The Effect of Bioglass Nanoparticles and Strontium Component on Tensile Strength of Polycaprolactone/Bioglass Electrospun Nanocomposites

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Abstract— Tissue engineering is a new approach for eliminating defects and bone damages. The goal of tissue engineering and tissue transplants, creating biodegradable scaffolds, fixing flaws and damaged bone tissue. Electrospun polycaprolactone-bioglass nanofiber composite scaffolds, excellent performance in cell attachment, proliferation and its influence. In this study, sol–gel derived glasses based on CaO–SrO–SiO2–P2O5 system were prepared. The results showed that the substitution of Sr for Ca in the glass, increased the mechanical Strength of nanofibers.
composition poly(ε-caprolactone)/bioglass were electrospun using a high DC voltage of 18 kV at a distance of 16 cm. SEM morphology of the PCL/BG electrospun nanocomposite revealed that bioglass nanoparticles were distributed in nanofibers during the electrospinning process. The results revealed that BG contains a higher percentage of strontium oxide increases significantly ($p < 0.05$) the tensile strength of composite than other BGS.

Keywords--- Bone tissue engineering, Scaffold, Bioactive glass, Polycaprolacton, Strontium

I. Introduction

TISSUE engineering is a new approach and multi-disciplinary field to replace or restore ill or damaged tissues of the human body, such as bones. Tissue engineering apply innovative and bioactive materials, which are capable of reacting with physiological fluids to form tenacious bonds to bone through the formation of bone-like hydroxyapatite layers [1]. Bioceramics such as calcium phosphate, hydroxyapatite and bioactive glasses and glass-ceramics are biocompatible, osteoconductive and osteointegrative materials that are extensively used as bone filler and bone tissue engineering scaffolds. Many studies have been done on these materials to improve their applied properties and clinical abilities [2]. Hong et al. [3] studied the effect of nanoparticulate BG-ceramic content on the properties of nanocomposite scaffolds, which exhibited improved mechanical properties. Strontium is one of ions that plays a key role in cell activation mechanisms by controlling many growth-associated processes and functional activities of cells. It enhances the replication of reosteoblastic cells, and simulates bone formation in calvarial cultures in vitro [2, 4]. The useful effect of Sr on bone formation and healing osteoporotic tissues has been extensively reported. It has been confirmed that Sr strengthens bone; increases bone mass and density due to its higher atomic weight in comparison with Ca and lessens the possibility of vertebral and hip fracture in elderly women[5, 6]. Sr is a bone-seeking element, and different compounds have served to provide Sr in bone metabolism studies [7]. This study deals with a sol–gel derived Sr-containing glasses (with Sr concentration of 0–10 mol%) based on this quaternary system. Structural properties of the glasses and the effect of Sr conponent on tensile strength. The aim of the present study was to prepare strontium-incorporated bioactive glass scaffolds instead of calcium oxide and strength was investigated between neat PCL nanofiber and PCL/BG composites.

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II. Material And Methods

A. materials

Poly (e-caprolactone) PCL (average Mw: 80,000) was purchased from Aldrich Company (US). Sol-gel derived glasses based on CaO–SrO–SiO2–P2O5 system with the properties as described in Ref.[2] were synthesized in dental Biomaterial Laboratory, tehran University of Medical Sciences, Iran. By replacing SrO Instead of CaO with (0 to 5wt% SrO). Chloroform and methanol (merck, Germany) were used as received.

B. Protocol of Study

BG nanoparticles were dispersed in the mixtures of chloroform/methanol with ratios of 3/1 v/v and stirred for 6 h with a magnetic stirrer. Into these nanoparticles dispersions was added and dissolved the weighed amount of PCL to obtain 10 wt% polymer composite solutions, which were then stirred overnight. The percentage of the nanoparticles added was 5wt% of the PCL content. The composite solution thus prepared was sonicated for 20 min for further dispersion. Then solution was quickly drawn into a syringe having a needle gauge 20. Elecrospinning was carried out at a flow rate of 0.7 ml/h using a high DC voltage of 18 kV at a distance of 16 cm and the nanofibers were collected on the rotating drum. The electrospun nanofibrous web was dried in a vacuum oven for 24 h and then kept in the desiccator. Nanofibrous webs were cut into the rectangular dimensions of 5 mm width and 20 mm length. five samples at the cross-speed head of 2 mm/min were tested and tensile strength and strain at break were calculated

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based on the stress–strain curves of each sample. Results were reported as an average and standard deviation of five measurements.

C. Statistical Analysis

Statistical data analyses were conducted using a one-way analysis of variance (ANOVA) and Tukey Test. A probability value of 95 % ($p < 0.05$) was used to determine the level of significance.

III. Results

Analysis of the mechanical properties of the nanocomposite fibrous webs is necessary for understanding their performance in the bone regeneration scaffold. In this study, the mechanical properties of PCL nanocomposite webs were measured in both tensile and strain modes and then compared with those of neat PCL. Figure I shows recorded tensile strength for three composites, which SrO component was replaced by CaO. The percentage of SrO was varied from 0% to10%.

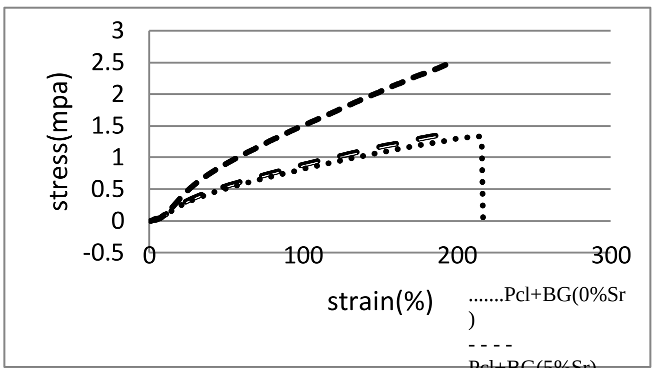

Fig. 1 Representation of stress-strain curves for PCL/BG whit different percent of SrO content.

The results of the present study show that there was a significant increase in tensile strength of nanofibers as the amount of strontium was added.

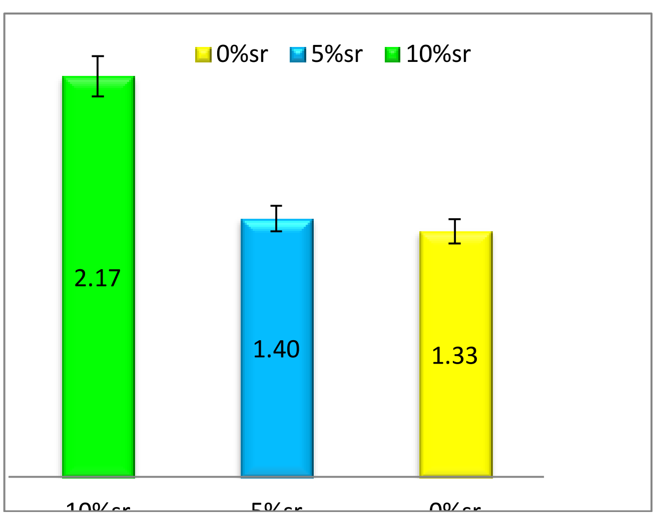

Fig. 2 Representation of increasing tensile strength by SrO content adding.

FigureII shows that increasing in percentage of SrO from 5% to 10% significantly($P<0.05$) increased strength from 1.4MPa to 2.17MP, but There is no significant difference between nanofiber composites containing 0%Sr and 5%Sr.

IV. Discussion

Our study indicated that enhancement of the Sr increase the tensile strength. Replacement of Ca2+ with Sr2+ which couse some distortion in the lattice structure due to ionic radius of calsium is bigger than ionic radius of strontium. These distortion create residual stress in glass structure. Residual stress icrease the strength of glass. Finally the glass nanoparticles are distributed in composite web, amplificate the composite strength with enhancement of strontium component[8].

V. Conclusion

tensile strength for PCL without BG was 1.33 MPa, which significantly ($p < 0.05$) increased to 2.17 MPa by increasing the nanoparticles concentration to 5 wt% due to the reinforcement effect of BG (ceramic materials have stiffer mechanical properties than polymers) within the polymer matrix while the tensile strain at break decreased. The glass nanoparticles are distributed in composite web, amplificate the composite strength with enhancement of strontium component

Acknowledgment

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