Experimental Cell Research 347 (2016) 60–64

Contents lists available at ScienceDirect

Experimental Cell Research

journal homepage: www.elsevier.com/locate/yexcr

Research article

# A new design for electrospinner collecting device facilitates the removal of small diameter tubular scaffolds and paves the way for tissue engineering of capillaries

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ARTICLE INFO

*Article history:*
Received 27 May 2016
Received in revised form
10 July 2016
Accepted 13 July 2016
Available online 19 July 2016

*Keywords:*
Electrospinner
Scaffold
Nanofiber

ABSTRACT

Electrospinning is a technique widely used for tissue engineering. Despite hurdles, electrospun vascular tissue scaffolds has shown great promise in *in vitro* studies. One problem is the removal of tubular scaffolds from a electrospinning collection device with no unwanted crumpling or tearing, especially for small diameter scaffolds. To tackle this problem we designed a collection device for simple removal of the scaffold from the collector while no chemical pretreatment was required. The scaffolds fabricated on this collecting device maintained their tubular structure and showed favorable surface properties, mechanical strength and biocompatibility. The device offers a new opportunity for tissue engineering researchers to fabricate tubular scaffolds from materials which have not been possible to date and help them improve the quality of synthesized scaffolds.



## 1. Introduction

Electrospinning is broadly used for fabrication of tissue-engineering scaffolds [1,2], mainly due to the unique features of electrospun fibers and the diversity of electrospinnable materials [3]. The method has been applied for spinning different tubular-shaped polymers, subsequently used as substitutes for blood vessels [4,5]. The method is based on using high voltage electricity for deposition of polymer solution or melt as a non-woven scaffold on the surface of a collector [6]. However, particularly for tubular-shaped scaffolds with small diameter, polymers may adhere to the surface of the collector due to the remaining solvent in their structure, resulting in crumpled and creased scaffolds after their stripping from the collector. This problem destructs the scaffold's natural texture and causes its tearing. Electrospinning conditions and solvent composition are determining factors in morphology, structure, diameter and mechanical and thermal properties of fibers [7–9]. Crumpled and broken structures cause the loss of mechanical strength of the scaffold [2]. Hence, a few approaches have been suggested that tackle the problem and facilitate the removal of electrospun scaffolds from the surface of the rod-shaped collectors. One method has been to use nonadhesive or less adhesive and smoother surfaces as collectors. Teflon coating or use of glass collectors are two approaches which have been used to facilitate the removal of tubular materials from mandrel [10]. This method needs extra treatments especially when the material sticks to the surface of the collector. Another method is to use a water soluble separating medium like polyethylene glycol (PEG) polymer. The medium is applied to the surface of the collector and dried before electrospinning. Dipping the collector in water solubilizes and removes the separating layer and the tissue is peeled off from the surface of the collector [11]. One problem is that using a separating medium may cause the adhesion of residual amount of the medium to the scaffold. Usually in this case removing these residues is not possible. Despite developing several methods to solve this problem, because of insufficiency of the currently available methods, novel, easier and more reproducible methods are necessary.

Described here is a collecting device, designed by our group, to easily fabricate and remove the scaffold from the surface of the collector. The device can be used on any electrospinning device which could adopt a rotating collector.

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http://dx.doi.org/10.1016/j.yexcr.2016.07.012
0014-4827/

## 2. Materials and methods

### 2.1. Collector and method of use

Collector was designed at SABZ Biomedicals Co. (Tehran, Iran). It consisted of two components: an inner rod-shaped bar with the diameter of 1 mm and total length of 25 cm and an outer tube with the diameter of 3 mm and the length of 20 cm. On one side of the outer tube a longitudinal groove with the length of 18 cm was made from one end to near the other end (Fig. 1), capable of passing aluminum foil through itself. The 2 cm region of outer tube with no groove strengthens the outer tube structure during rotation. Both parts of the collector were made from stainless steel. An aluminum foil at one end was stuck to the inner rod-shaped bar and rolled around it. A few millimeters of the other end of the foil were remained free (Fig. 1A). The inner rod-shaped bar was then inserted into the outer tube so that the free end of aluminum foil flanked out of the groove on the outer tube (Fig. 1B). Then the flanked segment of the foil was rolled around the outer tube and fixed with two clips (Fig. 1C and D). Afterwards, the assembled collector was used to spin a tubular scaffold. To remove the scaffold from the surface of the collector, we removed the collector from electrospinner, opened the clips and turned the inner rod-shaped bar counterclockwise one or two rounds (Fig. 1G). Then the scaffold was removed from the collection device. A video supplement detailing all the step from A to H is provided as the supplement file of this article.

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.yexcr.2016.07.012.

### 2.2. Fabrication of tubular electrospun scaffolds

We used a method previously described for preparation of nanofibrous scaffolds by electrospinning method [12]. 12% (w/v) solution of PLLA (sigma) in dichloromethane (Merck, Germany) was placed in a 5 mL syringe connected to a 21- gauge needle through an extension tube. The collector, described in the previous section, was used to collect the electrospun nanofibers in a distance of 15 cm from the needle. The solution was fed into the needle with a rate of 1 mL/h. A 20 kV-voltage between the needle and collector was applied to force the solution droplet to leave the needle and deposit on the collecting device in the form of ultrafine fibers. Having reached a thickness of about 200 μm, the material was detached from the collector as described in the previous

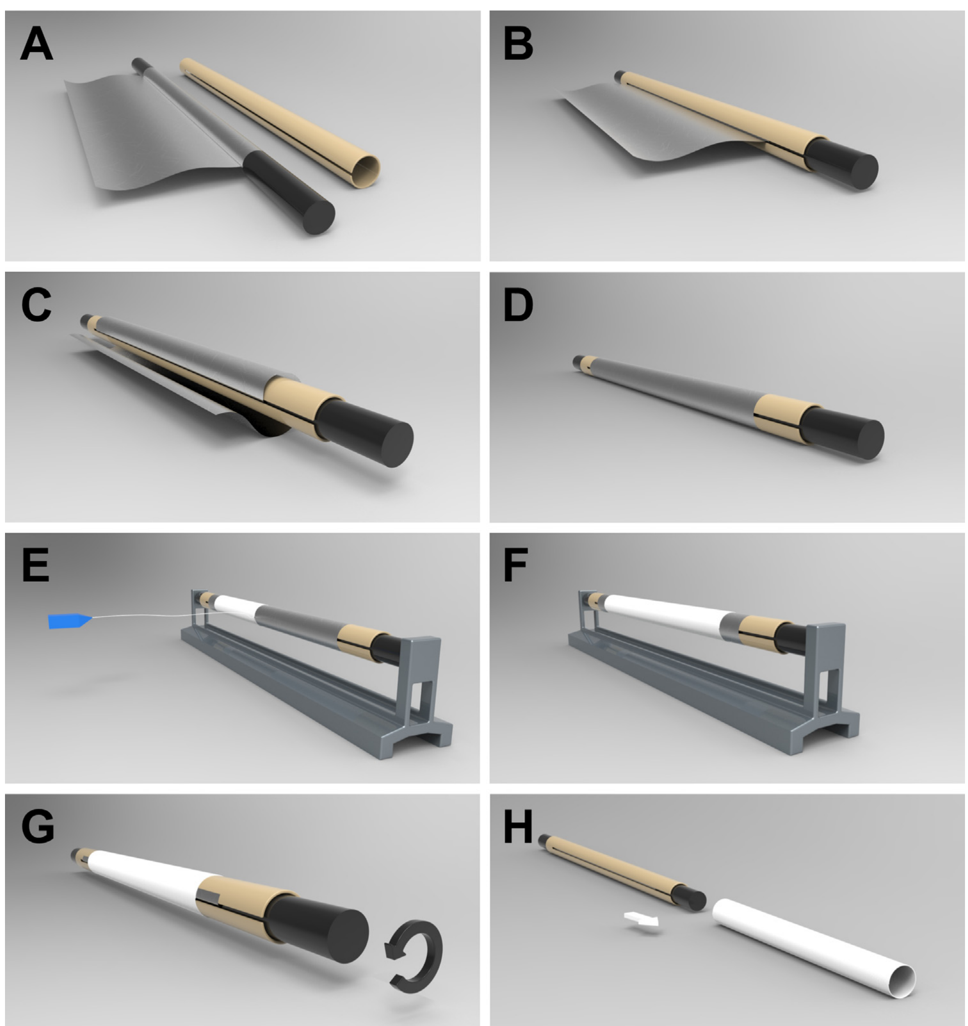


**Fig. 1.** Schematic representation of the device and the method of use; an outer tube with longitudinal groove (1A) and an inner rod-shaped bar to which an aluminum foil is attached at one end. The aluminum foil was then rolled on the inner axis (1A). The inner axis was then inserted into the outer tube so that the free end of the aluminum foil flanks out of the outer tube groove (1B). The foil was further rolled on the inner axis by turning of the inner axis (1B). The remaining free part of the foil (slightly longer than the outer diameter of the outer tube was rolled around the outer tube and fixed with two clips (1C). The collection device was placed in the electrospinning box and electrospinning was performed as described in the sections 1E and 1F. The collector was then removed from the electrospinning apparatus and the inner axis was turned for two rounds counterclockwise (1G), then the scaffold was released and removed from collector (1H).