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Effect of voltage and distance in electrospinning of Gelatin

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Abstract

Gelatin is a natural polymer with strong polarity. It has molecular chains connected through strong hydrogen bonds, constituting a 3D macromolecular network. Because of its many merits, such as its biological origin, biodegradability, biocompatibility and commercial availability at relatively low cost, gelatin has been widely used in the pharmaceutical and medical fields. Electrospinning is a simple and versatile technique to generate nano to micrometer fibrous structures which are very similar to the natural febrile extracellular matrix (ECM). Morphology of electrospun fibers depends on solution, device and environmental parameters. Then in this research, we electrospinning 9 samples in different device conditions 3 different voltage (10,12,15 kV) and 3 different distance (distance between nozzle to collector: TCD) (10,15,20 CM). we surveyed FIBERS CHARACTERISTICS in device electrospinning parameter by SEM and FTIR tests that they observed nanofibers in the average standard deviation of them were 10-15% and their range varies also were between 79 to 139. and I also understood by increasing the voltage as well as the TCD, more fibers can be obtained with less beads and more uniformity.

Keywords: Electrospinning, Gelatin, Nanofibers.

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1. Introduction

Gelatin is an important natural polymer with strong polarity [1]. It has molecular chains connected through strong hydrogen bonds, constituting a 3D macromolecular network (double or triple helix) with reduced mobility [2,3]. Because of its many merits, such as its biological origin, biodegradability, biocompatibility and commercial availability at relatively low cost, gelatin has been widely used in the pharmaceutical and medical fields [4,5]. One of the main reasons for using Gelatin compared to collagen is that the triple helical structure is broken and thus the R-G-D sequence is much better exposed which may be somehow hidden in the collagen triple helical structure. Therefore, using Gelatin instead of collagen can be beneficial because it is denatured and short, and it promotes cell adhesion, migration, differentiation, and proliferation in the field of tissue engineering applications [6,7,8]. In some previous studies, scaffolds including Gelatin were prepared to obtain desired porosity and biocompatibility for soft tissue engineering [9]. Electrospinning is a simple and versatile technique to generate nano to micrometer fibrous structures, which are very similar to the natural febrile extracellular matrix (ECM) [10]. This process involves applying an electric field to draw solution continuously from the needle to the collector plate [11,12]. Morphology of electrospun fibers depends on solution, device and environmental parameters [10,13,14].

Tao Li and his colleagues surveyed electrospinning strategies such as blend, emulsion and coaxial electrospinning on gelatin for wound healing and skin regeneration applications [1]. Hongrang Chen and coworkers repaired skin of mouse with PLA/Gelatin nanofibers by using electrospinning device [15]. Yuliet Montoya and colleagues surveyed physicochemical properties of PLA/Gelatin electrospinnig scaffold [16].

2. Materials and Methods

2.1. Preparation*, characterization and quantification of nG(nano fiber Gelatin):*

The solutions with 27% (w/v) gelatin content, were prepared by dissolving 27% gelatin powder (type A, Bio Reagent with code G1890 from porcine skin was purchased from SIGMA ALDRICH) in 5cc acetic acid (66%) (was also purchased from SIGMA ALDRICH) and 5cc deionized distilled water (from HYDRO PARS KIMIA of IRAN) . then the solution was stirred at room temperature for 1h for making a homogenous solution. this solution was later used for electrospinning.

2.2. Electrospinning *of gelatin nanofibers:*

The polymer solution was taken in a 3 ml syringe with a blunt-end needle and loaded in the electrospinning setup. The polymer solution was electrostatically drawn from the tip of the needle by applying a high voltage between the tip of the needle and the grounded target (collector) using high-voltage power supply (Gamma High Voltage, IRAN). The flow rate of the solution was kept at 0.6 ml h−1, we used three voltages (10 kV,12 kV,15 kV) and the needle tip and collector distance (air gap) at 5,10,15 cm. Nano scaffolds of gelatin were electrospun using standardized electrospinning conditions as above in many time. finally, nanofibers were spinning at room temperature for 15 min [2].

2.3. SEM*:*

The morphology of Gelatin nanofibrous scaffolds was studied by SEM. To improve the sample conductivity, scaffolds were coated with gold, using a sputter coater. The diameter of the fiber was measured manually from SEM micrographs using the text/multi-point measurement tool in the SEM. The size and distribution of prepared gelatin nanofibers (nGs) were analyzed using Scanning electron microscopy (SEM) (XL30 Philips microscope) with Atlas Tescan software for image analysis.

2.4. FTIR*:*

Fourier transform infrared spectroscopy (FTIR) was used to identify the chemical structure of nanofibers. The spectral scan was carried out from 600 to 4000 cm−1 and 4 cm-1 resolution using an IR-spectrometer (IRAFFINITY-1 (SHIMADZU company)

3. Result

3.1. Morphology *of Gelatin/Nanofibers Scaffold:*

This process involves applying an electric field to draw solution continuously from the needle to the collector plate [11,12]. Morphology of electrospun fibers depends on solution, device and environmental parameters [4,17,14]. As Sander and coworkers used Acetic Acid for solvent and its effect on morphology of electrospoun fibers, we also used Acetic Acid solution to 1to2[18]. In this research, as you can see SEM figures of nanofibers scaffold in Fig1, we electrospinning 9 samples in different device conditions (voltage &distance between nozzle to collector(TCD). In this research we used 3 different voltages (10,12,15 kV) and 3 different distance (10,15,20 Cm) that in below we survey their analyses:

Table1: Electrospinning Results

Sample No	Average Diameter	Standard Deviation	Voltage	Distance
1	**116.3**	**40.03**	**10**	**10**
2	**118.4**	**14.54**	**12**	**10**
3	**139.9**	**29.74**	**15**	**10**
4	**0**	**0**	**10**	**15**
5	**79.63**	**9.69**	**12**	**15**
6	**129.8**	**22.53**	**15**	**15**
7	**0**	**0**	**10**	**20**
8	**101.9**	**11.8**	**12**	**20**
9	**138.7**	**29.48**	**15**	**20**

In voltage 10 kV and distance 10 cm (Fig A) you see nanofibers with full of beads. Although when we increased distance to 15 ,20 cm we did not have nanofibers and nanofibers did not form that It can be applied due to low voltage, which increases the gap between the nozzle and the collector (Fig B, C). Figure A, D, G shows 10 centimeters TCD in different voltages. In voltage 10 V, nanofibers were full of beads. Which beads decrease with the increase in the voltage in the scaffold, which can be due to the low flow rate, which is formed by increasing the steady state flow rate in the fibers and the scaffold [18]. The mean standard

deviation of the nanofibers is 10-15% and their range varies between 79 to 139. As shown in Fig. H, I, at the 15 v voltage and 15, 20 cm TCD, the fibers are produced with lower beads and more uniformity by increasing TCD. At 12 volts with distances of 15 and 20 cm, the shape is E, F. The fibers are formed with a minimum of beads and uniformity, with fibers having a lower diameter in 20 cm than 15 cm, which is probably due to the effect of increased viscosity and the corresponding electrical forces [19]. table1 shows different conditions characteristics of electrospinning.

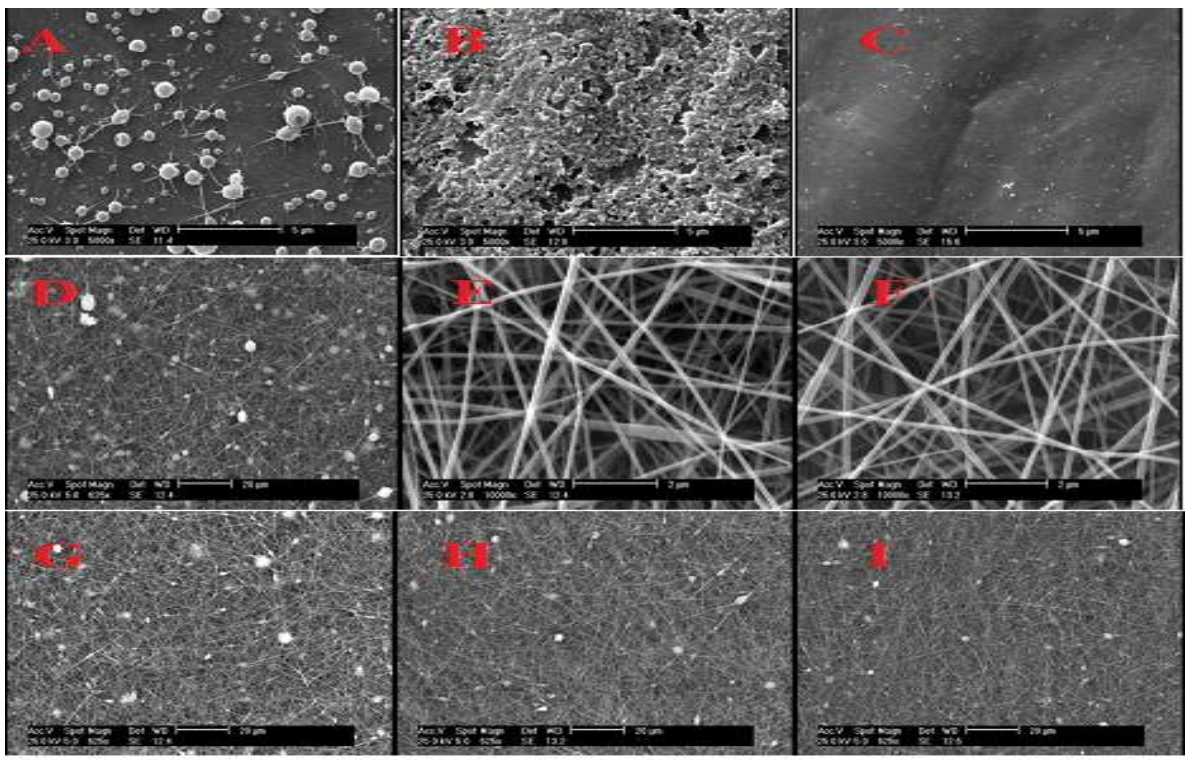

Figure 1: A:Voltage :10 kV,TCD:10 cm-B:Voltage:10 kV,TCD:15cm-C:Voltage:10 kV,TCD:20 cm D:Voltage:12 kV ,TCD:10 cm-E:Voltage :12kV,TCD:15cm-F:Voltage:12 kV,TCD:20 cm G:Voltage:15 kV,TCD:10 cm-H:Voltage15 kV,TCD:15 cm-I:Voltage:15 kV,TCD:20 cm.

3.2. *Fourier* transform infrared (FT-IR) spectroscopy:

Fig.2 reports the FTIR spectra of gelatin scaffold prepared from acetic acid/water solution. The FT-IR spectrum of gelatin showed many bands that we report in table 2 in below. These bands consists 3443 cm−1 due to N–H stretching of amide bond, C–H stretching at 2925 cm−1, C=O stretching at 1635 cm−1 , the bands at 1383 cm−1 and 1444 cm−1 arise from C–C bond and methyl group C–H bond of gelatin respectively. Among them, the amide I band is caused by C-O stretching vibrations of peptide linkages in the backbone of protein and the amide II band is caused by the combination of N–H in plane bending and C–N stretching vibrations and N–H out-of-plane wagging at 610 cm−1[20,21].

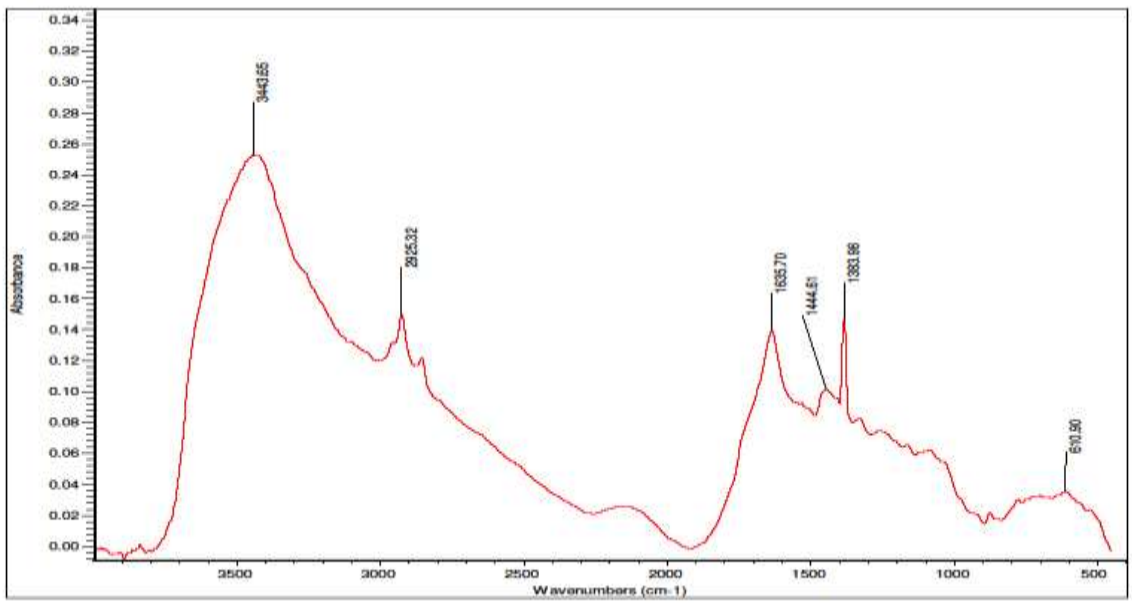

Figure. 2. FT-IR of gelatin scaffold (27 wt.% in 50% acetic acid ,20% water) mixed at 50:50 (v/v) ratio].

Table2: ATR-FTIR of Gelatin Peaks and Band Assignments

Peak Position (CM−11)	Band Assignment
610	–
1383	– CH_3
1444	C–C Stretch
1635	Amide I (C=O Stretch)
2925	– CH Stretch
3443	O–H Stretch , NH Stretch

4. conclusions

The minimum voltage for electrospinning gelatin nanofibers is 10 KV at a TCD of 10 cm. By increasing the voltage as well as the TCD, more fibers can be obtained with less beads and more uniformity and finally we achieved smaller diameter fiber in voltage 12 KV and TCD 20 cm. The average standard deviation of the nanofibers is 10-15% and their range varies between 79 to 139.

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