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Potential of Biomaterial as a Medical Fiber using Electrospinning Method: A Review

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Abstract

With the growing demand for wound care worldwide, the quality of medical equipment continues to advance, driven by the increasing need for more effective and efficient treatment solutions. The rapid growth of the healthcare industry, coupled with technological advancements, has led to significant improvements in wound management techniques. However, despite these advancements, medical fibers remain the primary tools used by healthcare professionals for wound closure due to their versatility, biocompatibility, and effectiveness in promoting healing. One of the most promising techniques for fabricating medical fibers is electrospinning, a widely recognized method for producing ultrafine fibers from a broad range of starting materials, including synthetic and natural polymers. Among the various fiber production techniques available today, electrospinning stands out as a superior method due to its ability to generate fibers with diameters ranging from nanometers to microns. This process is not only efficient and relatively simple but also offers precise control over fiber morphology, porosity, and mechanical properties. Such characteristics make electrospun fibers highly suitable for biomedical applications, particularly in tissue engineering, drug delivery systems, and wound healing. In recent years, the use of natural polymers as biomaterials for electrospinning has gained significant attention, as they offer excellent biocompatibility, biodegradability, and minimal risk of adverse reactions. Polymers such as alginate, chitosan, gelatin, and glucomannan have been extensively studied for their potential in medical applications. Their inherent bioactive properties contribute to enhanced cell adhesion, proliferation, and overall wound healing efficiency. This paper aims to provide a comprehensive review of the latest advances in the potential of biomaterials as fibers—particularly focusing on their structural characteristics, functional modifications, and research developments. Additionally, the discussion will explore their applications in modern medicine and how their properties can be optimized to meet evolving medical needs.

Keywords: Biomaterial, fiber, medical field, alginate, chitosan, gelatin, electro spinning.

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1. Introduction

The publication 'Technical Textiles and Industrial Nonwovens: World Market Forecast to 2010' by David Rigby Associates (DRA) posits that the global market for technical textiles and industrial nonwovens is projected to grow at a rate of 3.5% annually from 1995 to 2005, followed by a 3.8% annual increase from 2005 to 2010. This growth is expected to culminate in a volume of 23.8 million tonnes, corresponding to a market value of $126 billion by the year 2010. In the year 2000, the global consumption of textile materials for the production of medical and hygiene products reached over 1.5 million tonnes, with a valuation of US$5.4 billion. This is expected to increase in volume terms by 4.5% per year. The year to 2010 reached 2.4 million tons with a value of US$8.2 billion. The medical fiber market currently generates over $1.3 billion annually. This development aims to meet the increasing consumer demand, along with growing population, environmental problems, and energy crises.

The role of wound healing is very important considering the incidence of wounds and the number of infections due to wounds from small to deadly scale. The incidence of injuries increasing every year, both acute and chronic wounds. Acute wounds occur as a result of abrasions, avulsions, burns, cuts, and punctures, and healing time depends on size and number of layers of skin affected [1]. Medical fibres serve as fundamental components of bio textiles. Typically, these materials are produced from a variety of natural polymers, including cellulose, collagen, gelatine, chitin, chitosan, silk, and alginate, alongside synthetic polymers such as polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL), polypropylene (PP), and polythene terephthalate (PET) [2]. Although most fiber production is still using synthetic polymers, nowadays use of natural polymers (biomaterials) is starting to get the spotlight. The term 'biomaterial' derives from the Greek words 'bios,' signifying all that pertains to life, and 'materials,' which refers to substances or components possessing specific properties utilised as inputs in production or manufacturing processes.

A biomaterial may be characterised as a substance, whether derived from nature or synthesised by humans, that comprises either wholly or partially a living or biomedical structural device. Biomaterials are fundamentally employed and modified for various medical applications [3]. The main requirement biomaterial for medical used is non-toxic, non-allergenic, sterile, strong, tenacious, durable, and suitable for nature (biocompatibility). It can also be used both inside and outside the body (intracorporeal or extracorporeal) in the biological environment as a medical device to improve the health and condition of the patient [4]. This review is mainly focused on how much potential of the biomaterial as a fiber especially alginate, chitosan, gelatin, and glucomannan using an electro spinning method, through the natural characteristics of the fiber, modifications and looking at the research and the development prospects of this fiber to fulfil the medical needs.

2. Medical Fiber

Fibres constitute a fundamental component of textile materials, encompassing filaments, yarns, and various fabric structures derived from both natural and synthetic fibrous substances. Fibre materials exhibit a variety of unique properties, such as strength, stretch ability, flexibility, breathability, and the potential for three-dimensional configurations, differences in fibre length, fineness, cross-sectional shapes, and absorbency. These characteristics render them particularly appropriate for medical applications. Nonetheless, particular designs, attributes, or an amalgamation of characteristics may be necessary for specific applications. Consequently, enhancing a product's characteristics based on its intended application becomes essential. Features such as high surface area, excellent absorbency, and diverse product forms have paved the way for the development of more advanced and innovative products in the medical textile industry [5]. The current landscape of medical fibre products encompasses a wide array of variations in unit value and performance. This diversity spans from fundamental sewing threads and basic wound closures to medical protective garments, extending to intricately designed scaffolding for tissue regeneration or replacement, ranging from the nano to macro scale [2]. Figure 1 illustrates the procedure involved in the production of medical textiles derived from polymers.

Fibres derived from either natural or synthetic polymers undergo a processing phase to be transformed into yarns, which are subsequently woven or knitted to produce fabrics tailored for particular applications.To efficiently produce fibrous materials, a polymer must meet specific criteria, limiting the number of polymers suitable for manufacturing medical fabrics. These polymers must possess the ability to dissolve or melt for the purpose of extrusion, and their molecular chains ought to be characterised by linearity, length, flexibility, and the capacity for orientation and crystallisation [6-8]. An ideal textile material for medical applications must fulfil specific criteria to promote healing, reduce side effects, and improve patient comfort. The essential characteristics encompass biocompatibility, resistance to alkalis, acids, and microorganisms, alongside remarkable dimensional stability, elasticity, and the absence of contaminants or impurities. Additionally, they exhibit suitable absorption or repellency and optimal air permeability. The structure and properties of polymeric materials, which constitute the fundamental elements of medical textiles, play a crucial role in determining the biodegradability, biocompatibility, absorbency, antibacterial effectiveness, and overall functionality of the resultant medical textile products [9].

3. Medical Fiber Manufacturing Methods

Many methods have been developed for producing fibers from synthetic polymers, most notably, including melt extrusion, wet spinning, electro spinning, centrifugal spinning etc [10]. Melt extrusion is a method in which molten polymer is applied to the build platform, facilitating the creation of three-dimensional objects by regulating the x-y movement of the extruder and the z (height) positioning of the build platform. The outcome of this process is a product that occupies a state intermediate between semi-solid and solid preparations. This process has the potential for medicinal applications including oral, parenteral, and topical. The disadvantage of this process is the high sensitivity to shear forces and temperature, has a short residence time compared to other conventional processes, and cannot be used for various types of sensitive molecules such as peptides and proteins [11]. Wet spinning is a process where polymer is dissolved in suitable solvent and the polymer solution is extruded through the spinner into a liquid bath containing low molecular weight chemicals. Wet spinning process only can apply to polymers which do not melt and dissolve only in non-volatile or thermally unstable solvents [12]. Centrifugal spinning involves ejection of a polymer solution or melt from a rotating spinning head. When centrifugal force surpasses surface tension of polymer liquid, polymer jet experiences a stretching process, ultimately leading to its deposition on collector, where it solidifies into nanofibers.

Centrifugal spinning possesses ability to produce various forms of nanofibers, including polymer nanofibers, carbon nanofibers, & ceramic nanofibers, among others. The study of centrifugal spinning has primarily focused on its applications in tissue engineering, drug delivery, and energy sectors [13]. Electrospinning is a fiber manufacturing technique by utilizing electrostatic forces as a driving force for a polymer solution when injected from a needle (spinneret) into a collector. The emission of solution will thin out and dry with the evaporation of solvent, until a dense web of fibers formed. From these various methods, electrospinning method is a versatile method that is effective and efficient, and quite simple in its application process, but can produce nanofibers with smallest size range from 0.04 to 2 microns [14]. Electrospinning can obtain very fine fibers and offers certain advantages compared to conventional fibers, having a very large surface area, due to diameter of nanoscaled (1 nm = 10^{-9}m) [15-16]. Figure 2 illustrates essential elements of an electrospinning apparatus, which include: (1) a capillary tube fitted with a need2le or syringe, (2) a high-voltage power supply, and (3) a collector or target. Electrical connections establish link b/w high-voltage supply, capillary tube containing a polymer solution, and target.

The distance between the capillary tube and the target is kept relatively short. Various materials have been employed as targets for fiber collection during electrospinning, including copper plates, aluminum foil or plates, rotating drums, and even human hands [17-18]. the polymer solution is propelled through the syringe pump to the needle, utilizing either gravitational force or a mechanical advancement system. At first, the phenomenon of surface tension maintains the position of the pendant droplets of the solution. When a critical voltage is applied, a conical structure known as a Taylor cone form. From the cone, a straight jet extends for a few centimeters before becoming unstable. The jet transitions into a translucent conical shape, following a complex path. As the jet moves conically, bending instabilities occur, and it is guided toward the oppositely charged collector. During its journey to the collector, the solvent evaporates, leaving behind dry polymer fibers [19-21]. A variety of parameters within the electrospinning process influence fiber formation, including characteristics of polymer solution, operational parameters, and the surrounding environmental conditions [22-24].

The characteristics of the polymer solution include the relative molecular mass of the polymer, viscosity, surface tension, and conductivity. The relative molecular mass of the polymer constitutes a significant parameter influencing electrospinning, as it has a direct impact on the rheological and electrical characteristics of the electrospinning solution. The preparation of the fibres via electrospinning is contingent upon the polymer achieving a specific relative molecular mass threshold. The viscosity plays a crucial role in electrospinning, as the entanglement of polymer molecular chains within the solution leads to a specific viscosity level, which is essential for the successful fabrication of fibres through the electrospinning process. The increase in relative molecular mass of the polymer correlates with an extended molecular length, facilitating entanglement of the polymer molecular chain within the solution, thereby enhancing the solution's viscosity. Between ages of 25 and 30. The surface tension of the solution constitutes a significant variable influencing process of electrospinning. In the electrospinning process, it is essential that electrostatic repellent force acting on the surface of charged polymer solution or fusant exceeds its surface tension. The conductivity of a polymer solution intrinsically linked to its capacity for electrification [25-30].

The conductivity of a polymer solution rises with an increase in its carried electric charge, and this conductivity has a direct impact on the morphology of electrospun fibres. [31-33]. the parameters of the process include the applied voltage, the flow rate of the solution, and the distance at which the fibres are received [34-37]. During the electrospinning process, it is essential for the voltage applied to the polymer fluid to surpass a specific critical threshold. This enables the electrostatic repulsive force to effectively counteract the surface tension, leading to the formation of a microjet that subsequently produces fibres [38-39]. The flow rate of the electrospun solution constitutes a significant parameter in the electrospinning process, as it profoundly affects the morphology of the fibres produced. The flow rate of the solution is a critical factor that dictates the quantity of spinnable solution available during the electrospinning process. A reduced flow rate is advantageous for the evaporation of the solvent, thereby enhancing the rate of material transfer [40-41]. The distance between the syringe nozzle and the collector for fibre reception influences the extent of solvent volatilization, thereby regulating the size and morphology of the electrospun fibres.

The solvent can be adequately volatilized when the receiving distance is extended to a particular degree, resulting in the production of electrospun fibres with reduced diameters [42-45]. The environmental parameters, including ambient temperature and humidity, exert an influence on the morphology of the fibre during the electrospinning process [46-48]. The kinetic activity of the solution molecules intensifies as the ambient temperature rises, thereby enhancing the conductivity of the solution. Moreover, the rate of solvent evaporation is enhanced as ambient temperature rises. The alteration in environmental humidity influences not only the volatility of solvent but also induces a transformation in fibre surface morphology. The dissolution of hydrophobic polymers in organic solvents, under conditions of elevated relative humidity, results in emergence of porous nanofibers. Furthermore, quantity and dimensions of pores fluctuate in accordance with humidity levels [49-51]. Nanofiber membranes produced by electrospinning method have unique and diverse properties, such as a large surface area per unit mass ratio, high porosity, and gas permeability as well as excellent mechanical performance. These properties are highly beneficial in a variety of applications, such as filtration (air and liquid), chemical and optical sensors, hydrogen storage media, component parts in fuel cells, tissue engineering, and biomedical raw materials [52] (Table 1).

4. Biomaterial

Over the years, numerous fibers have been created using a variety of natural and synthetic fiber-forming polymers. Natural polymers encompass a variety of substances, including cellulose, chitin, chitosan, and proteins such as gelatine and collagen, in addition to alginic acid and hyaluronic acid. Conversely, the principal polymers that form synthetic fibres encompass polythene terephthalate, polyamide, polyacrylonitrile, polypropylene (PP), polythene, polyurethanes, polyvinyl chloride, polyvinyl alcohol, polytetrafluoroethylene, aramids, aliphatic polyesters, polyanhydrides, and polyamino acids [7-8]. For certain compositions and conditions, the addition of synthetic polymers can improve the mechanical properties for fibers. In addition to being soluble in water, cheap and easy to obtain, synthetic polymers also have chemical and temperature stability, are not easily degraded under various physiological conditions and the most important are biocompatible and non-toxic, so they do not cause tissue disturbances and safe for human application [53].

Polyvinylpyrrolidone (PVP) is a highly biocompatible synthetic polymer that has been used as a biomaterial or additive for drugs [54]. The numerous advantages of PVP, coupled with the distinct benefits of electrospinning, render PVP a prevalent choice in the production of fibres through the electrospinning technique, often in conjunction with a variety of other materials serving as polymer carriers [55]. Conversely, polyvinyl alcohol (PVA) is a hydrophilic, biodegradable, and biocompatible synthetic polymer that finds extensive application in the biomedical domain. Polyvinyl alcohol serves as a remarkable material for production of fibres. This material is insoluble in organic solvents, but soluble in water. This material is also relatively non-toxic and has good insulating properties [4]. Biomaterials that are ideally used in medical field must have high biocompatible properties, have no adverse tissue reactions, are corrosion resistant, and have good fatigue strength and toughness. Biomaterials such as alginate, gelatin and chitosan are raw materials to produce medical textiles which are currently quite widely used, besides being easy to find these materials also have relatively low prices [56].

4.1 Alginate

Brown seaweed *Sargassum Duplicatum* had potential as source for alginate. Alginate is a polysaccharide extracted and especially can be found at the cell wall and intracellular space from brown seaweed. Which is a mixture of calcium, potassium, and sodium salts of alginic acid. Alginates that can be used in the food and pharmaceutical industries are alginates that are free from cellulose, which is characterized by their white and bright colors [57]. Alginate is widely used for medical purposes because the raw materials are easily obtained domestically and can reduce dependence on imported raw materials. In addition, alginate has a high absorption capacity, easier to apply, elastic, does not interfere with new tissue damage, and can accelerate healing [58]. Alginate is also biodegradable, biocompatible, and nontoxic and does not cause allergies. In the medical field, alginate is widely used as a wound dressing, to regenerate blood vessels, skin, and cartilage and so on. The impact of alginate fibre on wound healing has been examined in scholarly articles for more than three decades; its application in dressings for both partial and full thickness wounds revealed through histological analysis after fourteen days that the alginate was not only well-accepted by bodily fluids and cellular elements but also served as an effective haemostatic agent [59]. There is a study using a mixture of materials derived from Alginate and Polyvinyl Alcohol (PVA) with electrospinning method.

The results obtained the best ratio to produce fiber is in volume of Alginate/PVA 2/8%. The results of the fiber formed from this experiment have various sizes, which are around 100 nm to 500 nm, so that product can be classified as a nano-quality medical textile product [60]. Alginate has been known to have anti-bacterial properties, or the product is not a growth medium for bacteria, but alginate/PVA are not known containing for their properties against bacteria. Therefore, an experiment was conducted using two types of pathogenic bacteria, namely *Escherichia coli* (gram negative) and *Staphylococcus aureus*, (gram positive). The purpose of this experiment is to determine whether the product supports growth of microorganisms. One of the reasons for choosing these pathogenic bacteria is because they are abundant around us and cause various diseases such as skin tissue infections. The method used in this resistance test is the diffusion method [61]. From the results of the resistance test on the alginate/PVA, it is known that bacteria are not present in the product and there is a zoning area, which is an average of about 20 mm, which indicates that test is anti-biotic, because it has antimicrobial properties resistant to microorganisms (bacteria tested). Result tell's that alginate/PVA web material has been produced in the form of a thin layer which is dominated by fibers measuring <500 nm and can be classified as a nano-quality medical textile product.

4.2 Chitosan

Chitosan is a polycationic biopolymer obtained from chitin, a key constituent of crustacean exoskeletons, through alkaline treatment. The most widely used is shrimp, small crabs, and crabs. In Indonesia the mollusk family is also a very promising alternative source for producing chitosan, such as in shellfish and snails. In addition, insects such as flies, grasshoppers and silkworm cocoons have also been proven to produce chitosan as a source of other alternative materials [62]. Chitosan is polysaccharide and one of the biomaterials that can be used as an option in the manufacture of fiber. Chitosan was selected due to its notable biocompatibility and biodegradability. Additionally, its antimicrobial properties render it a frequent choice in the biomedical sector, particularly in the production of wound dressings [63]. Chitosan can be transformed into various forms, such as fibers, nanofibers, hydrogels, membranes, scaffolds, and sponges, making it a versatile material for numerous applications. These encompass tissue engineering, enzyme immobilisation, drug delivery systems, regulation of absorption rates in synthetic absorbable sutures, and sophisticated wound care solutions.

Furthermore, chitosan has exhibited considerable promise in the realm of wound dressing applications owing to its advantageous characteristics. The capacity to integrate effortlessly with widely accessible fibres, including cotton and viscose rayon, significantly enhances its functionality and versatility across various sectors and biomedical applications [64]. There is a study using a mixture of materials derived from chitosan/PVA – PVP with electrospinning method. The results obtained the best ratio of chitosan, PVA, and PVP to produce fiber is the volume of chitosan/PVA – PVP 3/7% [65]. The results also showed that the fiber had antibacterial properties, as evidenced by the presence of a clear zone with a diameter of 6.0 – 11.6 mm which indicated an inhibitory response to bacterial growth. The antibacterial test was carried out by preparing a 6 mm chitosan/PVA/PVP electrospun fiber membrane which was then put into a petridish that had been filled with nutrient agar and smeared with the Staphylococcus aureus and the Escherichia coli bacteria.

Then the diameter of the clear zone was observed after an incubation period of 1 x 24 hours at 37°C. Antibacterial activity was observed based on the diameter of the clear zone formed compared to the negative control. The results of the water absorption test on electro spun fiber are 82.76 – 212.31%. Water absorption was measured by the swelling method and expressed as the degree of swelling (s) which was calculated in grams wet per gram dry. The Flory Huggins equation was applied to calculate the magnitude of the swelling level that occurred, to obtain a value for the development of water absorption in electrospun fiber. The high-water absorption or degree of swelling of the chitosan/PVA/PVP electrospun fiber can occur due to the hydrophilic nature of the material and is important for rapid absorption of exudate as a wound dressing material. This result is also in accordance with the research conducted by Charernsriwilaiwat (2014) [66] with water absorption capacity of chitosan/PVA nanofibers of 90 – 210%.

4.3 Gelatin

Gelatin is a protein derivatives compund and partially hydrolyzed collagen which is widely found in the skin, fish bones, muscles, bones of mammals and the skin of chicken feet. Gelatin is a natural polymer that is approved by the Food and Drug Administration (FDA). The main properties of gelatin are biodegradable, non-toxic, biocompatible, inexpensive, and readily available, making it commercially widely used in the medical field [67]. There is a study using a mixture of materials derived from Gelatin and Polyvinyl Alcohol (PVA) with the electrospinning method.

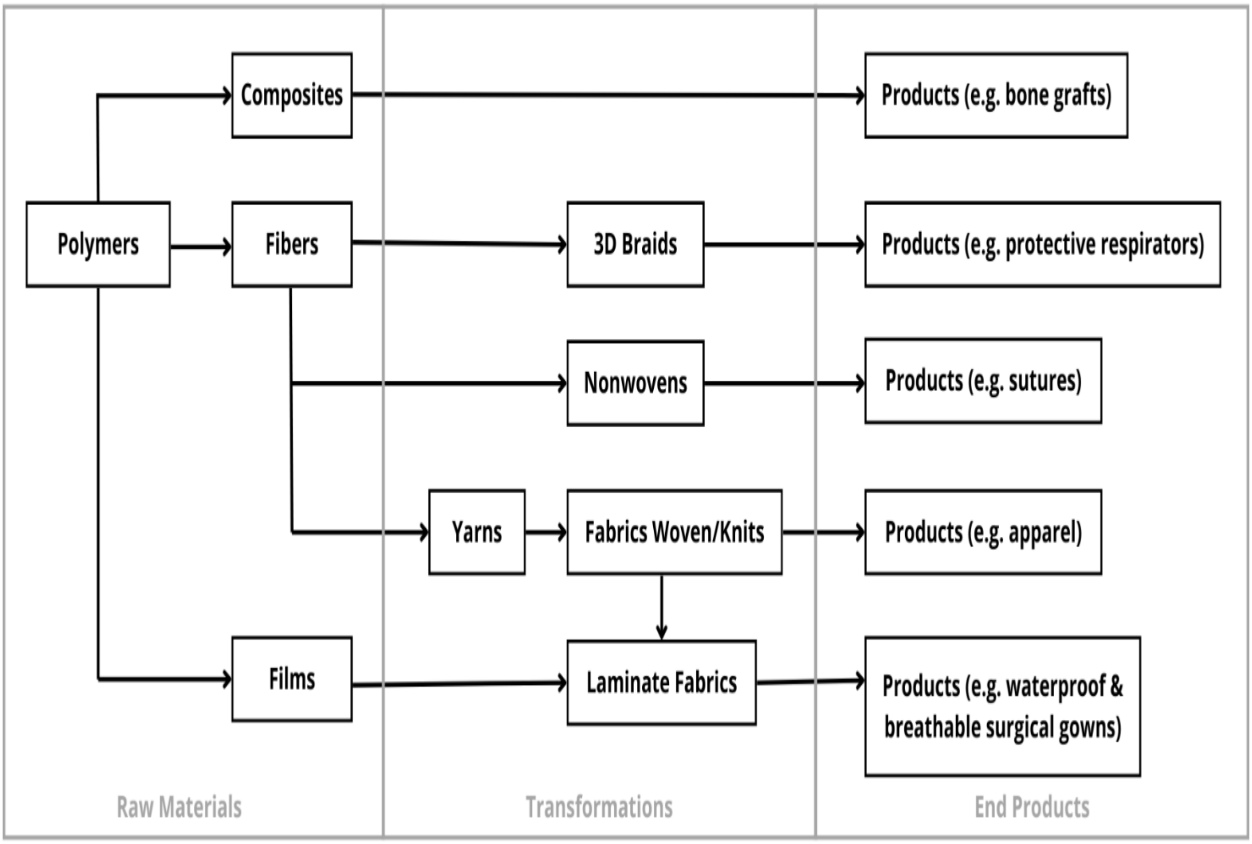

Figure 1. Process of medical textile production from polymers

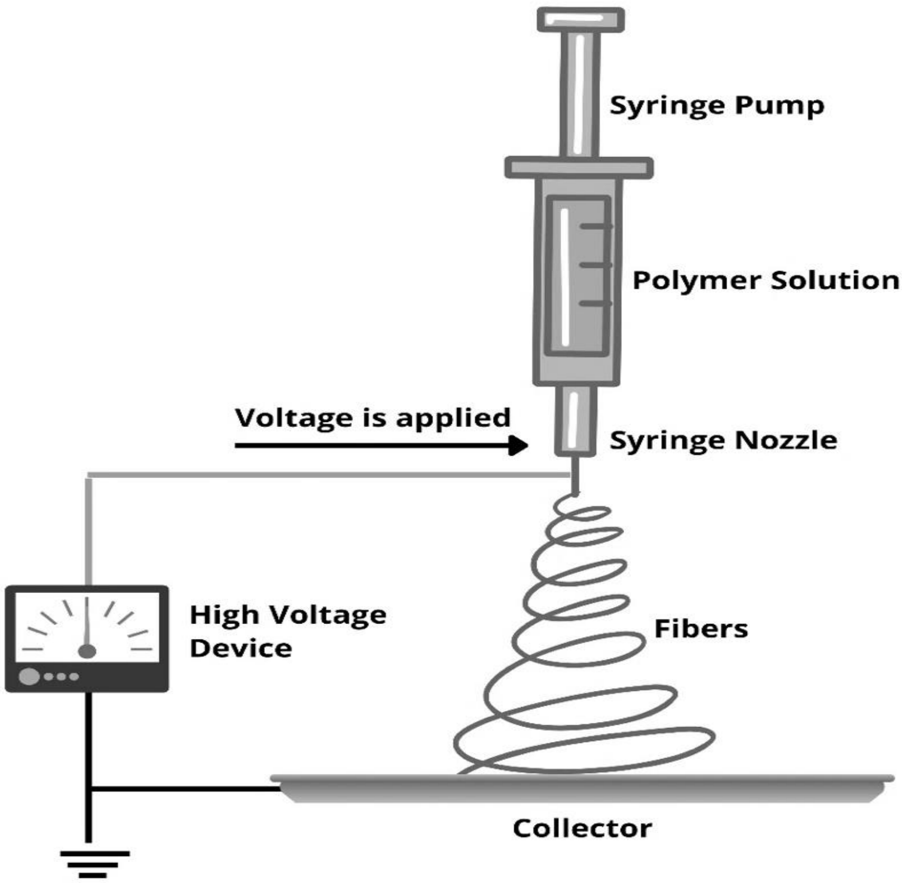

Figure 2. Electrospinning Tools

Table 1. Different fiber used in electrospinning and their applications.

Materials	Applications	References
Chitosan, KGM	Wound dressing	[74]
KGM, chitosan	Wound dressing, antibacterial	[81]
KGM, polyvinyl alcohol	Wound dressing	[72]
KGM/Gelatin	Wound healing	[82]
Chitosan/Silk	Wound dressings	[83]
Chitosan/PEO	TE scaffold,drug delivery, wound healing	[84]
Chitosan and cellulose nanofibers	Bone Tissue Engineering	[85]
Chitosan/PCL	Liver Tissue Engineering	[86]
Gelatin	Scaffold for wound healing	[87]
Gelatin/polyaniline	Tissue engineering scaffolds	
Gelatin	General tissue engineering	[88]
Gelatin	Nerval tissue engineering	[89]
Gelatin	Bone Tissue Engineering	[90]
Gelatin/PVA	Bone Tissue Engineering	[91]
Gelatin/PCL	Liver Tissue Engineering	[92]
Poly(glycolicacid) and chitosan	Vascular tissue engineering	[93]
Alginate/PVA	Wound dressing	[94-95]
Alginate/PVA	Tissue Engineering	[96-97]
Alginate/PVA/hydroxyapatite	Tissue Engineering	[4]
Silk	Tissue Engineering	[98]
Collagen	Tissue Engineering/Collagen foams	[99]
Collagen	Bone Tissue Engineering	[100]
Chitin	Vascular tissue engineering	[101]

The results obtained the best ratio to produce fiber is the volume of Gelatin/PVA 10/5% with a composition ratio of 70/30. Under these conditions, fibers with an average size of 300 nm are obtained with a fairly good level of uniformity and fiber distribution [68]. The electrospinning process was carried out using an electrospinning machine at room temperature, using a 10 ml syringe with an inner diameter of 0.838 mm. The electric voltage used is 38 kV, the distance between the tip of the nose tip and the ground collector is 10 cm, and the solution flow rate is 0.4 ml/hour, and the temperature is 25ºC. Nanofiber membranes are believed to be very useful especially for medical textile purposes, such as wound dressing products or topical drug delivery media.

4.4 Glucomannan

Glucomanan is a natural polysaccharide derived from Amorphophallus konjac plant, also known as the konjac plant. Glucomanan consists of long chains of mannose molecules (derived from glucose) connected by the β-glucosidic bonds.

KGM is widely recognized as safe by the US Food and Drug Administration (GRAS). Furthermore, owing to its remarkable biocompatibility and environmentally friendly characteristics, KGM has garnered considerable interest and investigation from the scientific community. KGM, a water-soluble natural biopolysaccharide, finds extensive application across food industry, biomedicine, and numerous other fields due to its non-toxic nature, film-forming capabilities, gel characteristics, and biocompatibility. KGM has subject of considerable investigation and application in wound dressings, owing to its exceptional ability to absorb and retain water [69-73]. The pronounced affinity of KGM for water molecules can be ascribed to existence of acetyl and hydroxyl groups, which confer considerable elasticity as a membrane substrate and facilitate absorption of substantial quantities of liquid. KGM serves as an effective hydrophilic double-layer film suitable for wound dressings [74].There is a study using a mixture of materials KGM/galactoglucomannan (GGM) were fabricated using electrospinning technology.

Studies have demonstrated that the incorporation of GGM significantly improves the thermal and mechanical characteristics of the nanofiber membranes. In the examination of thermal properties, the pyrolysis peaks for the KGM/GGM nanofiber membrane and the pure KGM film were observed within the range of 300 to 350°C, specifically at 307.0°C and 319.7°C, respectively. The pyrolysis peak area for the KGM/GGM nanofiber membrane was slightly larger compared to the pure KGM membrane [75]. Wang (2017) proposed nanofiber membranes made from KGM and using electrospinning techniques, it showed demonstrated significant inhibitory effects against foodborne pathogenic bacteria. This provides a practical approach for modifying KGM-based biopolymers into nanofilms, offering potential applications in wound dressings [76]. The integration of hydrophilic KGM with hydrophobic macromolecules resulted in the formation of hybrid microfibers that possess both hydrophilic and hydrophobic segments, effectively inhibiting microbial growth.

4.5 Other Recommendations Materials

Among the various types of biomaterials used in the medical field, such as alginate, chitosan, gelatin, and glucomannan, there are also other materials derived from animal-based proteins, such as wool, silk, or plant-based cellulose like cotton, kapok, and sisal, as well as other regenerated proteins like casein and collagen. These materials have proven to be effective in various medical applications, including wound care, drug delivery systems, and tissue engineering. Furthermore, they have shown great potential in the development of fibers for medical textiles, as demonstrated by numerous studies in the literature. For example, animal-based proteins like collagen and casein have been successfully used to produce fibers with excellent biocompatibility and mechanical properties [77-78]. Similarly, plant-based fibers like cotton and silk have been extensively explored for their suitability in medical applications due to their natural abundance and ability to support cell growth [79-80].

5. Conclusion & Future Perspective

From several studies that have been carried out using alginate, chitosan, gelatin and biomaterials with the electrospinning method, the result of the fiber formed this experiment have various sizes which are around 100 – 500 nm and can be classified as a nano – quality medical fiber product. With the best ratio to produce the fibers is alginate/PVA 2/8%, gelatin/PVA 10/5%, chitosan /PVA-PVP 3/7%. The results also showed that electrospinning fiber has anti-bacterial properties, which is indicated by the presence of a clear zone <20 mm which means it has very good bacterial resistance. These products pass preclinical tests and can be used in medical textiles such as wound dressing products or topical drug delivery media.

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