Saba Saifoori, Mahshid Fallah-Darrehchi, Payam Zahedi* and Abdolmajid Bayandori Moghaddam

Fabrication of random and aligned-oriented cellulose acetate nanofibers containing betamethasone sodium phosphate: structural and cell biocompatibility evaluations

DOI 10.1515/polyeng-2016-0134
Received April 14, 2016; accepted February 1, 2017

Abstract: The objective of this work was to prepare electrospun cellulose acetate (CA) nanofibers containing betamethasone sodium phosphate (BSP). Two different morphologies including random and aligned orientations were rationally designed to improve the performance of samples in in vitro experiments. By comparing the CA nanofibrous samples with randomly and aligned-oriented morphologies, the scanning electron microscopy images showed that the neat aligned-oriented nanofibers with an average diameter of 180 ± 15 nm could be obtained using a high-speed rotating collector. Subsequently, the tensile test confirmed that the aligned CA nanofibers had higher mechanical properties than that of the randomly oriented ones. Moreover, the BSP release profile obtained by UV-vis spectrophotometry depicted that the aligned samples had an initial burst release of BSP followed by a slow penetration of the drug with a gentle slope during 72 h. Furthermore, the ultimate amounts of BSP released from the random and aligned CA nanofibers into the phosphate buffer solution were 63% and 53%, respectively. Finally, human adipose-derived mesenchymal stem cells were seeded on both aligned and random electrospun CA nanofibrous samples containing BSP. The thiazolyl blue and hematoxylin and eosin staining results showed that the BSP-loaded nanofibers with the aligned morphology provided the most suitable environment for the cells’ growth, viability, and proliferation.

Keywords: Betamethasone sodium phosphate; cellulose acetate; cell viability; drug release; nanofibers.

1 Introduction

Currently, using highly dominant drugs classified in the corticosteroids family is an inevitable issue for the scientists in their research. Among these drugs, betamethasone sodium phosphate (BSP) is a well-known anti-inflammatory and immunological drug that has been encapsulated into nanoparticles such as functionalized silica, zinc oxide (ZnO), and poly(lactic-co-glycolic) acid/poly(lactic acid) (PLGA/PLA) by a number of researchers to have a better control on the drug release profile [1–4]. However, electrospinning has recently turned into the most favorable technique for large-scale fabricating nanofibers. It provides the opportunity to adjust nanofibers diameters in the range of nanometers to micrometers. Therefore, electrospinning is considered as one of the most promising methods for generating nanofibers as versatile materials in the field of biomedicine [5–8].

Among nanocomposites and nanomaterials based on biopolymers, cellulose and its derivatives have been the subject of much interest because of their prevalence and abundance [9]. Cellulose acetate (CA) covers an extensive range of nanofibrous applications including membranes [10, 11], wound dressings [12, 13], filter media [14, 15], cosmetics [16, 17], biosensors [18], nanomaterial-loaded antimicrobial mats [19], and tissue engineering [20, 21]. Amid various applications of biodegradable and biocompatible polymer-based nanofibers, their use has recently attracted a great deal of attention for cell repair and tissue regeneration. By culturing diverse types of cells on the electrospun scaffolds such as osteoblast cells [22], fibroblast cells [23], Schwann cells [24, 25], stem cells [26, 27], and so forth, researchers have found that these nanofibrous materials are potentially suitable for tissue engineering purposes.
Recently, Vatankhah et al. [28] investigated CA/gelatin nanofibrous scaffolds seeded with human dermal fibroblast cells and revealed their adequate adhesion to the samples. Also, Luo et al. [29] explored the biocompatibility of multilayered CA nanofibers containing multiwalled carbon nanotubes by culturing L929 cells on them. The cells’ viability along with their adhesion proved that they could migrate to and penetrate matrices similar to natural extracellular matrices.

Interestingly, the alignment of nanofibers increases their mechanical stretching; this leads to an improvement in the growth and spread of cells. Also, it causes a suitable orientation of cultured cells on the aligned electrospun scaffolds [30–33]. The orientation of nanofibers can play a key role in controlling the drug release rate at the final stages [34]. Hom and coworkers [32] studied the effect of the alignment of nanofibers based on poly(ε-caprolactone)/chitosan/CA hybrids on the growth extent of cultured endothelial cells. Their findings exhibited that the alignment of the nanofibers had a remarkable effect on improving the growth of the cells. Moreover, Mirzaei et al. [35] found that the aligned topology could elongate the stem cells along the fibers, which led to better proliferation and also efficient differentiation to neuron-like cells. Continuously, Ranjbar-Mohammadi and colleagues [36] demonstrated the efficacy of alignment topology by providing biomimetic cues in contrast to random structure by culturing the neuroblast cells onto poly(L-lactic acid)-based nanofibers surfaces.

Drug delivery systems are used to promote remedial yield of drugs by delivering them at an appropriate rate pertaining to the physiological environments of a certain site over specific periods [37–39]. Based on these systems, CA has been used as a biodegradable and biocompatible drug carrier. Tungprapa et al. [40] evaluated the release behavior of CA films and CA nanofibers loaded with four different drugs including naproxen, indomethacin, ibuprofen, and sulindac. Compared with CA films, the ultimate amounts of the released each drug were greater in CA nanofibers. They concluded that CA nanofibers were more desirable drug carriers than CA films. In another work, Suwantong and coworkers [41] used curcumin-loaded electrospun CA fiber mats as carriers for topical and/or transdermal drug delivery. They also measured the release of curcumin through a total immersion method for both film- and nanofiber-based CA. Their results showed that electrospun CA nanofibers were more advantageous than CA films. Furthermore, Kontogiannopoulos et al. [42] fabricated Shikonin/Alkannin-loaded CA nanofibers. They observed that the addition of the drugs had no effect on the morphology of the nanofibers. The release trend of the nanofibers showed a rapid initial drug release followed by a slower second stage to the point that after 48 h, it reached a plateau. Therefore, CA nanofibers can be considered as potential candidates for tissue regeneration scaffolds. By searching in the literature, it was found that Yu et al. [43] prepared ketoprofen-loaded CA nanofibers, coated with a layer of blank CA to omit initial burst release. The modified nanofibers offered a better zero-order kinetic model for the drug release. Gouda and coworkers [44] used CA nanofibers loaded with tetracycline to investigate their antibacterial properties. They found out that the incorporation of tetracycline caused a 77%–88% bacteria (Escherichia coli) reduction during a 1-h period as well as an 83%–85% reduction of Staphylococcus aureus. On the other hand, Castillo-Ortega et al. [45] prepared amoxicillin-loaded CA/polyvinyl pyrrolidone nanofibers to study their potential as biological media by evaluating their thermal, mechanical, and morphological properties as well as their drug release characteristics in particular. They deduced that these nanofibers blends were a good alternative for treating dental or skin infections. Finally, Absar et al. [46] investigated the synthesis and processing of cellulose, CA, and poly(ethylene oxide) (PEO) nanofibers incorporating anticancer/tumor drug cis-diammine-platinum (II) dichloride (cisplatin) using electrospinning technique. They showed that the morphological development of the fibers and corresponding mode of drug encapsulation were correlated with process parameters such as applied voltage, concentrations, and relative feed rates of the solution and conductivities of the solvents.

Owing to numerous published research works with an emphasis on the topology of polymeric nanofibers, we aimed to investigate the extent of alignment effect on morphology and the number of cultured stem cells onto the surface of CA nanofibers. Moreover, we decided to use an anti-inflammatory drug, BSP, to evaluate the influence of drug incorporation along with the aligned orientation and its release behavior through a physiological medium.

2 Materials and methods

CA (biodegradable, acetyl content 39.8%, molecular weight of 30 kDa) was obtained from Sigma-Aldrich Co. (St. Louis, MO, USA). Acetic acid (glacial grade, 100% anhydrous) was purchased from Merck Millipore, Germany. This acid and deionized water were mixed by volume. The mixed solvent containing acetic acid/water at a ratio of 75:25 by volume was abbreviated to acetic acid/water (75:25). BSP (Scheme 1) (formula: C_{22}H_{28}FNa_2O_8P, a water-soluble white

2   Materials and methods

CA (biodegradable, acetyl content 39.8%, molecular weight of 30 kDa) was obtained from Sigma-Aldrich Co. (St. Louis, MO, USA). Acetic acid (glacial grade, 100% anhydrous) was purchased from Merck Millipore, Germany. This acid and deionized water were mixed by volume. The mixed solvent containing acetic acid/water at a ratio of 75:25 by volume was abbreviated to acetic acid/water (75:25). BSP (Scheme 1) (formula: C_{22}H_{28}FNa_2O_8P, a water-soluble white
powder) was donated from DaruPakhsh Co., Iran. The other chemicals were analytical reagent grade and used without further purification.

Weighed BSP powder was dissolved in mixed acetic acid/water (75:25) solution. Afterward, weighed CA powder was also added gradually to the mixture until a uniform solution was attained. Eventually, a 19% (w/v) solution of CA containing 300 μg/ml BSP was obtained at room temperature. According to the literature [47], to prepare the nanofibrous samples using the electrospinning device (model Full Option Lab ES, Nanoazma Co., Tehran, Iran), the operation parameters were adjusted as follows: gauge needle tip diameter of the syringe, 0.7 mm; applied voltage, 19.5 kV; distance between the syringe needle tip and the rotating collector, 15 cm; and solution flow rate, 1 ml/h. To generate the random and aligned-oriented samples, the rotating collector speeds were set at 400 and 3000 rpm, respectively.

The morphology observation of the prepared nanofibrous samples was studied by using a scanning electron microscope (SEM) (model AIS 2100; Seron Technology, South Korea) at 15,000× magnification. First, the samples were initially coated with a thin layer of gold using a sputter coater (model Emitech K450X, United Kingdom). Then, their average diameters were measured by applying image analysis software (ImageJ). Eventually, size distribution curves were plotted by Origin 8.5 software. For reducing the statistical errors and calculating standard deviation (SD) for average diameter of the nanofibers, the diameters of five different sections for each sample were measured.

The mechanical properties of the aligned and randomly oriented nanofibrous samples were measured using Instron model 5566 (Amersham, United Kingdom) according to ASTM D 882-02 to report the Young’s modulus, yield stress, and elongation at break. The operating conditions were as follows: the cross-head speed for the samples extensions was 10 mm/min and the gauge distance was 40 mm. For each sample, three measurements were done and the SD was less than 5%.

To determine BSP release rate from the nanofibrous samples, a UV-vis spectrophotometer (model 2800, UNICO, United States) was used. The calibration curve of BSP at its absorbance wavelength of 241 nm was plotted with a regression coefficient (r²) of 0.99 according to the Beer-Lambert law represented by Equation (1):

$$A(\text{BSP}) = \varepsilon \times I \times C = 0.03391 \times C$$  \hspace{1cm} (1)

where “A” is the amount of absorbance, “ε” is the extinction coefficient of BSP, and “I” is the distance that light travels through the material.

The molar extinction coefficient for the BSP (an anti-inflammatory drug) in distilled water was found to be 17,511.12 (l mol⁻¹ cm⁻¹) for 1 cm of the linear Beer-Lambert curve. Adsorption occurred at 241 nm on the basis of concentration.

Equation (2) indicates the relation between cumulative amounts of drug release from the nanofibrous samples into phosphate buffer solution (PBS) and release time. For the statistical information, the results were repeated three times and data with an error bar of less than 5% were reported. Moreover, a key role to explain how the drug could be released from the nanofibers with different morphologies is their porosity. Accordingly, Equation (3) is usually used to calculate this parameter for the samples [48]:

$$\text{Cumulative release percentage } = \frac{\sum_{t=0}^{t} M_t}{M_0} \times 100,$$  \hspace{1cm} (2)

$$\text{Porosity } (%) = 100 \times \left(1 - \frac{\rho}{\rho_0}\right),$$  \hspace{1cm} (3)

where “M₀” and “Mₜ” are the initial weights of the drug loaded onto the samples and the cumulative amounts of BSP released at each sampling point, respectively. For reducing the statistical errors and calculating standard deviation (SD) for average diameter of the nanofibers, the diameters of five different sections for each sample were measured.

The mechanical properties of the aligned and randomly oriented nanofibrous samples were measured using Instron model 5566 (Amersham, United Kingdom) according to ASTM D 882-02 to report the Young’s modulus, yield stress, and elongation at break. The operating conditions were as follows: the cross-head speed for the samples extensions was 10 mm/min and the gauge distance was 40 mm. For each sample, three measurements were done and the SD was less than 5%.

For further evaluation of the random and aligned CA nanofibers with and without BSP, human adipose-derived mesenchymal stem cells (hADSC) were selected and cultivated on the surfaces of the samples. Regarding this test, the following recipe was applied to investigate the cells’ proliferation and their viability. Briefly, after the cells reached a suitable numerical value of approximately 25 × 10⁵ cells/ml, they were seeded on the nanofibrous samples in 24-well and 6-well plates to study their morphology, viability, and hematoxylin and eosin (H&E) observation. Afterward, in regard to in vitro cell morphology studies, the nanofibrous samples were sterilized under UV light for 3 h and placed on a 24-well...
plate. Subsequently, the cells with numerical values of $5 \times 10^5$ cells/ml were seeded on the surfaces of the samples and later they were washed by PBS after 3 days and fixed with 4% formaldehyde for 24 h at 4°C. The SEM test was carried out at 1500× and 3000× magnifications to observe the cells’ morphology on the nanofibers surfaces. To prepare the samples, after fixing, they were dehydrated by immersing into ethanol/distilled water mixtures with concentrations varying from 50% to 100%, increasing 10% each time, at 10-min intervals. The cytotoxicity of the electrospun nanofibrous samples was characterized at day 7 by using 3-[4,5-dimethyl thiazol-2-yl]-2, 5-diphenyl tetrazolium bromide, thiazolyl blue (MTT) according to the following steps: first, the cells’ feed environment, Dulbecco’s modified Eagle’s medium (DMEM-F12), was replaced with MTT and the recovery process was carried out by succinate dehydrogenase – which becomes activated in live cells – in an incubator at 37°C for 3 h. During this process, MTT converted to a dark-blue product (formazan). As the samples were inside the 24-well plate for cell culture, 200 μL dimethyl sulfoxide was added to each well until formazan crystals were dissolved. The optical density of the formazan solution was detected using an ELISA reader (Dana 3200, Iran) at 570 nm. To observe the cells’ morphology, the sterilized nanofibrous samples were placed inside a Jam lamella coated with poly-L-lysine (to enable the cells to attach to the lamella’s surface). The samples that attached to each lamella were carefully placed in the 6-well plate and the cells (numerical value of $2 \times 10^5$ cells/ml) were seeded on the nanofiber surfaces. After a 3-day period, the cells were washed by PBS and then fixed with ethanol 70% (v/v) for 10 min. Subsequently, the nanofibers containing the cells were placed into the H&E solution for staining. The cells’ observation was carried out through optical microscopy (BX-51, Olympus, Japan) with a scale bar of 50 μm.

3 Results and discussion

Before discussing the different analyses in this work, it should be noted that our goals can be listed as follows: (1) regarding the morphology of the electrospun CA nanofibrous samples in both random and aligned orientations, it is essential to show the role of BSP in the mean diameter change of CA nanofibers, their uniformity, and the orientation ratio of the samples with aligned topography; (2) in regard to mechanical properties, the important results, such as Young’s modulus, yield stress, and elongation at break of the random and aligned CA nanofibers, are compared; (3) toward the drug release, the effect of alignment on the surface porosity of the nanofibrous samples and concentration of BSP influencing its release from the samples into the PBS environment are investigated; and (4) after determining the best sample, it is evaluated for in vitro cell growth and proliferation after a specific incubation time treatment. To confirm these above claims, we discuss the analyses in detail. Moreover, by following up the literature, it was found that BSP release has been abundantly considered by using its encapsulation into different organic and polymeric nanoparticles, whereas there have been neither reports about BSP-loaded electrospun CA nanofibers nor their release studies with an emphasis on alignment morphology.

Figure 1A–D shows the SEM micrograph images of the samples as follows: the neat electrospun aligned CA nanofibers (A), the BSP-loaded electrospun aligned CA nanofibers (B), the neat randomly oriented CA nanofibers (C), and the BSP-loaded randomly oriented CA nanofibers (D). By considering Figure 1A,C, an increase in the speed of the rotating collector led to a reduction in the nanofiber diameters and caused the formation of highly oriented CA nanofibers with orientation ratio in the range of 0.25–0.3 [49], making them more suitable for cell culture. Due to high-speed rotation of drum and CA nanofibers stretching, the mean diameters of the samples in random and aligned morphologies were calculated as 220 ± 30 nm and 180 ± 15 nm, respectively. On the other hand, BSP incorporation into the electrospun aligned CA nanofibers resulted in an increase in the average diameter from 220 ± 30 nm to 250 ± 30 nm (Figure 1A,B).

To provide a correlation between the mechanical properties of CA nanofibers and their potential for biomedical applications such as cell growth and proliferation as well as drug loading, the tensile of the aligned and randomly oriented nanofibrous samples were measured to monitor the Young’s moduli, yield stress, and elongation at break. Figure 2 indicates the load-extension curves for the random and aligned nanofibrous samples. As it can be seen from Table 1, the Young’s modulus of the aligned nanofibers (~1.1 MPa) was higher than that of the random nanofibers (~0.9 MPa) owing to the longitudinal orientation of a large number of CA nanofibers in aligned shape. Additionally, the elongation at the break for the aligned sample (~10.3%) was greater than that of the random sample (~5.3%), confirming the higher ultimate rupture of the aligned CA nanofibrous sample along the longitudinal stress direction. From the stress-strain test, it can be concluded that the orientation distribution of the nanofibers significantly enhanced their mechanical properties.
BSP is an anti-inflammatory and hydrophilic drug; a characteristic that can be a significant criterion for its release in PBS. Owing to the hydrophilic property of BSP, it tends to immigrate from the CA nanofibers’ bulk to their surface and penetrates to the PBS as a polar medium. To control the drug release, two types of electrospun CA nanofibers (aligned and random) containing BSP were prepared and their release profiles as well as the drug calibration curve are represented in Figure 3A,B. As it can be seen, at the first stage up to 10 h, a large number of drug molecules near the surface of the nanofibers exited from the nanofibers into the PBS and led to an initial burst release. At the second stage, after 10 h, in both samples, the released BSP showed trends with a gentle slope because most of the drug content was released into the PBS during the first stage and the residual drug moved gradually from the bulk to the surface of aligned and random samples and then diffused out. Because alignment enhances the density and decreases the porosity of nanofibers, the drug released from the aligned nanofibers is less than that of the random ones into PBS. The porosity of the samples is one of the main factors to explain the rate of the drug molecule diffusion from the CA nanofibers with random and aligned topographies, which were calculated as $82 \pm 4$ and $75 \pm 2$. 

Figure 1: SEM micrographs of CA nanofibrous samples with 19% (w/v) solution concentration of (A) neat aligned nanofibers, (B) BSP-loaded nanofibers, (C) neat random nanofibers, and (D) BSP-loaded nanofibers (scale bars, 3 μm).

Figure 2: Load-extension curves of the electrospun CA nanofibrous samples (black solid line) aligned orientation and (red solid line) random orientation.
These results confirmed that the higher porosity of the nanofibers led to an increase of the drug molecule diffusion. As a result, the aligned CA nanofibers showed a controlled BSP release compared with randomly oriented nanofibrous samples. Consequently, the drug release rate of aligned nanofibers was lower than that of randomly oriented nanofibrous samples; a characteristic that made the aligned nanofibers plausible candidates for cell culture and proliferation. Accordingly, the ultimate BSP released from the random and aligned CA nanofibers into PBS were 63% and 53%, respectively.

Figure 4A–E depicts the morphologies of hADSCs proliferated on the random and aligned neat and BSP-loaded electrospun CA nanofibers. Evidently, the extent of proliferation and configuration of the cells could be observed on the surfaces of neat electrospun random CA nanofibers (Figure 4A), the BSP-loaded electrospun random CA nanofibers (Figure 4B), the neat electrospun aligned CA nanofibers (Figure 4C), the BSP-loaded electrospun aligned CA nanofibers (Figure 4D), and the cells cultured in DMEM-F12 environment (control; Figure 4E) after a 3-day incubation period. The objective was to evaluate the ability of the prepared samples to provide the stem cells with a suitable environment for complete growth and proliferation as a function of the fibers’ alignment. As it can be concluded from Figure 4A,B, the drug used in the random CA nanofibers led to a remarkable proliferation of the cells in both longitudinal and transversal directions. Consequently, although BSP is classified as an anti-inflammatory drug, it exhibits a promising effect on the growth of cells. On the other hand, the cell growth and proliferation onto the surface of the drug-loaded electrospun aligned CA nanofibers were higher than that of the neat samples (Figure 4C,D). This was possibly because the presence of BSP enhanced cell adhesion by modifying cell surface glycoproteins, leading to a decrease in cell migration. Moreover, the cells cultured on the aligned nanofibers possessed integrity and showed better adhesion. Comparing the neat random and aligned samples, the fiber alignment has an effective role on longitudinal proliferation of the cells (Figure 4C). The results revealed that both the presence of the drug and the nanofiber alignment had a tremendous effect on the cells’ proliferation; the effect of the alignment of CA nanofibers on cells proliferation and integrity was more significant. In conclusion, it was clear that the best sample for a complete hADSC was the aligned electrospun CA nanofibers, in which the cells could grow sufficiently compared with other samples during 3 days of incubation time. Concerning the thickness of the samples, they were 700–900 μm in thickness and thus the stem cells were able to proliferate through the surfaces of the samples, especially those with the alignment containing BSP.
critical point was evidence that there was a slight configuration in fiber alignment for the sample loaded by BSP after the incubation time owing to the deacetylation reaction [47] during 3 days. This observation was related to the CA fibers’ alignment changes and their morphologies were converted to randomness status in the DMEM-F12 as a feed medium of the cells.

Figure 5 portrays the UV absorbance of the stem cells at 570 nm, illustrating their viability after 5 h (~day zero), 3 and 7 days of culture on the neat random electrospun CA nanofibers, BSP-loaded random electrospun CA nanofibers, neat aligned electrospun CA nanofibers, and the drug-loaded aligned electrospun CA nanofibers, respectively. It can be concluded that the cells’ viability on the BSP-loaded aligned electrospun CA nanofibers was higher than that of other samples. Afterward, the quantitative values of MTT test regarding the number of cells on the nanofibrous samples at day 7 can be conveyed as follows: numerical values of hADSC on the neat random electrospun CA nanofibers, BSP-loaded random electrospun CA nanofibers, neat aligned electrospun CA nanofibers, and the aligned drug-loaded electrospun CA nanofibers were $1.2 \times 10^5$ (60%), $1.68 \times 10^5$ (84%), $1.36 \times 10^5$ (68%), and $1.8 \times 10^5$ (90%) cells/ml, respectively.
However, cell viability on the surface of the BSP-loaded aligned CA nanofibers was still 90% of the control ($2 \times 10^5$ cells/ml, 100%).

The results discussed above were confirmed by optical microscopy images of the H&E-stained cells on the surfaces of the prepared nanofibrous samples, as shown in Figure 6A–D. Figure 6A shows that the cells’ nucleus was formed whereas the cells did not spread sufficiently throughout the surface of the neat random CA nanofibers. Conversely, the other samples showed interesting results regarding the number of cells’ nucleus and their colony areas. To better clarify, the cells’ cytoplasm and their formed colonies were marked by solid black curves. As expected, aligned CA nanofibers containing BSP possessed a larger colony with a higher accumulation of cells (Figure 6D).

### 4 Conclusion

During this work, neat and drug-loaded random and aligned CA nanofibers were engendered through an electrospinning process. SEM test was carried out to investigate the morphological suitability of the electrospun nanofibers. Micrographs of the drug-loaded CA nanofibers showed a uniform morphology without

![Figure 5: Effect of BSP (300 μg/ml) on randomly oriented and aligned-oriented electrospun CA nanofibers with and without the drug on hADSC viability after 0, 3, and 7 days.](image)

![Figure 6: Optical microscope photographs from grown hADSC after 3 days on (A) neat random CA nanofibers, (B) BSP-loaded random CA nanofibers, (C) neat aligned CA nanofibers, and (D) BSP-loaded aligned CA nanofibers (with 400 × magnification, comparing the pink spots on the micrographs, which are signed by black arrows).](image)
beads, confirming that the electrospinning process conditions were desirable. The mechanical strength of CA nanofibers was reinforced due to alignment. BSP release from the random and aligned nanofibers to physiological environment, PBS, were compared during a 72-h period. Eventually, the alignment of the nanofibers caused a more controlled drug release at the final stages of drug release owing to the lower porosity in their structure. Mesenchymal liver stem cells were cultured on the samples to evaluate the effect of orientation of the fibers on cell growth and adhesion. SEM and MTT results indicated that proliferation and adhesion of the fibers on cell growth and adhesion. SEM and MTT results revealed that aligned BSP-loaded electrospun CA samples. Furthermore, these results were confirmed by nuclei and cytoplasm H&E staining. In conclusion, the results reveal that aligned BSP-loaded electrospun CA nanofibers can be a promising material for a wide range of biomedical uses.

References


