed as temporary filling materials in the posterior dental region [76]. The need to fortify those cements has prompted an increase in research on concepts for reinforcement. Incorporating second-phase ceramic, glass, or metal particles was the subject of several prior strategies [77]. Compounding reactive glass fibers has produced encouraging results [78, 79].

- **Advantages and Limitations of Glass Ionomer Cements:**

GIC are dental materials that are aesthetically pleasing from a clinical standpoint and have special qualities that make them effective as adhesive and restorative materials. These characteristics include adhesion to wet dental structures and base metals, anti-cariogenic effects brought on by the release of fluoride, thermal compatibility with tooth enamel, biocompatibility, and low toxicity. The poor mechanical strength and toughness, however, may lead to restrictions

in their applications [80]. The following are the advantages and disadvantages of Glass Ionomer Cements.

- **Advantages of Glass Ionomer Cements:**

Glass ionomer cement (GICs) has several advantages, including:

1) **Adhesion:** GICs have good adhesion to both enamel and dentin, which helps to create a strong bond between the tooth and the restoration [81, 82, 83, 84, 85].

2) **Release of fluoride:** Over time, GICs release ions of fluoride that help to regenerate the tooth structure and prevent dental decay [86, 87, 88].

3) **Chemical bonding:** Chemical bonding: GICs form a tight seal and stop microleakage by chemically attaching to the tooth structure [89, 90, 91, 92, 93].

4) **Biocompatibility:** GICs don't damage the surrounding tissues and are biocompatible [94, 95].

5) **Aesthetics:** Since some GICs resemble natural teeth, they are a good choice for restorations in areas of the mouth that are visible [79].

6) **Usability:** GICs can be installed quickly and are simple to handle [80].

7) **Versatility:** GICs can be used to restore teeth in several ways, such as by filling cavities, securing crowns and bridges, and fixing structural flaws in the teeth [96, 97].

All things considered, GICs are a dependable and adaptable restorative material that provides dental patients with several benefits.

- **Limitations of Glass Ionomer Cements:**

Glass ionomer cements (GICs) have some benefits, but they also have certain drawbacks and restrictions, such as:

Strength: When compared to other dental restorative materials like resin composites and ceramics, GICs are less strong [98, 99].

Wear resistance: Compared to other restorative materials, GICs are not as wear-resistant and may need to be replaced or repaired more frequently [100.101.102].

Sensitivity: Some patients may experience sensitivity to GICs, particularly in the initial days following implantation.

Technique sensitivity: When placing GICs, proper technique is essential, and any mistakes in placement can affect the material's performance [103].

Sensitivity to moisture: GICs, mechanical characteristics, and adhesion may be impacted by moisture during the setting process [103].

Limited indications: GICs may not be suitable for all restorative applications, especially those requiring high strength and wear resistance [104].

Overall, GICs are a useful restorative material with some limitations and disadvantages that should be considered when selecting the appropriate material for a specific clinical situation.

D. Gutta-percha filling for a root canal.

Research is constantly being done to develop better endodontic obturating materials than those currently available to meet biological requirements and produce predictable long-term treatment outcomes. The root canal has been filled with a variety of substances. The outcomes ranged from favorable to occasionally devastating. Out of all the investigated materials, gutta-percha (GP) has

proven to be the most durable, consistently performing well in clinical settings all around the world. No other material can currently be thought of as a potential replacement for GP in its different forms. As a result, GP might be regarded as the ideal material for obturation [105]. GP is a rare species of tropical plant's dried, coagulated sap. It was first produced from the Sapotaceae family of plants, which are common in Southeast Asia's Malay Peninsula. Perca, the name of the plant, means "percha sap" in Malay. The Malay Archipelago, Singapore, Indonesia, Sumatra, the Philippines, Brazil, South America, and other tropical nations are where you can find the trees the most frequently. These trees range in height from medium to tall (around 30 m), with trunk diameters up to 1 m. One of the factors contributing to its high cost is the fact that it is typically imported from Central and South America for use in dentistry [105].

A common dental material used in root canal therapy to fill and seal the root canal system is called gutta-percha. Since the middle of the 19th century, this organic polyisoprene substance has been utilized in dentistry. It is extracted from the sap of the Palaquium tree. Because gutta-percha comes in a range of sizes and forms, it can be customized to fit the contours of the canal that has been prepared. In addition, it comes in solid and thermoplastic forms that can be heated to a softer consistency to better adhere to the canal walls [105].

There are multiple steps involved in using gutta-percha in root canal therapy. To get rid of any damaged or infected tissue, the root canal must first be cleaned and shaped. After the canal is ready, any moisture left behind is dried using absorbent paper points. Next, a sealer is applied to the canal walls, such as a resin-based sealer or zinc oxide eugenol, to create a seal between the gutta-percha and the walls [106].

Next, gutta-percha is chosen in the right dimensions and form to fit the canal that has been prepared. Usually, heat is applied to soften it so that it can better cling to the canal walls. Next, using a carrier or hand plugger, the softened gutta-percha is inserted into the canal from the apex toward the orifice. Several tools are used to compact the gutta percha into the canal so that a tight and full fill is achieved. To produce a smooth and condensed filling, excess gutta-percha is then removed with heated instruments or rotary files [107].

To make sure the final gutta-percha filling is properly adapted and filling the canal, radiography is used to verify it. After the filling is finished, the tooth is restored with a crown or filling to keep it safe from further decay or damage [106].

In general, the dentist or endodontist doing the treatment needs to be skilled and experienced in using gutta-percha in root canal therapy. Because the gutta-percha filling forms a tight seal between the filling material and the canal walls, keeping bacteria and other microorganisms out of the system, placing the filling precisely is essential to the treatments success. Gutta-percha is a material that is widely used for root canal therapy because of its biocompatibility, thermal stability, and resistance to solvents and chemicals. These qualities make it an excellent choice for filling and sealing the root canal system.
Gutta-percha, like any dental material, has benefits and drawbacks. The characteristics, benefits, and drawbacks of gutta-percha will all be covered in this study.

- **Advantages of gutta-percha:**

Biocompatibility: The body can tolerate gutta-percha well because it is a non-toxic and non-irritating substance. To keep bacteria and other microorganisms out of the canal system, gutta-percha is used in root canal therapy to create a tight seal between the filling material and the canal walls. This aids in the healing of the surrounding tissues and helps to prevent reinfection [106].

Thermal stability: Gutta-percha does not conduct heat or cold as well as other materials due to its low thermal conductivity. For patients who are sensitive to temperature changes in their teeth, this makes it a good option [106, 107].

Chemical and solvent resistance: Gutta-percha is a material that works well for root canal fillings because it is chemical and solvent resistant [107].

Versatility: Gutta-percha can be shaped to fit the contours of the prepared canal because it comes in a range of sizes and forms. In addition, it comes in solid and thermoplastic forms that can be heated to a softer consistency to better adhere to the canal walls [108].

- **Limitations of gutta-percha:**

Restricted strength: When compared to other dental materials like resin composites and ceramics, gutta-percha is less strong [109].

Restricted wear resistance: Gutta-percha may need to be replaced or repaired more frequently because it is not as wear-resistant as other restorative materials [109].

Sensitivity: Some patients may experience sensitivity to gutta-percha, particularly in the initial days following implantation [110].

Technique sensitivity: When placing gutta-percha, proper technique is essential, and any mistakes in placement could negatively impact the material's performance [110].

Sensitivity to moisture: During the setting process, gutta-percha is susceptible to moisture, which may have an impact on its adhesion and mechanical qualities [110].

In summary, gutta percha is a dependable and adaptable material with several benefits for root canal therapy. It is the best choice for filling and sealing the root canal system because of its biocompatibility, thermal stability, and resistance to solvents and chemicals. When choosing the right material for a particular clinical scenario, one should consider its limitations regarding strength and wear resistance, as well as its sensitivity to moisture and technique sensitivity.

CHAPTER III

3. Methodology:

3.1. The basis of the study

3.1.1 Sources of Study

We performed a search on 5 databases (PubMed, SCOPUS, Web of Science, Google Scholar, and Scientific Information Database (SID) using the keywords amalgam, composite, dental implants, dental fillings, and tooth decay. The results were retrieved in the last ten years until April 29, 2023, and the search revealed more than 8 million results, including articles, scientific research, and doctoral theses.

3.1.2 Criteria for Research Inclusions:

The criteria on which the research relied were the comparisons between the materials of dental fillings, the clarification of the advantages and limitations of each material in all respects, and the comparison of these materials with each other in order to distinguish and differentiate between them. Also, reliance was placed on individual randomized trials that were conducted in clinics as well as experimental trials that were conducted by a group of scientists to study a specific type of material. Also research inclusions were to rely on studies that were conducted in the same way, which is analytical statistics, in addition to that, reliance on studies that were conducted in some remote areas such as Africa and the Middle East from 2000 to 2019.

Article information was obtained from some medical research and practical experiments conducted on some patients. We identified more than 1245 studies that met the criteria we want, but in the end, 12 studies were highly relied upon these studies included randomized trials, systematic reviews, scientific studies, and individual experiences.

3.1.3 Criteria for Elimination

Studies that are published in other languages that are not English were eliminated. Articles and studies older than 10 years were also canceled, in addition to canceling messages and editors' comments.

3.2. Multicriteria Decision-Making (MCDM) Models

The MCDM technique [111] concentrates on the decisions made when deciding between alternatives based on the desired study criteria. In order to properly inform, clarify, justify, and evaluate judgments, the MCDM technique considers a theoretical approach to dealing with decision-making difficulties that are centered on selecting actions that include solving various types of problems [111]. An MCDM technique called PROMETHEE aids decision-makers in conducting accurate analytical investigations [112], while Fuzy PROMETHEE aids particularly when the data is qualitative and vague, in order to help them offer the best options in an unclear circumstance [111], [113]. In this case, fuzzy logic enables decision-makers considering vague data in their analysis [114].

3.2.1. Fuzzy PROMETHEE and its Applications

Fuzzy logic and PROMETHEE approaches, both are having a variety of uses in the disciplines of engineering, math, sociology, medicine, etc. [111]. Fuzzy logic depends on human reasoning that looks at ambiguous facts from a range of possible outcomes [115]. Even without exact and precise reasoning, it offers an acceptable type of reasoning that aids in resolving uncertainty-related issues. Fuzzy algorithms produce a neutral value between distorted YES and NO responses.

Unlike machines, it considers human thinking between true and false or between yes and no by including partial possibilities between those two statements. The fuzzy logic was created by Lofti Zadeh [116] using expansion of the Boolean logic. Absolute Incorrectness, Incorrectness, Slight Inaccuracy, Slight Inaccuracy, Correctness, Absolute Correctness, or Certainly Yes, Possibly

Yes, Cannot Say, Possibly No, Certainly No are some statements that can be considered in fuzzy logic compared to Boolean logic [116]. In order to create plausible facts between the answers YES and NO, Lofti Zadeh [115] developed the fuzzy logic. Fuzzy PROMETHEE uses possible inputs and also sometimes feelings to get a clear ranking result [115]. Therefore, Fuzzy PROMETHEE is a suggested system that takes into account data with a range of sizes and capacities, from micro to big networked control systems for ranking the alternatives under various criteria [115]. According to Zadeh's 1996 analysis, fuzzy logic is preferable to Bayesian logic, often known as predictable logic [116]. Numerous researchers harassed the fuzzy PROMETHEE technique because of its adaptability and usefulness in comparing and assessing options based on determined parameters or criteria to reach a trustworthy and helpful conclusion and results. In a study by [111], the authors used fuzzy PROMETHEE to assess the Covid-19 therapy choices. The study's findings led to the conclusion that the fuzzy PROMETHEE methodology is an effective method for weighing criteria of the alternatives and determining them when there is uncertainty. Another study by [117] used the fuzzy PROMETHEE to evaluate the efficacy of AuNPs with that of other nanomedicines in the treatment of cancer. According to the study's findings, the fuzzy PROMETHEE technique can be used to compare, assess, and evaluate various sets of options in order to produce a conclusion that can be relied upon scientifically [117]. [118] used the fuzzy PROMETHEE method to evaluate the various treatment options for spinal cord tumors and came to the conclusion that the method is successful for producing an accurate finding when comparing, ranking, and evaluating a variety of options in this specific subject [119].

3.2.2. Application of fuzzy PROMETHEE in the selection of dental fillings

This study applied the fuzzy PROMETHEE technique to rank, evaluate, and compare dental materials that are used in dental fillings, which include amalgam, composite, gold, gutta-percha, and glass ionomer cements. These materials are used in dental fillings either in the treatment of caries or in the treatment of tooth roots. The triangle linguistic fuzzy scale was used to assess the linguistic values in the study and define the selection criteria weights as demonstrated in Table 1.

In this study, triangular linguistic fuzzy scale represents the linguistic terms of very high (VH), high (H), moderate (M), low (L), and very low (VL), with their accompanying scaling of fuzzy

numbers/sets. The materials used in dental fillings treatment processes were explained and determined using the triangular linguistic fuzzy scale. The following factors were considered when applying the analysis of the performance of the dental filling materials: life length (in years), cost (in $), strength, aesthetics, number of sessions, patient satisfaction, and allergy risk. These factors were taken into account after extensive studies and taking into account the priorities of doctors and researchers in the field of dentistry. For the linguistic variables, the fuzzy numbers were assigned, and the Yager index was also used to defuzzify the fuzzy values. Then, the Gaussian preference function is used for the PROMETHEE approach.

Table 1: Triangular Linguistic Fuzzy Scale

Linguistic Scale	**Triangular Fuzzy Scale**
Very High (VH)	(0.75, 1, 1)
High (H)	(0.50, 0.75, 1)
Medium (M)	(0.25, 0.50, 0.75)
Low (L)	(0, 0.25, 0.50)
Very Low (VL)	(0, 0, 0.25)

3.3. Selecting the Criteria/Parameters of the Dental Filling Materials

This section explains the justification for assigning a weight of importance to each criterion of the dental filling materials based on the parameters found through literature searches and expert knowledge.

Life length (in years): The periods of holding the dental fillings vary with the factors of change that occur on the teeth. Some fillings last from 10 to 15 years, such as amalgam [22, 23], and others from 15 to 18 years, such as gold, taking into account periodic visits to the doctor. Also, there are some fillings that last for a shorter period, such as glass fillings from 3 to 5 years [89, 90]. It is often used for children and composite fillings. It lasts for a period ranging from 7 to 10 years. This was explained above [39, 40].

Cost: The cost is one of the main reasons for the patient to take the appropriate decision in testing the appropriate filling for them, because some dental fillings are very expensive, which the patient may not be able to afford. Amalgam fillings are the least expensive fillings [21], and gold fillings are the most expensive dental fillings [60, 61].

Allergy risk: The materials used vary in terms of limits and negative effects, as some materials have harmful effects on health and the environment, such as amalgam, and there are high-cost materials such as gold, and there are weak materials that cannot withstand pressure, such as glass fillings. Examples of the risks of allergy to the use of amalgam include concerns about its use of mercury (Hg), which is one of the important components of amalgam, as it makes up approximately 50% of body weight. It appears that toxic mercury ions are released from the amalgam that crystallized in the form of mercury vapors, which are toxic vapors that may cause diseases, lung allergies, and stomach poisoning if swallowed [20, 21]. Also Gutta-percha can cause sensitivity in some patients, especially in the first few days after placement [110]. As for the rest of the materials, they were explained in detail previously.

Strength: The positive effects differ in each material of dental fillings from others. For example, gold fillings are considered one of the best dental fillings, as they have an aesthetic shape, a long period of time, and withstand pressure, but dentists do not use them much due to its very high price, compared to composite, which is considered the best solution for all teeth due to its distinctive qualities of aesthetic shape, multi-use, multi-color, and other characteristics, in addition to other materials and their different use For example, composite fillings can break if exposed to high pressure [41], as can glass ionomer cement fillings [76]. As for gold and amalgam fillings, they can withstand pressure and are very strong [14, 56, 57].

Aesthetics: Dental fillings differ from each other in terms of aesthetics, as amalgam is gray or silver in color, while gold is golden in color, and it is not preferable to use it in the front teeth of each of them because it does not reflect a suitable aesthetic shape due to its difference from the original teeth. Glass Ionomer Cements and composites are characterized by being similar to the

color of the teeth. And some of the materials used in dental fillings are not visible to the eye because they are inside the teeth, such as gutta percha [20, 39, 81, 106].

Number of the session: The duration of treatment varies from one patient to another according to the teeth affected by decay and the materials used in filling the teeth, as the front teeth take a shorter treatment period than the back fillings or nerve fillings because the posterior dental fillings and nerve fillings need two or three visits to the dentist. As for front teeth, you need one visit to the doctor [40,58,59,77,95 ,94].

Patient satisfaction: In the past, the use of amalgam and silver fillings was successful for the patient because it was important at that time because there was no other alternative to treat tooth decay. But with the progress of science and the presence of modern dental fillings that have the same natural color as the teeth, the presence of amalgam fillings in the mouth became the patient represents dissatisfaction because it differs from the color of the teeth. Patient satisfaction is one of the main reasons for success. The development of dental fillings is one of the reasons why the patient does not feel different from others after treatment, and this increases the chances of using modern fillings such as composites and glass ionomer cement.
The data collected in order to compare the dental filling materials and provide detailed information on various important features is provided in Table 2.

Table 2. A group of materials used in dental fillings with their corresponding parameters

Material& Criteria	Life length years	Cost ($)	Strength	Aesthetics	Number of the session	Patient Satisfaction	Allergies Risk Yes / No
Importance Weight/Scenario 1	VH	M	VH	VH	L	H	H
Importance Weight/Scenario 2	-	-	VH	VH	L	H	H
Aim	Max	Min	Max	Max	Min	Max	Min

Amalgam	10-15 Years [H] [22-23]	-50 250$ [L] [21]	VH [14]	VL [20,21]	2-3 times	L	YES
Gold	10-20 Years [VH] [61-62]	500-1500$ [VH] [61-62-63]	VH [56-57]	M [60-61-62]	2-3 times [58-59]	H [60]	YES [61-63-62]
Resin composite	5-8 Years [M] [41]	100-400$ [M] [40-41]	M [41]	VH [40- 41]	1-2 times [40]	VH [52 - 41]	NO [42-43]
Glass ionomer cement	4-7 years [L] [76-77]	100-300$ [M] [76-77-78]	L [76]	VH [76]	1 time [77]	VH [68]	Yes [83]
Gutta-percha	10-15 years [H] [93-94-]	500-1000$ [H] [93]	H [105]	Non placed inside the roots [105]	2-3 times [94-95]	VH [105-106]	NO [93]

(Very high (VH), high (H), moderate (M), low (L), very low (VL))

CHAPTER IV

4. Results and Discussion

4.1 Results

In this study two analysis carried and results obtained based on the different scenarios. The cost and the life length criteria are eliminated from the data and the materials ranked accordingly in Scenario 2. Table 4 shows the fuzzy PROMETHEE ranking results based on the full data (based on Scenario 1) which is considered and provided in Table 2.

The cost and the life length criteria are eliminated from the data and the materials ranked accordingly in scenario 2. Table 5 shows the fuzzy PROMETHEE ranking results based on Scenario 2.

In Scenario 1, Amalgam ranked as the first alternative with a 0.1554 net flow value. And it is followed by Gutta-Percha, with a 0.0270 net flow value.

In Scenario 2, Resin composite ranked as the first alternative with a 0.0143 net flow value. And it is followed by Gutta-Percha, with a 0.0108 net flow value. To summarize, amalgam is the most widespread because of its great use in the past and also because of its use in remote countries because of the low cost and the advantages that distinguish amalgam, such as durability. Resin is the most used material in developed countries, as it is characterized by aesthetics and a white color gradient to suit all tooth colors. It is also characterized by hardness and longevity.

Table (4): The complete ranking of dental fillings for scenario 1 by fuzzy PROMETHEE

Rank	Alternatives	Phi	Phi+	Phi-
1	Amalgam	0,1554	0,1840	0,0287
2	Gutta-percha	0,0270	0,1176	0,0906
3	Gold	0,0127	0,1202	0,1075
4	Glass ionomer cement	-0,0833	0,0826	0,1659
5	Resin composite	-0,1118	0,0638	0,1756

Table (5): The complete ranking of dental fillings for scenario 2 by fuzzy PROMETHEE

Rank	Alternatives	Phi	Phi+	Phi-
1	Resin composite	0,0143	0,0160	0,0017
2	Gutta-percha	0,0108	0,0140	0,0032
3	Glass ionomer cement	0,0009	0,0108	0,0099
4	Gold	-0,0071	0,0037	0,0108
5	Amalgam	-0,0189	0,0023	0,0212

Figure 5 and Figure 6 displays the positive and negative features of the materials that are used in dental fillings based on selected importance weights for the criteria, specified as Scenario 1 and Scenario 2 sequentially. The criteria specified above 0 level shows the positive side of the materials and while the criteria specified below 0 level shows the negative side.

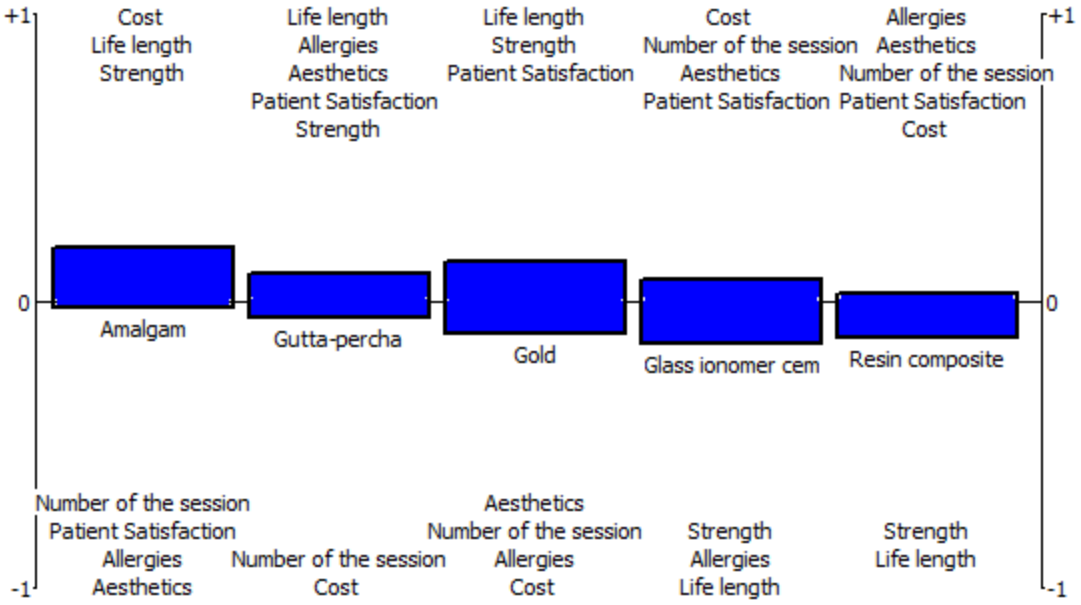

Figure (5) The PROMETHEE evaluation result for scenario 1

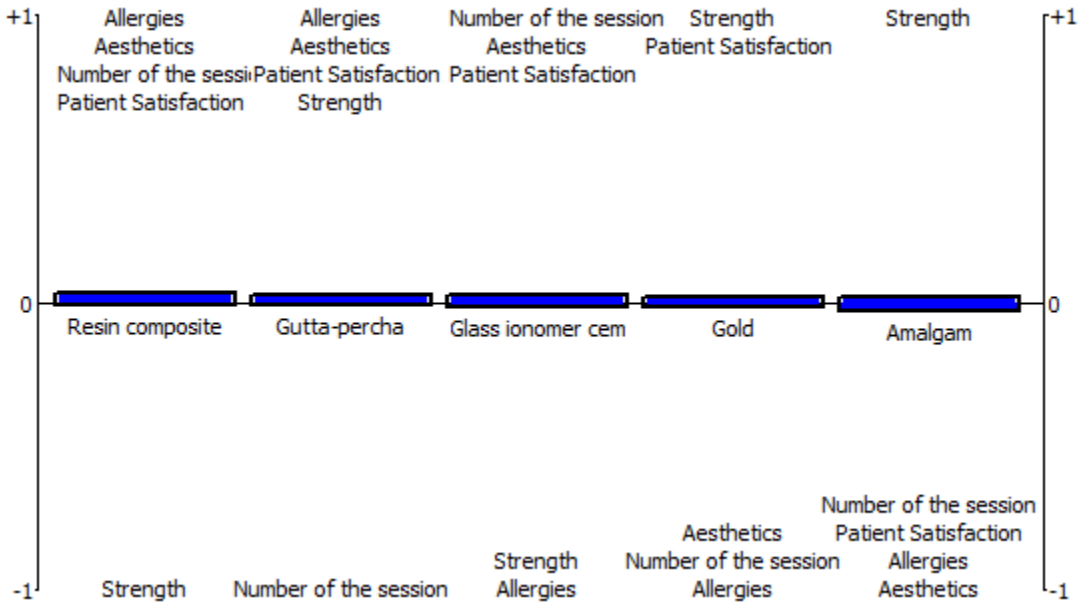

Figure (6) The PROMETHEE evaluation result for scenario 2

The PROMETHEE network figures are provided in Figure 7 and Figure 8 based on Scenario 1 and Scenario 2 respectively. Those figures show the magnitude of the difference between the alternatives. Figure 8 shows that even though resin composite is ranked as the first material, the second-ranked material, gutta-percha, has no big difference compared to the first one.

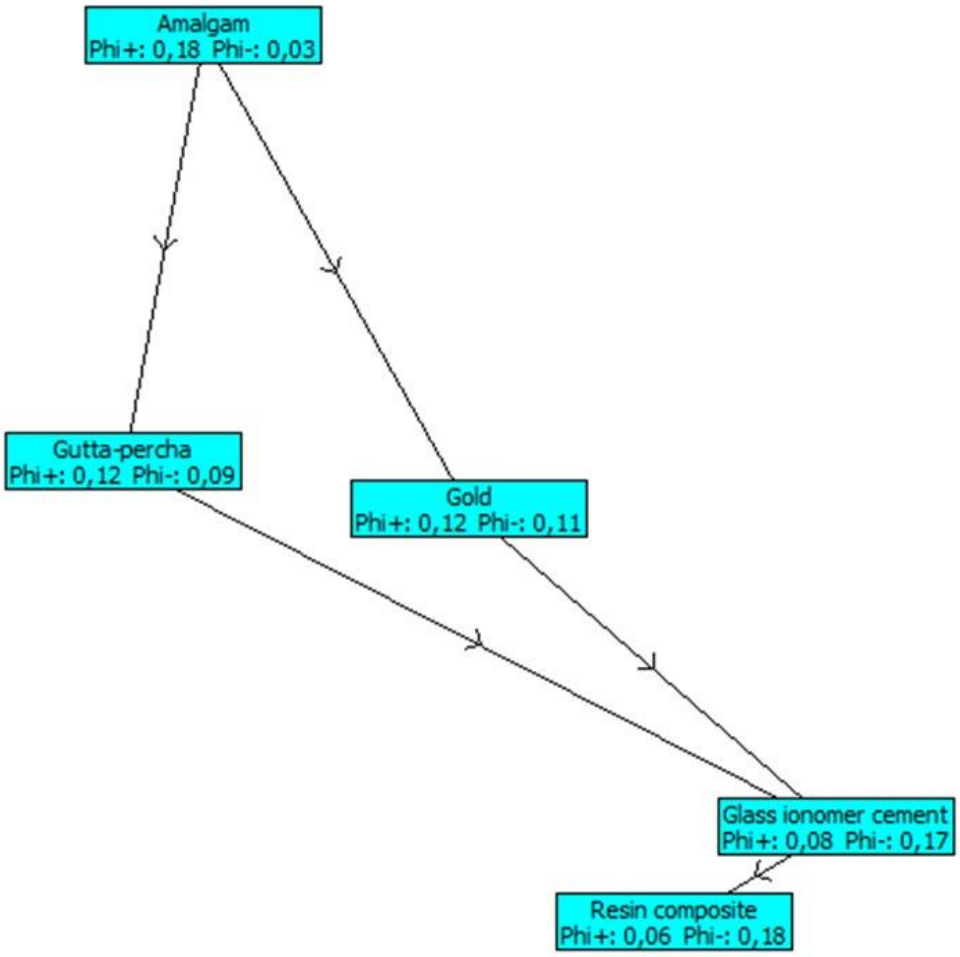

Figure (7) PROMETHEE Network Figure for scenario 1

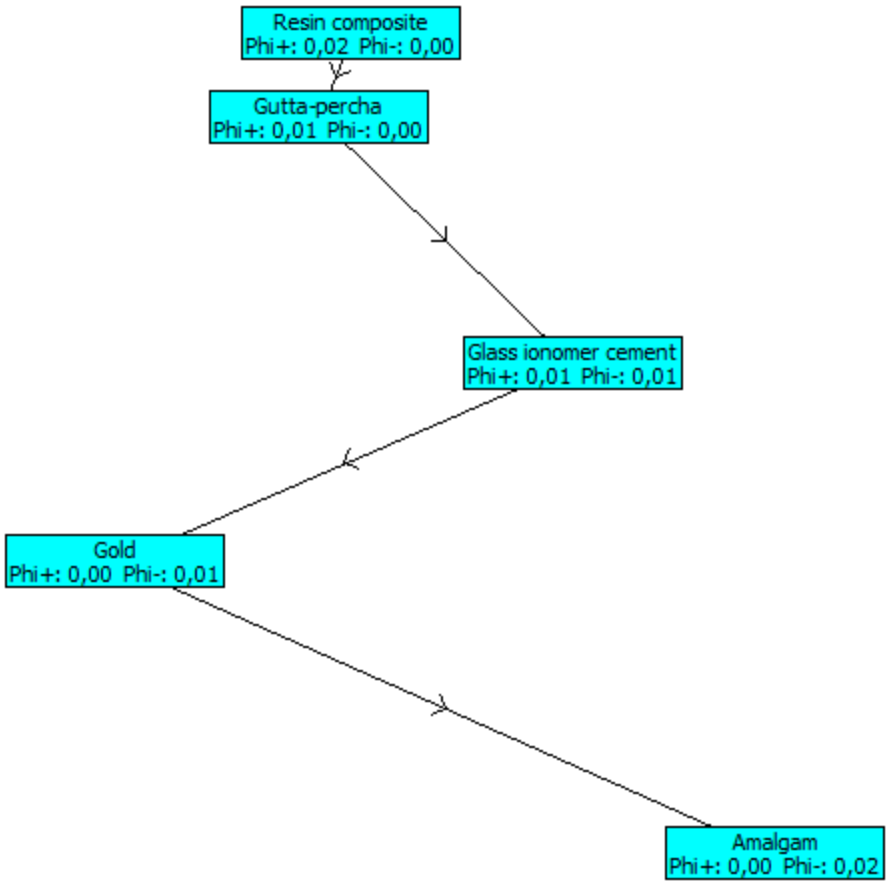

Figure (8) PROMETHEE Network Figure for scenario 2

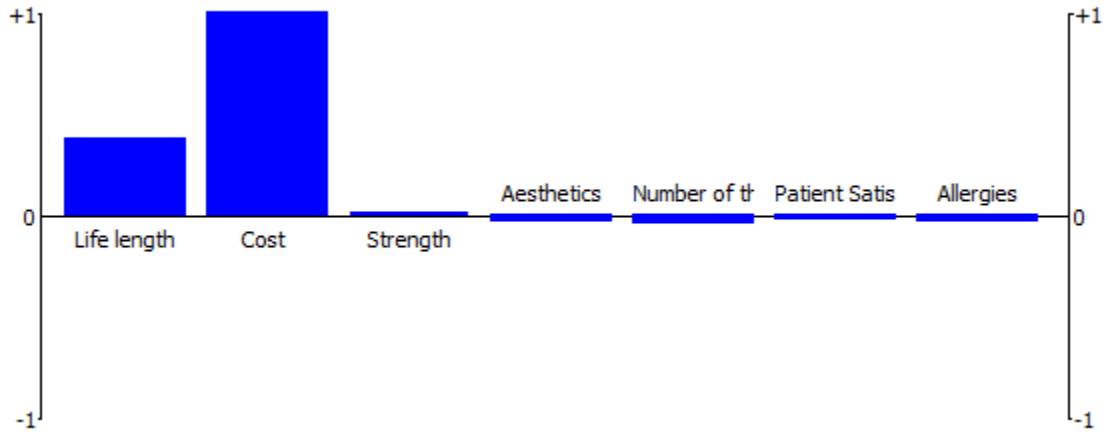

Figure (9) Amalgam action profile

Figure 9 shows that the benefits of the amalgam are shown in both cost and life length.

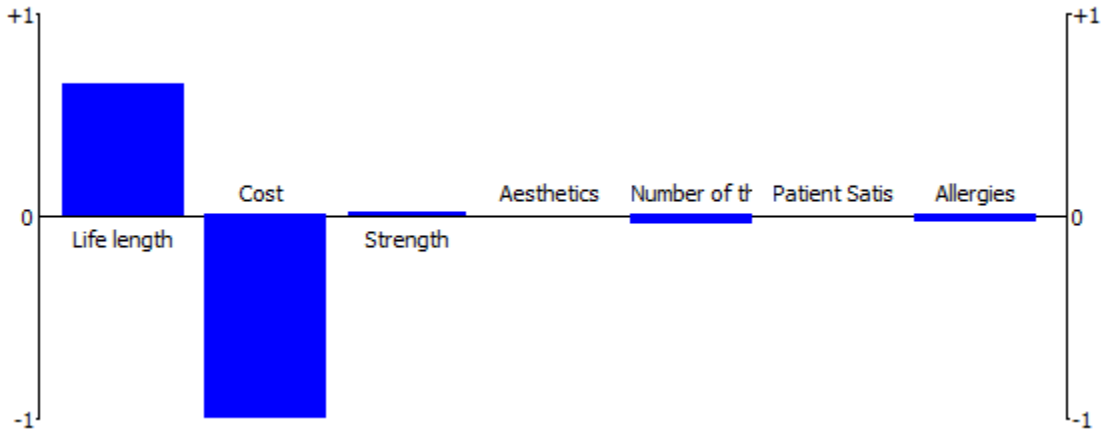

Figure (10) Gold action profile

Figure 10 shows that the benefits of the gold appears in life length and limits in cost.

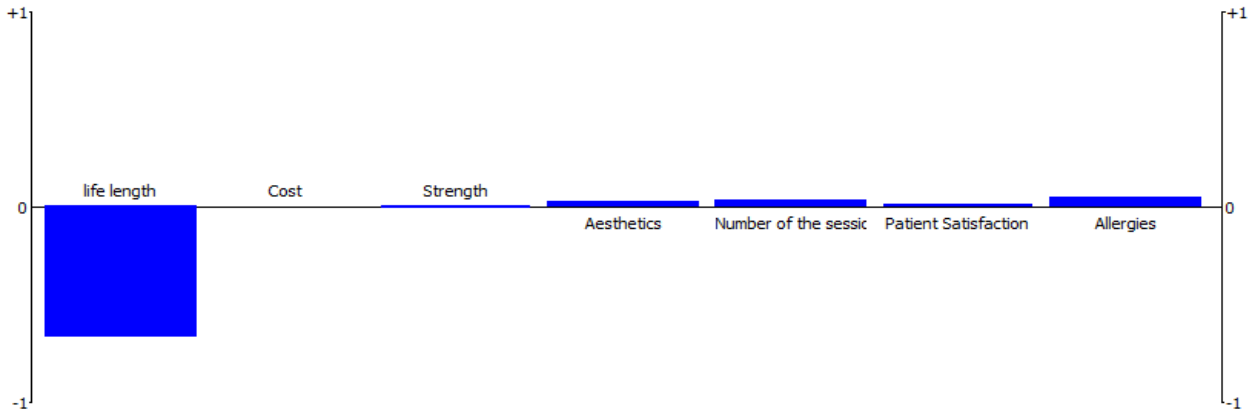

Figure (11) Resin composite action profile

Figure 11 shows that the limits of the resin composite appear in the life length.

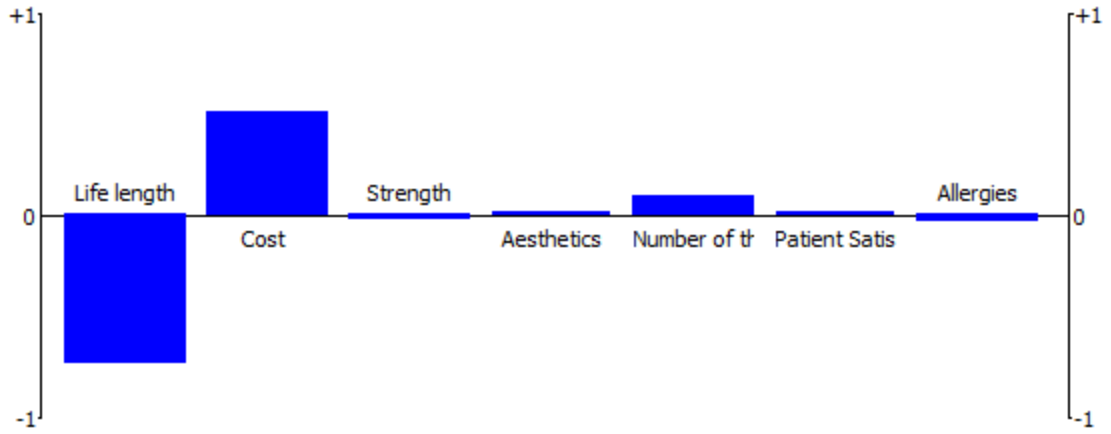

Figure (12) Glass ionomer cement action profile

Figure 12 shows that the limits of the glass ionomer appear in the life length and the advantage in the low price.

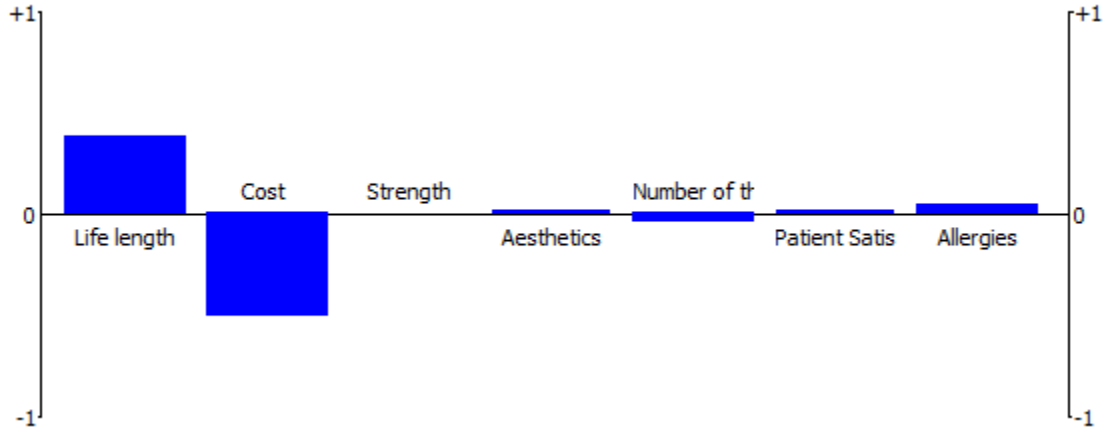

Figure (13) Gutta-percha action profile

Figure 13 shows that the advantage of the gutta-percha appears in the life length and limits in the higher price.

CHAPTER V

Conclusion

This study has shown that the fuzzy PROMETHEE technique can be deployed to rank, compare, and evaluate the materials used in dental fillings. The most common aspects of material usage are life length, strength, aesthetics, number of sessions, and allergy risk. These standards were determined by experts in the field of dentistry. The fuzzy PROMETHEE approach can be deployed to identify the most effective materials in dental fillings. Most of the materials used in fillings are of high quality or efficiency, but sometimes the lack of these materials due to the poor economic conditions of the countries leads to the use of dental fillings that are of lower quality and pose a risk to patient health. This thesis demonstrated that the most effective materials among dental filling materials can be identified, as the materials can be classified and evaluated intelligently and systematically by collecting important relevant information.

Based on the first scenario (considering all of the criteria: cost, life length, strength, patient satisfaction, aesthetics, number of sessions, and allergy risk), using the fuzzy PROMETHEE approach indicated that the first-ranked material used in dental fillings is amalgam with a net flow value of 0,1554. It is followed by gutta percha with a net flow value of 0,0270, and then gold with a net flow value of 0,0127. Glass ionomer cement with a net flow value of -0,0833 ranked fourth, and in the end, resin composite with a net flow value of -0,1118 ranked fifth.

However, with the deletion of two criteria (price and life length), it was observed that the results differed greatly, as resin composite ranked as first alternative with a net flow value of 0.0143. Then gutta-percha ranked second that with a net flow value of 0.0108, which is the same rank in the first scenario. And then glass ionomer cement ranked as third with a net flow value of 0.0009, followed by gold with a net flow value of -0.0071. Finally amalgam with a net flow value of -0.0189 ranked as a fifth alternative.

The advantage of fuzzy PROMETHEE is that it can process many different vague features of the alternatives for their evaluation. Using fuzzy PROMETHEE, we could have a clear picture of the dental fillings, which has increased the burden on doctors and students to raise awareness among patients so that they make the best choices for their patients safety in the future. Amalgam has

been used as a dental filling despite the existence of better alternatives, but this is due to reasons related to the patient, the doctor, and the economic situation. With alternatives of the same quality and price, it is possible that the percentage of amalgam use will change in the future. Also, doctors have an important role in increasing patient awareness. It can be concluded from the study that the fuzzy PROMETHEE approach can successfully be applied for the performance evaluation of dental filling materials.

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Appendix A

Curriculum Vitae

Amar Mohamed

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ammar.saad1962@gmail.com

Date of Birth/Place: 28 December 1994

Language

Arabic (native)

English (fluent in speaking, and writing)

Turkish (basic in speaking)

Education

Master of Science, Biomedical Engineering, 2021-2024. Near East University, Faculty of Engineering, Mathematics Department, Nicosia, Cyprus. Masters' thesis title: “Dental Fillings Materials and Their Evaluation by Using Fuzzy Promethee Method and Clarifying The Risk Factors Of Amalgam.”.

Bachelor of Science, Biomedical Engineering, 2017-2021. Near East University, Faculty of Engineering, Mathematics Department, Nicosia, Cyprus.

Job Experiences

Salesmen in Rafal Medical Corporation -01/12/2014 – 01/08/2017 – Najran, Saudi Arabia

Research:

Lab-On-A-Chip Devices for Neural Tissue Engineering

analytical unite decision-making in health and medicine.

Projects:

Wheelchair controlled by the brain.

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Appendix B

Similarity Report