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Electrospun Nanofibers In Wound Care: Mechanistic Insights And Therapeutic Perspectives

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ABSTRACT

Tissue injury is more common than before,and it requires innovative tissue engineering and regenerative medicine strategies. In this work, egg yolk oil-infused electrospun nanofibers were developed and characterized for the potential applications as scaffolds in the tissue engineering domains. Because of their relatively large surface area and their ability to mimic the extracellular matrix, electrospun nanofibers have great potential as substrates for cell adhesion and proliferation. Widely used in the biomedical area and tissue engineering, the addition of egg yolk oil (bioactive components as phospholipids and antioxidants), enhances nanofiber structure at mechanical and biological level. These features allow for the controlled release of bioactive molecules, accelerating cell proliferation and tissue recovery. The findings highlight the enhanced biocompatibility and regenerative potential of egg yolk oilinfused nanofibers in areas such as wound healing, bone regeneration, and nerve regeneration. While formulation stability and regulatory issues may limit its application, this method could be a promising avenue in creation of tissue constructs and should be explored, to optimize these nanofibers and implement them, further inclinic.

Keywords: *Tissue engineering, Electrospun nanofibers, Egg Yolk Oil, Biocompatibility, Regenerative medicine.*

1. INTRODUCTION

Tissue engineering and regenerative medicine have been developed over recent decades to enhance clinical outcomes of tissue defects and degenerations that lead to potentially grave disorders that place health at risk. This is very important because human tissues have very limited capacity for regeneration. The area has progressed significantly over the last few years creating innovative artificial matrices as a result of advancements in materials science, tissue engineering, and regenerative medicine. These consist of and are used for electrochemical signaling, cell adhesion and biosorption enhancement.[1]

This sector has been largely interested in electrospun nanofibers with unparalleled characteristics of large surface area, controlled porosity, ECM mimic, making them the potential scaffold material. They are typically fabricated from synthetic and natural polymers and are employed in various tissue engineering processes, such as skin regeneration, neural, and bone healing.

A natural product rich in bioactive factors like essential fatty acids, phospholipids, and antioxidants, egg yolk oil, was discovered to improve wound healing, kelp inflammation, and boost cell activity. These favorable properties render egg yolk oil as an attractive candidate toward incorporation into biomaterial formulations for use in tissue engineering. [2]

In response to the need for effective treatment of tissue lesions and degenerations that can precede severe disorders involving loss of health, tissue engineering and regenerative medicine have emerged during the past few decades to enhance patients' clinical outcomes. That is significant, given that human tissues have a highly limited capacity to regenerate. New Regenerative Engineering Updates This sector has progressed notably over the past few years due in large part to new developments in materials science, tissue engineering, and regenerative medicine, resulting in new artificial matrices. They are employed for electrochemical signaling, cell adhesion and biosorption improvement.

2. ELECTROSPINNING OF NANOFIBERS FOR TISSUE ENGINEERING

Electrospinning is a flexible and extensively used technology for creating nanofibers, which are distinguished by their high surface area-to-volume ratio, porosity, and tiny diameters. These qualities make electrospun nanofibers suitable for a wide range of applications, particularly in tissue engineering. Tissue engineering scaffolds strive to imitate tissues' natural extracellular matrix (ECM), while electrospun nanofibers are a candidate of interest due to their potential to mimic the fibrous structure of ECM. In electrospinning, an electrical field is applied to draw fibres out of a polymer solution or melt. Depending on the polymer used, solution concentration and electrospinning process conditions, the fibre diameter can vary from nanometres to micrometres.

These nanofibers can then serve as scaffolds for cellular growth and tissue repair. The use of egg yolk oil in the electrospinning of nanofibres necessitates the careful optimisation of the electrospinning process to allow well-dispersed bioactive components present in the egg yolk oil, such as essential fatty acids, phospholipids and antioxidants to retain bioactivity while achieving stable fibres formation.[4]

2.1. Electrospinning process: principles and parameters

The electrospinning process involves the following basic steps:

2.1.1POLYMER PREPARATION SOLUTION : Prepare a polymer solution or melt by dissolving or melting a polymer in a suitable solvent or mixing it with egg yolk oil. The polymer should possess some requirements of being good solubility, biocompatibility, and continuous nanofibers formation in the electrospinning condition

2.1.2 ELECTRO SPINNING SETUP: The components of electrospinning system includes, a syringe, a needle, a high-voltage power supply and a collector (typically rotating drum or plate). The polymer solution is subjected to a high voltage that causes the polymer solution to form an electrically charged jet. Electrostatic forces stretch this jet, which, as a solvent evaporates, can be solidified into nanofibers.

2.1.3 FIBER FORMATION : Nanofibers are formed because the polymer jet is attracted by the collector. The cross-sectional diameter and morphology of those fibers can be influenced by several factors.[5]

2.2.ELECTROSPINNING PARAMETERS AFFECTING NANOFIBERS PROPERTIES

2.2.1 POLYMER COCNCENTRATION AND VISCOSITY: The polymer solution concentration has a great effect on the fiber formation. If the polymer concentration is low, fibers may not be formed at all, and it is too high polymer concentration could cause beaded structures to be generated instead of smooth fibers. The viscosity of the solution has an influence on the stability of the jet and the viscosity changes brought on by adding egg yolk oil may affect fiber morphology.

2.2.3 APPLIED VOLTAGE: Higher voltages cause faster stretching of the polymer solution and can produce thinner fibers. Nonetheless, very high voltages can induce the development of non-negligible fibrous products (i.e., an irregular fiber or droplet instead of a jet). Thus, the voltage has to be optimized to ensure the perfect uniformity of fiber and egg yolk oil dispersion

2.2.4 FLOW RATE: This measurement is required in order to control the rate at which the polymer solution is being drawn into the electrospinning apparatus. If the flow rate was high, the fibers were thicker but if the flow rate was low, the fibers were finer3. Egg yolk oil is likely to alter the viscosity of the solution, so it may be necessary to tune the flow rate

2.2.5 NEEDLE TO COLLECTOR DISTANCE: As the distance is increased, the solvent evaporation time is obviously longer, resulting in thin fibers which is a key parameter affecting the electrospun fiber uniformity.

2.2.6 ENVIROMENTAL CONDITIONS: Electrospinning process is influenced by humidity and temperature. High humidity may lead to inconsistent fiber formation due to solvent evaporation while low humidity can cause the solvent to evaporate so fast that a beaded fibers is formed. The solvent evaporation rate and the flow behavior of the polymer solution are also temperature dependent.

3. INCORPORATION OF EGG YOLK OIL INTO ELECTROSPUN NANOFIBERS

Egg yolk oil (EYO), composed of phospholipids, essential fatty acids (omega-3 and omega-6), and antioxidants, has been developed as an alternative biological material for tissue engineering. Although high bioactive egg yolk oil should be incorporated into electrospun nanofibers, their type needs to be considered in terms of their shapes and diffusion of oil to preserve bioactive capacity.[6]

.2.3.1. CHALLENGES IN INCORPORATING EGG YOLK OIL :

PHASE SEPARATION: If egg yolk oil is not emulsified, it may phase-separate from the polymer solution, which can result in inhomogeniety in egg yolk oil-distribution in nanofibers. This can impact the mechanical properties of the nanofibers and also the bioactive compound release profile from the oil.

- SOLVENT COMPATIBILITY**:** Since some solvents have a negative joint property with egg yolk oil, the egg yolk oil cannot be homogeneously induced in the polymer solution. In this case, the solvent systemmust be carefully selected so that both the polymer and the egg yolk oil can be successfully solubilized and evenly dispersed prior to electrospinning.

2.3.2. METHODS OF INCORPORATION

Several methods can be used to incorporate egg yolk oil into electrospun nanofibers:

- DIRECT MIXING**:** Egg yolk oil can be innocuously incorporated into the polymer solution via stirring or sonication to obtain a homogeneous mixture. Now the oil is electrospun with the Polymer solution.[7] This method is straightforward but the system must be carefully optimized to minimize phase separation during electrospinning.
- MICROEMULSION TECHNIQUE A further refined approach uses a

microemulsion, where egg yolk oil is dispersed into a solution of surfactants to generate stable droplets. These droplets are subsequently integrated into the polymer solution and can inhibit phase separation and enhance the homogeneity of the oil within the electrospun fibers

CO-AXIAL ELECRTOSPINING: Co-axial electrospinning was performed using a twoneedle setup, where the polymer solution and egg yolk oil were fed through separate needles. The encapsulated egg yolk oil is stabilized at and around the sheared nanofiber, in order to be incorporated in the core of the nanofiber in the form of core-shell nanofibers, which can prevent degrad**h**ation of bioactivity of egg yolk oil and regulate the controlled release.

2.4.CHARACTERIZATON OF ELECTROSPUN NANOFIBERS WITH EGG YOLK OIL

understand the quality and performance of the electrospun nanofibers in tissue engineering applications.

2.4.1 MORPHOLOGICAL CHARACTERIZATION**:** Electrospun nanofibers were visualized for surface morphology, diameter, and uniformity using scanning electron microscopy (SEM). Egg yolk oil distribution could also be evaluated based on both the ooze at the fiber surface and a visually uneven fiber surface.[8]

2.4.2 MECHANICAL PROPERTIES: The mechanical strength, elasticity, and durability of the nanofibers are evaluated via tensile testing. Egg yolk oil affects the stiffness and fibre-tensile properties of the nanofibres, and the polymer composition must be optimised to achieve good bioactivity of the oil, whilst maintaining desirable mechanical properties of the scaffold

2.4.3 BIOACTIVITY AND BIOCOMPATIBILITY: It is also believed that the bioactivity of the nanofibers could be raised with the aid of egg yolk oil. Experiments such as cell viability (MTT or Live/Dead staining), proliferation, and differentiation assays in vitro are performed to determine the efficiency of the resultant nanofibers towards adhesion and growth of cells. Moreover, in vivo studies will be required to assess the regenerative capacity of such scaffolds.

3. EGG YOLK OIL : COMPOSITION AND BILOLOGICAL PROPERTIES

Egg yolk oil (EYO) is a natural and multidimensional substance that has attracted more and more attention for biomedical and tissue engineering applications because of its composition and biological properties. It comprises several bioactive substances such as essential fatty acids, phospholipids, antioxidants, and vitamins, which may improve tissue regeneration.[9] Egg yolk oil is also being considered an impactful bioactive component that can be embedded in fairly new electrospun nanofibers specific to tissue engineering to further stimulate cellular activities and tissue regeneration in a dynamic milieu.

This section provides an overview of egg yolk oil composition as well as its biological properties that could be useful as a formulation component of electrospun nanofibers, especially in the field of tissue engineering.

3.1. COMPOSITION OF EGG YOLK OIL

Egg yolk oil, obtained from the yolk of chicken eggs, comprises lipids, mainly phospholipids, essential fatty acids and fat-soluble vitamins.[10] These compounds are involved in biological activity and regenerative potential.

3.1.1. LIPID PROFILE

PHOSPHOLIPIDS

Lecithin, the most common phospholipid, is abundant in egg yolk oil. Lecithin and its derivatives are extensively found in cellular membranes, hence crucial in tissue repair and regeneration. Phospholipids enhance oil stability and might assist with the dispersion of bioactive compounds in electrospun nanofibers.

•TRIGLYCERIDES AND FATTY: Egg yolk oil is rich in triglycerides that includes different fatty acids. Egg yolk oil contains a combination of saturated, monounsaturated, and polyunsaturated fatty acids. Omega-3 fatty acids (ex: alphalinolenic acid (ALA)) and omega-6 fatty acids (ex: linoleic acid (LA)) are abundant polyunsaturated fatty acids.[11] These fatty acids are important for healthy cell membrane formation, regulation of inflammation, and tissue repair.

•CHOLESTROL: The egg yolk oil contains moderate amounts of cholesterol, which is crucial to the fluidity and function in the cell membranes. Although cholesterol in excess has negative consequences, moderate levels are necessary to sustain cellular structures and the proper function of cellular signalling pathways.[12]

3.1.2. ANTIOXIDANTS

• Egg yolk oil is rich in diverse fat-soluble antioxidants (vitamins A, D and E) that have proven anti-inflammatory and antioxidant properties. These antioxidants help in

• NEUTRALIZING FREE RADICALS that would otherwise damage cells and inhibit tissue regeneration

• REDUCING OXIDATIVE STESS It's typically a hindrance in wound healing or tissue regeneration. makes it an excellent additive for electrospun nanofibers, in particular for the purpose of enhancing healing of damaged tissues in regenerative medicine.

3.1.3. VITAMINS

•VITAMIN A (RETINOL): Both sectors play an integral role in processes such as cellular differentiation, immune response, and tissue regeneration. It is critical for epithelial tissue homeostasis and healing response. So vitamin A is present in egg yolk oil may stimulate cellular proliferation and regeneration of tissue-engineered frameworks.[13]

•VITAMIN D: Since vitamin D plays an active role in bone regeneration and remodeling, egg yolk oil is particularly important in bone tissue engineering applications. It improves the calcium absorption, which is important for bone tissue creation and healing.

•VITAMIN E(TOCOPHEROL): Vitamin E is a powerful antioxidant that helps to protect cells against oxidative damage, an essential property that ensures tissue engineering, as oxidative stress can reduce cell viability and tissue formation.[14]

3.2 BIOLOGICAL PROPERTIES OF EGG YOLK IOL FOR TISSUE ENGINEERING

Egg yolk oil as an additive for incorporation into fibrous tissue engineering constructed from electrospun nanofibers, given its biological properties. These properties have antiinflammatory activity, improve cell proliferation and have regenerative properties, which are important for tissue repair and regeneration..3.2.1. Anti-Inflammatory Effects

3.2.2. CELL PROLIFERATION AND DIFFERENTIATION

•Oil extracted from the yolk of an egg, which is rich in fatty acids and phospholipids simulates cell proliferation for tissue regeneration. Egg yolk oil fatty acids can combine with cell membrane structures and may be involved in metabolic activities in a cell, such as attachment, proliferation, and differentiation. Promotion of cell proliferation is of great importance in tissue engineering to achieve successful regeneration of functional tissues.[15]

•STIMULATION OF FIBROBLAST AND OSTEOBLAST PROLIFERATION: In the process

of wound healing, egg yolk oil has been demonstrated to stimulate the proliferation of fibroblasts responsible for the synthesis of collagen and extracellular matrix. Furthermore, egg yolk oil might support osteoblast differentiation, promoting bone tissue regeneration.

• NEUROPROTECTION:

The lipid profile of egg yolk oil may also contribute to neuroprotection, which is due to its involvement in the function and viability of nerve cells.[16] This renders egg yolk oilembedded nanofibers specifically stable for usage in nerve tissue engineering with emphasis on cell safety and restoration.

3.3. BIOCOMPATIBILITY

Moreover, because they are natural, they are biocompatible and biodegradable, these properties make egg yolk oil highly applicable for tissue engineering. Egg yolk oil is not toxic to cells when encapsulated in electrospun nanofibers, and the oil can be released in a sustained manner without adverse effects.[17] This is particularly important for scaffold development, given that scaffold material can be stimulating in terms of cellular growth, tissue development and immune response.

3.4.ENHANCEMENT OF WOUND HEALING

Egg yolk oil is very effective in wound healing due to its ability to stimulate migration of cells, collagen formation, and epithelialization. Egg yolk oil can also act as an auxiliary substratum for skin and soft tissue regeneration in tissue engineering, promoting cellular interactions that enhance healing outcomes. Its richest source of essential fatty acids and phospholipids helps in the reconstitution of cell membrane, so it is essential for wound healing and tissue repair.

4. ROLE OF EGG YOLK OIL IN ELECTROSPUN NANOFIBERS FOR TISSUE ENGINEERING

Incorporation of egg yolk oil into electrospun nanofibers for tissue engineering applications presents a number of benefits:

• BIOACTIVE RELEASE: The phospholipids, omega-3 fatty acids, and antioxidants in egg yolk oil are bioactive compounds that can be released from the nanofibers over time into the surrounding tissue. This controlled release stimulates prolonged cellular activity, such as proliferation, differentiation, and extracellular matrix deposition, promoting tissue repair.

• IMPROVED SCAFFOLD FUNCTIONALITY: Egg yolk oil enhances the mechanical characteristics of the nanofiber scaffolds with high flexibility and promotes cell adhesion and proliferation. By incorporating bioactive oil molecules into the nanofiber matrix, the overall bioactivity of the scaffold is significantly enhanced, leading to improved tissue damage repair efficacy.

• ENHANCED BIOCOMPATIBILITY AND REGENERATION: The natural composition and regenerative ability of egg yolk oil enhance the biocompatibility of electrospun nanofibers that create a favorable microenvironment for tissue regeneration. Such methods especially benefit complicated tissue types like skin and nerve, and bone(s).

5. FORMULATION OF EGG YOLK OIL INFUSED ELECTROSPUN FOR TISSUE ENGINEERING APPLICATIONS

Thus, the incorporation of bioactive agents into electrospun nanofibers has been proved to be an efficient way towards improving scaffold functional properties in tissue engineering. One of the bioactive agents that is rich in phospholipids, essential fatty acids, vitamins, and antioxidants, with important implications for biological properties in tissue regeneration, is egg yolk oil (EYO). Incorporating egg yolk oil in electrospun nanofibers will enable sustained release of bioactive agents, cell attachment and proliferation as well as increasing tissue repair. Part A: Preparation and Characterization of Egg Yolk Oil-infused Nanofibers for Tissue Engineering.[18]

POLYMER SELECTION FOR EGG YOLK OIL INFUSED NANOFIBERS

Selection of the polymer is of utmost importance for electrospinning since it influences the morphology, mechanical characteristics, and biocompatibility of the nanofibers. The chosen polymer needs to show high organic solvent solubility and desired mechanical behavior along with tissue engineering biocompatibility when considering electrospun nanofibers filled with egg yolk oil. These polymers are frequently used for tissue engineering scaffolds

5.1. 1.POLYCAPROLACTONE(PCL)

Advantages : Despite its advantages, the slow degradation rate of PCL can limit its application in tissue engineering, where rapid scaffold degradation is often required to match tissue growth rates.

ROLE IN FORMULATION: PCL can be mixed with egg yolk oil, obtaining a stable scaffold structure that allows gradual release of the bioactive compounds contained in the oil over time.5.1.2. Polylactic Acid (PLA)

• ADVANTAGES: PLA is another biodegradable polymer having good mechanical strength and biocompatibility. Hyaluronan is a naturally-derived polymer that is a commonly used scaffold material for tissue generation, particularly for bone and cartilage.[19]

• ROLE IN FORMULATION: PLA has a high degree of crystallinity, which is advantageous for furnishing stable scaffolds, and it is biodegradable, so the polymer gradually dissolves as the tissue regenerates

5.1.3. POLY(LACTIC CO GLYCOLIC ACID) (PLGA)

• ADVANTAGES: PLGA is a type of copolymer that is made up of chains of PLA and PCL, it has tunable degradation rates and improved mechanical properties combining benefits from both of its constituents.

• ROLE IN FORMULATION : PLGA can facilitate cell attachment and enchance tissue formation, making PLGA versatile in many tissue engineering uses, such as skin, bone, and nerve regeneration.[20]

5.1.4. CHITOSAN

• ADVANTAGES : Chitosan derived from chitin is a natural polymer with excellent biocompatibility, antimicrobial properties and supports both adhesion and proliferation of cells.

• ROLE IN FORMULATION : Chitosan's natural origin and its ability to form porous structures make it a good candidate for incorporating bioactive compounds like egg yolk oil, promoting cellular activities crucial for tissue regeneration.

5.2. PREPARATION OF EGG YOLK OIL INFUSED NANOFIBER SOLUTION

The introduction of egg yolk oil into electrospun nanofibers needed proper reagent preparation of polymer solution. Here we describe the general method for preparation of egg yolk oil containing nanofiber solution

5.2.1.EMULSIFICATION OF EGG YOLK OIL

• OIL DISPERSION: Egg yolk oil is hydrophobic, necessitating its emulsification into the polymer solution to prevent phase separation. Surfactants such as tween 80 or lecithin can be added to stabilize the oil droplets in a polymer matrix.

METHODS OF EMULSIFICATION:

- HIGH SHEAR MIXING: To emulsion the oil into small droplets that are homogeneously distributed in the polymer solution, the oil can be processed using a high-shear homogenizer or sonicator.
- MICROEMULSION APPROACH: Before slow evaporation of the solvent, a microemulsion method can be used in which the oil is added in small amounts into a water and surfactant mixture, forming a fine, stable dispersion of egg yolk oil in the polymer solution.[21]

5.2.2.POLYMER SOLUTION PREPARATION

Solubilizing the chosen polymer (PCL, PLGA or chitosan) in a suitable solvent (based on the solubility of the polymer in literature) such as chloroform, dichloromethane (DCM) or acetone.

- The egg yolk oil (in emulsified state) is finally incorporated to the polymer solution at the required concentration (generally 5-30% w/w) to maximize the oil release versus fiber generation.
- The final solution should be homogenous and prevents separation of the oil phase

5.3. ELECTROSPINNING PROCESS FOR NANOFIBER FABRICATION

When the egg yolk oil-loaded polymer solution is ready, the next task is to electrospin the solution to nanofibers. The relevant parameters involved in the electrospinning process are:

5.3.1 ELECTROSPINNING SETUP

Syringe and Needle: A syringe syringe filled with polymer solution, for polymer jet is produced with a fine needle

COLLECTOR : An grounded collector (flat or rotating drum) for collecting the electrospun

nanofibers.. High-Voltage Power SupplyThe syringe needle is subjected to a high-voltage power supply (usually of 10-30 kV), thus generating an electric field which draws the polymeric solution into a fiber.

5.3.2.PROCESS PARAMETERS

- APPLIED VOLTAGE Applied Voltage: Stretching and thinning of the polymer jet are controlled by the applied voltage. This produces thinner nanofibers but high voltages are unfavourable as they also cause defects like beads.
- NEEDLE TO COLLECTOR DISTANCE: The fiber diameter and morphology depend on the distance between the syringe needle and the collector. The longer distance favors higher fiber elongation and thinner fibers.
- FLOW RATE : Flow rate controls how much polymer solution is pushed through the needle. A flow rate that is too high leads to thick fibers, while a flow rate that is too low creates beads rather than continuous fibers.[22]

Environmental Conditions: Fiber formation is greatly affected by humidity and temperature. While low humidity can result in a high evaporation rate leading to uneven formation of the fibers, and, similarly, if the humidity is too high, solvent may not evaporate quick enough creating beaded fiber

6. CHARACTERIZATION OF EGG YOLK OIL INFUSED NANOFIBER

Nanofibers have to be characterized following electrospinning, to assess their morphological, mechanical and biological functions. To evaluate the quality of egg yolk oil-enriched nanofibers for tissue engineering applications, several characterization approaches are required:

6.1. MORPHOLOGICAL CHARACTERIZATION

- SCANNING ELECTRON MICROSCOPY (SEM): Silica nanofibers SEMAnalysis of the silica nanofibers fiber diameter, surface morphology, and uniformity was performed. This is important to assess the incorporation of egg yolk oil and its distribution in the fibers.6.2. Mechanical Properties
- TENSILE TESING: The nanofibers are mechanical tested to determine their tensile strength, modulus and elongation at break. These features allow the scaffolds to resist the mechanical loads that will be encountered in tissue engineering applications.6.3. Oil Release Profile[23]
- IN VITRO RELEASE STUDIES: Release kinetics of bioactive compounds (fatty acids, antioxidants, phospholipids) from the nanofibers is tested in a buffer solution at body temperature. This gives insight into the controlled release of bioactive compounds that can assist tissue regeneration over an extended period.

6.4. BIOCOMPATIBILITY AND CELL VIABILITY

In Vitro Cell Culture Studies: Test the biocompatibility of the egg yolk oil-infused nanofibers by culturing cells (fibroblasts, osteoblasts or keratinocytes) on the nanofiber scaffolds. By performing cell viability assays (e.g., MTT or Live/Dead assays) and proliferation studies, the ability of the scaffolds to allow cell attachment and growth can be evaluated

6.5. ANTIOXIDANT ACTIVITY Antioxidant Activity

• IN VITRO ANTIOXIDANT ASSAYS: Antioxidant activity of the egg yolk oil-infused nanofibers were evaluated by evaluating the free radical scavenging activity or total antioxidant capacity, which is critical for protecting cells during tissue regeneration from oxidative damage.[24]

7. APPLICATIONS IN TISSUE ENGINEERING

Electrospun nanofibers loaded with egg yolk oil demonstrate a high potential in several tissue engineering applications,

- The egg yolk oil is rich in anti-inflammatory and regenerative properties that can help wounds on the skin to heal faster.
- Nanofiber-incorporated egg yolk oil may be effective in promoting osteoblast proliferation and differentiation to improve bone tissue regeneration.
- Egg yolk oil has antioxidant and anti-inflammatory properties, which can help repair nerve tissues and, as a result, help restore nerve damages.[25]

8. CHALLENGES AND FUTURE PERSPECTIVES

Although egg yolk oil-loaded electrospun nanofibers showed good potential, the addition of egg yolk oil should not exceed a certain threshold, and appropriate conditions for electrospinning should be designed to prevent early phase separation and degradation of egg yolk oil before forming the electrospun nanofibers. Due to the popularity of egg yolk oil application, egg yolk oil is a natural product, which must pass the safety and suitability verification of each process for medical application, and the large-scale preparation of egg yolk oil-loaded nanofibers also encounters the comprehensive generalization of the formulation and the electrospinning process.

Further studies on egg yolk oil for tissue regeneration can be conducted in the future by improving the formulation, mechanical properties, and long-term effects. Moreover, synergistic effects can be achieved in promoting tissue healing by supplementing egg yolk oil with other bioactive molecules.

9. CONCLUSION

Electrospun nanofibers loaded with egg yolk oil show great potential for tissue engineering due to the balance between the excellent mechanical structure of nanofibers and the biological activity of egg yolk oil. This novel technique shows promise for tissue regeneration in many uses, including wound healing, bone, and nerve regeneration. Yet, additional studies are required to mitigate the obstacles associated with the stability of formulations, scalability, and regulatory clearance prior to these nanofibers being applicable in clinical settings.

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