Alginate Skin Wound Dressing Manufactured by Rapid Prototyping Technique

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Statement of Purpose: Ideally, skin wound dressings should keep the wound dry by allowing the evaporation of wound exudates and keep a moist environment around the wound. They should also allow oxygen circulation to aid tissue regenerations. Traditional hydrogel slabs have the disadvantage of poor air circulation and little exudate removal capability due to the lack of pores on the surfaces. Rapid prototyping (RP) has been used to make three-dimensional (3D) structures with controllable fiber and pore sizes. In this test, we proposed to make skin dressings with alginate hydrogel using various RP parameters and tested their suitability for use as skin wound dressing. The results from the porous fibrous structures are also compared to those of alginate gel slabs.

Methods: Setup: Alginate and $CaCl_2$ were dissolved in deionized water. An automatic dispensing machine was set up as shown in Figure 1. Alginate solution was added to the syringe held by a robotic arm, and calcium solution was added to the petri dish where specimens were made under a needle.

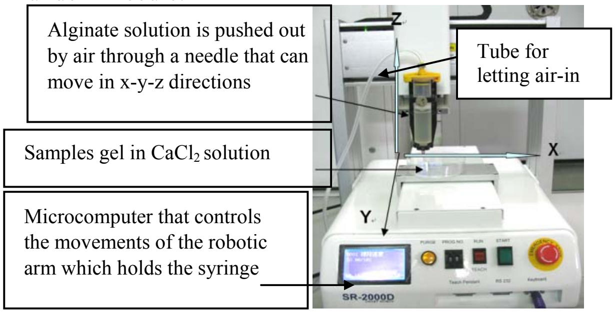

Figure 1. Setup of the rapid prototyping system.

RP parameters: The adjustable operating parameters used in the dispensing system to make the 3D porous fibrous dressings are listed in Table 1. They are pneumatic pressure **p** (bar), needle inner diameter **D** (μm), needle z-direction increment **h** (mm), and needle speed **v** (mm/s). Two kinds of alginate solutions **A** (%) and crosslinking $CaCl_2$ solutions **Ca** (%) were used to make the dressings and gel slabs. Alginate solutions were air dried and crosslinked in calcium solutions. Each specimen was made of 16 layers of fiber with each perpendicular to one another.

Tensile modulus **E** (kPa): a tensile tester with a load cell (25N) moving at 10mm/min was used to obtain the elastic modulus of the specimens (wet).

Swelling ratio **SR** (%): Dry weights of the specimens were recorded (Wo) before they were submerged in a phosphate buffered solution (PBS). At designated times, the wet weights of specimens were measured after the removal of excess liquid (W). Swelling ratio SR (%)= [(W-Wo)/Wo]x100.

Cumulative protein release **R** (%):100μl of 75mg/ml Bovine serum albumin (BSA) was added to each dry specimen. Specimens were placed in beakers filled with PBS. The concentrations of BSA in the solution were measure over time. The percentage of BSA released from the scaffolds was then calculated.

Water vapor transmission rate **WVTR** (g/m^2/day): This test followed descriptions in ASTM E 96/E 96M- 05.

Results: The data from all the tests is summarized in Table 1. Figure 1 shows the pictures of dressings, wet and dry, made by RP and by film casting.

Table 1. Data summary.

	Operating parameters						RP dressings				Gel slabs			
#	p	D.	Ca	A	h	v	E	SR	R	WVTR+	E	SR	R	WVTR+
1	3	150	5	3	0.4	50	33	2868	72	1670	913	160	9	1239
2	**4**	150	5	3	0.4	50	57	951	62	1399				
3	3	**200**	5	3	0.4	50	172	865	57	1210				
4	3	150	**0.5**	3	0.4	50	48	774	41	1911	219	1690	38	1352
5	3	150	5	**2**	0.4	50	118	986	63	1120				
6	3	150	5	3	**0.6**	50	141	770	74	2686				
7	3	150	5	3	0.4	**30**	56	971	71	1791				

+: WVTR (open cup) = 4915 g/m^2/day.

Figure 1. Representative pictures of dressings made by RP (left two) and film casting (right two). Scale bar=5mm.

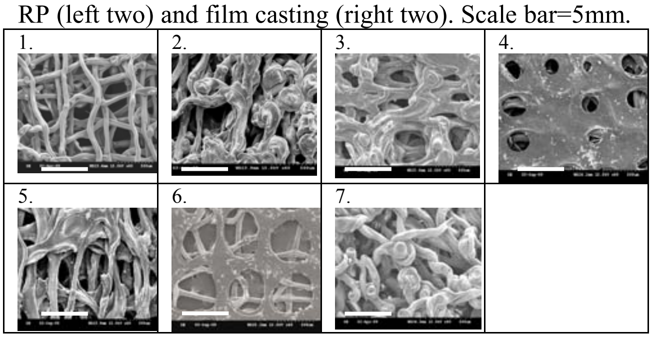

Figure 2. SEM micrographs. Scale bar=500μm.

Sample #1 had the smallest fiber diameter and largest strand spacing (largest pores) of all the samples. It, therefore, had the lowest elastic modulus and highest swelling ratio of all. The increase in p and D (#2,#3) allowed faster alginate flow and resulted in larger fiber diameters and smaller pores. A lower $CaCl_2$ concentration (#5) slowed down the gelation process and also resulted in larger fiber diameters and smaller pores. Sample #5 was less viscous and came out of the needle easily, thus the larger fiber size. An increase in h (#6) gave more time for the alginate solution to spread out in the Ca solution and resulted in larger fiber and smaller pores. The slower the needle moved (#7), the more the alginate solution accumulated and resulted in thicker fibers.

Conclusions: From the above observations, it is concluded that changes in RP parameters result in different fiber and pore sizes of dressings made and, therefore, different physical properties, such as those listed in Table 1.

References: Lee SJ et al. Sensor Mater. 2007;19:445-451.
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