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Accelerated Degradation of polymeric surgical suture materials

Abstract: The degradable polymer Polydioxanone (PDO) is used for medical implants since 1981. Manufacturers state a degradation timeframe of <180 days or an absorption duration of 182-238 days [1, 2]. Aim of this study was to find *in vitro*-conditions to degrade PDO films within four weeks. Therefore the degradation of PDO was performed in accelerated conditions in tempered alkaline glycine NaOH buffer. Molecular weight and mass loss were studied. PDO results were compared with poly lactic-co-glycolic acid P(LLA-co-GA).

Keywords: biodegradable polydioxanone, poly lactic-co-glycolic acid, accelerated degradation, alkaline.

1 Introduction

Degradable polymers like PDO, P(LLA-co-GA) or poly lactic acid (PLLA) and their combinations are used for medical implants since 40 years. Within the mentioned polymers PDO shows a comparably fast degradation behavior. Therefore sutures, plates, meshes, screws, pins and clips represent typical PDO applications.

Degradation is induced by hydrolysis of the ester groups within the polymer. Lin et al. and Brito et al. showed PDO suture degradation in phosphate buffer (pH 7.4) at 37 °C [3, 4]. There PDO showed a weight loss of 10% within 10 weeks and 12 weeks, respectively [3, 4]. Molecular weight loss was not reported there.

Here conditions for an accelerated degradation study were determined.

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2 Materials and methods

2.1 Samples

PDO Resomer X 206 S and P(LLA-co-GA) Resomer LG 857 S were obtained by Sigma Aldrich. The polymer films were prepared as described by Petersen et al. [5]. Briefly the polymer was dissolved in a solvent (chloroform for P(LLA-co-GA) and hexafluoroisopropanol for PDO) and poured into a glass petri dish. The solvent was allowed to evaporate until an approx.100 µm thick film had formed. Polymer films were washed twice using methanol and water. Afterwards circular 6.0 mm punches were made.

2.2 Molecular weight analysis

The molecular weight data of polymer films were obtained at 30 ºC using a PSS SECcurity SEC system (Polymer Standard Services GmbH, Mainz, Germany) including a RI detector combined with a WGE Dr. Bures g 2010 viscosity detector (WGE Dr. Bures GmbH, Dallgow, Germany). Separation was performed with three PSS SDV columns (10^3, 10^5 and 10^6 Å respectively). Chloroform stabilized with ethanol was used as eluent at a flow rate of 1 ml/min. The samples were prepared with a concentration of 1.5 mg/ml in chloroform with hexylbenzene as internal standard and the injection volume was 0.1 ml. The molecular weights were calculated by the universal calibration method using twelve polystyrene calibration standards in a range between 376 and 2,570,000 g/mol.

2.3 Degradation conditions

Test specimens were incubated in 4 ml alkaline glycine buffer (pH 8.7). They were given on a rotating platform-shaking device (Unimax 1010, Heidolph Instruments GmbH&Co. KG, Schwabach, Germany) at 100 rpm and at a temperature of 50 °C. Every seven days the medium was replaced by fresh buffer. Sample withdrawal occurred after 0, 7, 14, 21 and 28 days.

3 Results and discussion

In consideration of the Q10 temperature coefficient a degradation temperature of 50 °C was chosen. Additionally the pH was increased to 8.7 compared to standard degradation conditions in phosphate buffer (pH 7.4) at 37 °C. As Figure 1 shows, the masses of the P(LLA-co-GA) samples do not decrease significantly after four weeks in medium.
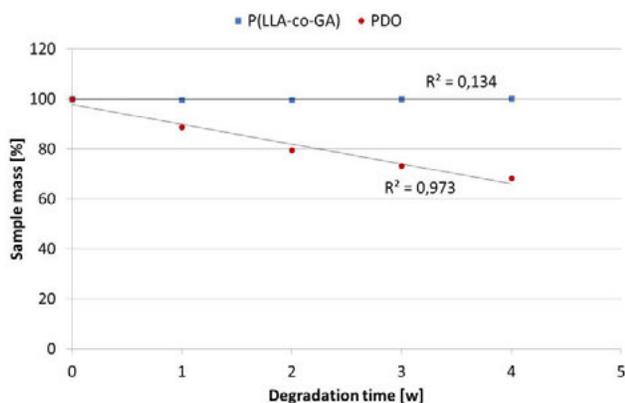
Figure 1: Accelerated polymer degradation of PDO and P(LLA-co-GA); mass loss; Mean values, n = 3. PDO values shown with linear regression. Regression executed with Microsoft Excel.

However, PDO shows a linear decrease of the polymer mass resulting in a value of 68% of the initial mass (see table 1). A weight loss of 10% was found after 1 week.
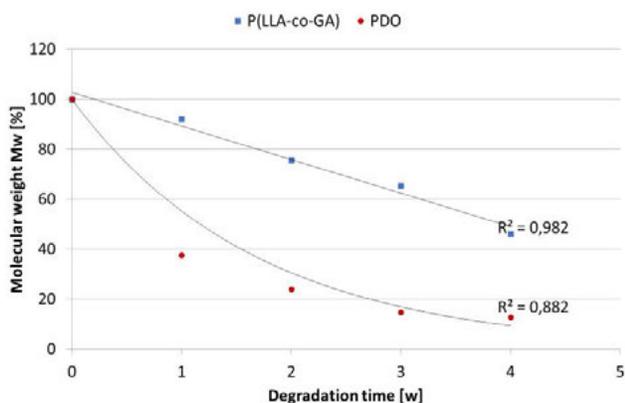
Figure 2: Accelerated polymer degradation of PDO and P(LLA-co-GA); molecular weight loss; Mean values, n = 3. P(LLA-co-GA) values shown with linear regression. PDO values shown with exponential regression. Regression executed with Microsoft Excel.

Polymer degradation usually passes several steps. In the beginning of the degradation, water diffuses into the bulk. There hydrolysis starts predominantly in the amorphous phase. This reduces the molecular weight but not the mass. Short crystalline polymer chains are hydrolized and in a last step the remaining polymer chains are removed by the surrounding medium which leads to loss of polymer mass, molecular weight and physical properties [6, 7].

Table 1: Mass loss and molecular weight loss values.

Degradation time [w]	PDO Mass [%]	Molecular weight [%]	P(LLA-co-GA) Mass [%]	Molecular weight [%]
1	100.0	100.0	100.0	100.0
	100.0	100.0	100.0	100.0
	100.0	100.0	100.0	100.0
x̄	**100.0**	**100.0**	**100.0**	**100.0**
1	95.2	38.8	99.5	86.6
	95.0	37.9	99.6	98.0
	75.2	36.1	99.6	91.6
x̄	**88.5**	**37.6**	**99.6**	**92.1**
2	87.7	26.7	99.7	75.7
	68.8	26.1	99.7	75.9
	86.4	19.4	99.7	75.2
x̄	**80.9**	**24.0**	**99.7**	**75.6**
3	73.6	16.1	99.7	64.8
	77.1	14.8	99.7	70.2
	69.4	13.6	100.2	61.5
x̄	**73.4**	**14.8**	**99.9**	**65.5**
4	57.8	12.8	100.9	48.2
	72.7	12.9	99.8	44.2
	72.2	12.7	99.5	45.8
x̄	**67.6**	**12.8**	**100.0**	**46.1**

Regarding the molecular weight loss (Figure 2), PDO shows the major changes in the first week resulting in a value of 38% (see table 1) caused by the hydrolysis of amorphous PDO regions, enhanced by temperature and elevated pH. P(LLA-co-GA) shows a different degradation behavior. Here a linear molecular weight loss during the whole study was observed. Comparison of the P(LLA-co-GA) values with data recorded under standard conditions (37 °C, phosphate buffer, pH 7.4) shows a three times accelerated degradation (Figure 3) at the half value of the initial molecular weight.

This acceleration cannot be transferred straightly to PDO, but an approximation is supposed.
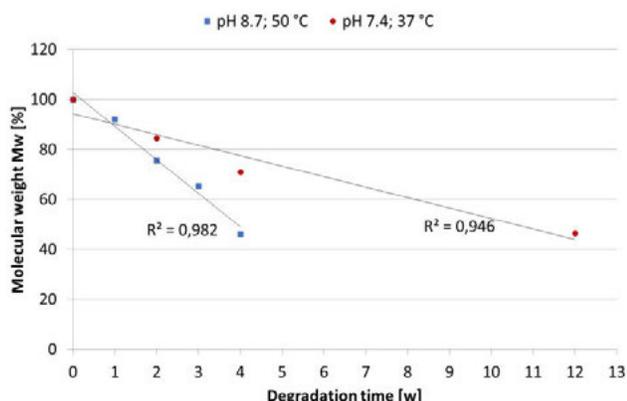
Figure 3: Molecular weight loss of P(LLA-co-GA); degradation in standard and accelerated conditions; Mean values, n = 3. Values shown with linear regression (executed with Microsoft Excel).

4   Conclusion

Conditions to degrade PDO *in vitro* within four weeks were developed. Therefore degradation was performed at 50 °C in alkaline NaOH glycine buffer (pH 8.7). Mass loss followed a linear progress. Last withdrawal of the PDO samples was conducted with a remaining mass of 68% of the initial mass. Samples showed fragmentation at that time. Medium change was no longer feasible without sample loss. Molecular weight degradation followed a non-linear, exponential-like progress with a molecular weight loss of 76% after two weeks and 87% after four weeks. In the same degradation medium P(LLA-co-GA) showed a three times accelerated degradation compared to standard conditions (37 °C, pH 7.4).

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