NEW POLY(ETHYLENE OXIDE) HYDROGEL FOR ORTHOPAEDIC APPLICATIONS

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Introduction

Hydrogels are composed of three-dimensional hydrophilic polymer networks imbuing large amounts of water. Biomimetic hydrogels have been used in diverse biomedical applications. One drawback of hydrogels is the lack of structural integrity, especially for those with high water content.

The conventional poly(ethylene oxide) hydrogel is such a case in point. A new fabrication process was developed for optimization of mechanical strength in PEO hydrogels. The objective of this study was to characterize the key properties of the PEO hydrogel, including gel fraction, swell ratio, compressive strength, and biocompatibility.

Materials and Method

The new PEO hydrogel fabrication process consists of: (1) molding of a PEO disk, (2) high-energy radiation treatment, and (3) hydration of the crosslinked PEO. Two gamma doses, 50 and 100 kGy, and two commercial grades of PEO, WSR-301 and WSR-303 (Dow), were evaluated. The conventional PEO hydrogel was prepared by gamma treatment of concentrated (8%) PEO solution. The sample ID for the various PEO hydrogel samples is listed in the table below.

<table>
<thead>
<tr>
<th>Dose</th>
<th>Conventional Hydrogel</th>
<th>New Hydrogel</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 kGy</td>
<td>WSR-303</td>
<td>WSR-303</td>
</tr>
<tr>
<td>100 kGy</td>
<td>WSR-303</td>
<td>N3-100</td>
</tr>
</tbody>
</table>

Gel fractions were calculated based on the formula: (W_{Dried Gel} / W_{Solid PEO}). Swell ratios were calculated based on the formula: (W_{Hydrogel} / W_{Initial Gel}). Gel strengths at ambient temperature were measured by compression of disc samples (~0.60“D x 0.275”H) between parallel plates on an Instron tester until fracture at a crosshead speed of 0.4 inch/min. Secant compressive moduli were measured at deformation of 0.020”.

For assessment of protein interactions with the PEO hydrogel, N3-50, bovine serum albumin (>99%, Sigma) was either embedded in the PEO matrix or adsorbed on the hydrogel surface by soaking in 2% albumin solution for 24 hours. Both types of samples were rinsed three times with R.O. water prior to brilliant blue R staining test.

Samples of PEO hydrogel, N3-50, along with polystyrene (positive control) in terms of the number of cells adhered. silicone rubber (negative control) and different (p<0.05) from comparison, the new PEO hydrogel is statistically similar (p>0.05) to polystyrene (positive control) in terms of the number of cells adhered.

Discussion

In this study, we demonstrated that a new fabrication process produced PEO hydrogels, Figure 2, with improved mechanical strength. Unlike poly(ethylene glycol), the PEO hydrogel adsorbed albumin on the surface. The pore openings of the hydrogel, Figure 3, allows for diffusion of macromolecules, like protein and glycosaminoglycan, in and out of the PEO matrix. In addition, we demonstrated that fibroblast cells do not adhere to the PEO hydrogel.

The new PEO hydrogel has been evaluated as an implant material for drug delivery and soft tissue regeneration. This study elucidates that new processing technique as well as chemical composition optimization plays a crucial role in qualifying hydrogel as the preferred material for demanding orthopaedic applications, such as disc nucleus replacement.

Table II: Compressive properties of PEO hydrogels

<table>
<thead>
<tr>
<th>Dose, psi</th>
<th>C38-100</th>
<th>N1-100</th>
<th>N3-50</th>
<th>N3-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.6</td>
<td>+/- 14.8</td>
<td>+/- 2.2</td>
<td>+/- 1.6</td>
<td>+/- 1.3</td>
</tr>
<tr>
<td>77.9</td>
<td>+/- 1.7</td>
<td>+/- 3.1</td>
<td>+/- 10.6</td>
<td>+/- 11.7</td>
</tr>
<tr>
<td>156.9</td>
<td>+/- 14.8</td>
<td>+/- 14.8</td>
<td>+/- 11.7</td>
<td>+/- 11.7</td>
</tr>
</tbody>
</table>

The number of cells adhered to each substrate after 18 hours is depicted in Figure 1. Based on one-way ANOVA with a Tukey post hoc comparison, the new PEO hydrogel is statistically similar (p>0.05) to silicone rubber (negative control) and different (p<0.05) from polystyrene (positive control) in terms of the number of cells adhered.

Reference

1. US Patent 5,681,869
2. US Patent pending

Figure 2 The new PEO hydrogel

Figure 3 ESEM microphotograph of the PEO hydrogel showing numerous pore openings