Supplementary Information

Poly(vinyl alcohol)/Sacran Hydrogel Microneedles for Anticancer Transdermal Drug Delivery

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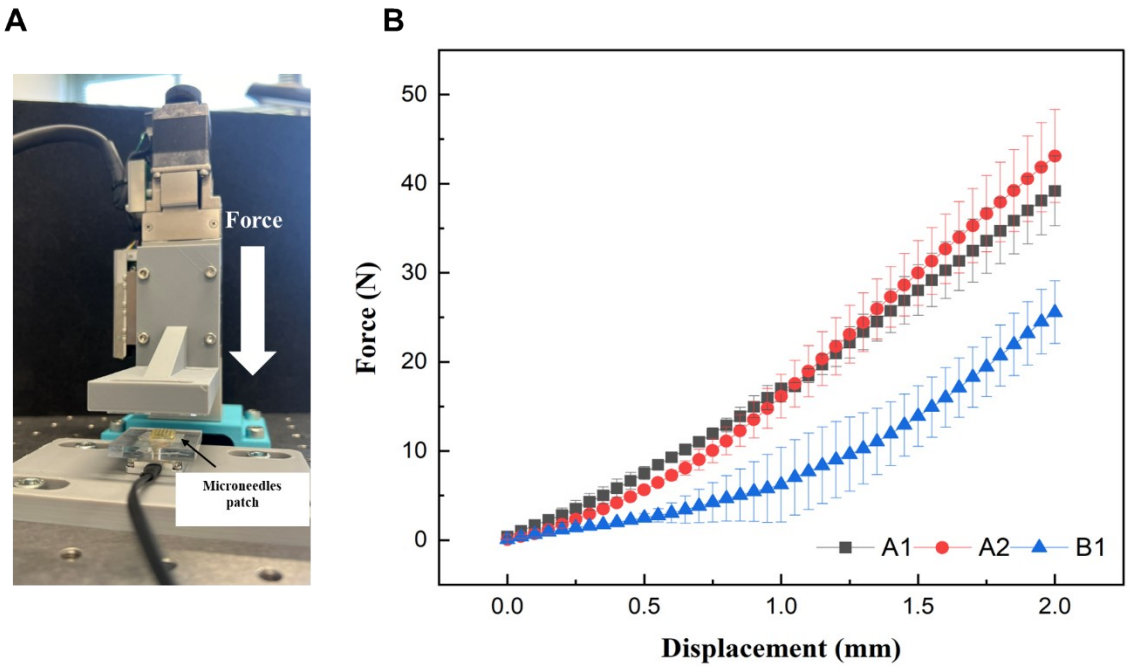

Figure S1. (A) Experimental set-up for mechanical testing of microneedle patches showing the direction of force application. (B) Force–displacement curves of different microneedle formulations (A1, A2, and B1) under compression testing. A1 and A2 demonstrate similar mechanical behaviour, with the maximum force of approximately 40 N at 2.0-mm displacement. B1 shows lower mechanical strength, with the maximum force of approximately 25 N. Data are presented as mean±SD.

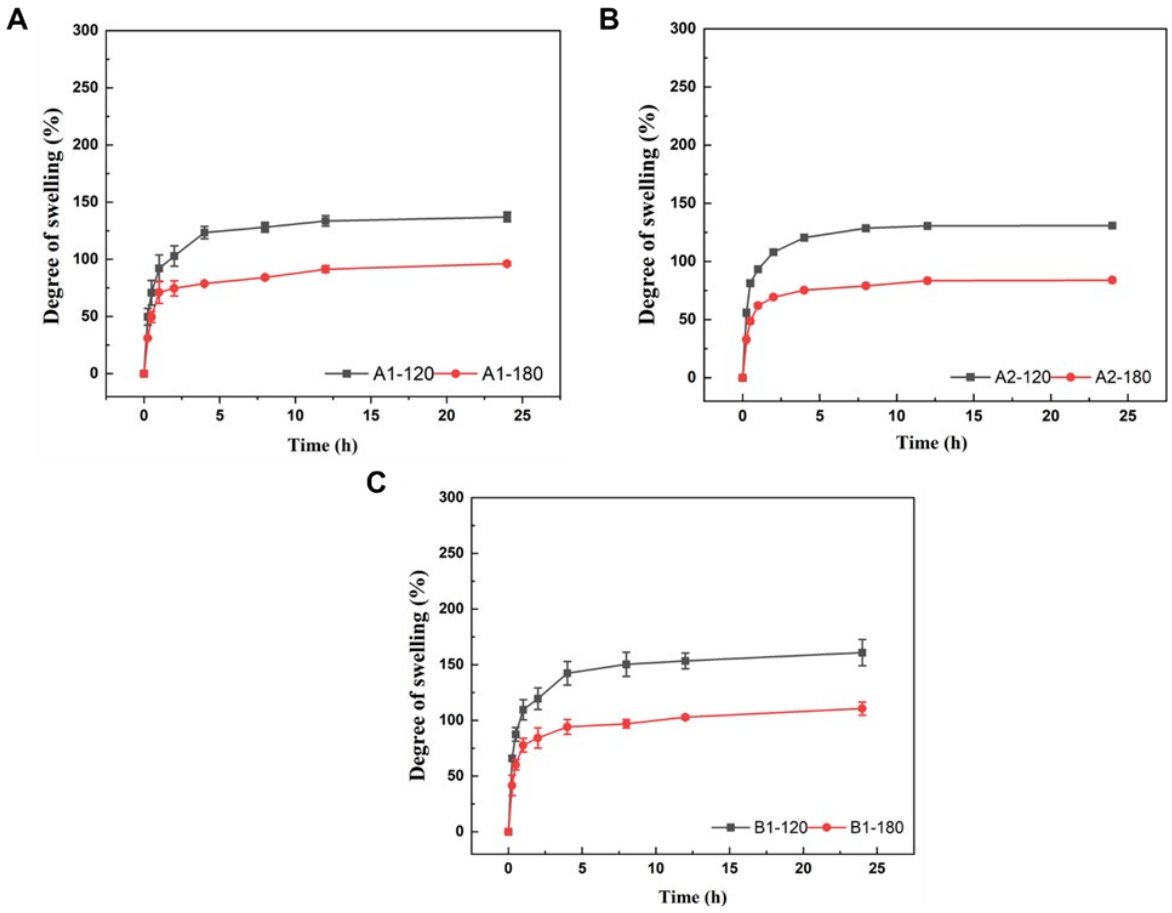

Figure S2. Degree of swelling in poly(vinyl alcohol) (PVA)/sacran hydrogel microneedles (HMNs) (A1 and A2) and PVA/Q-sacran (B1) with crosslinking durations of 120 and 180 min. The concentration of citric acid in the formulation was fixed at 1.0% w/v. All data are reported as mean ± SD, $n = 3$.

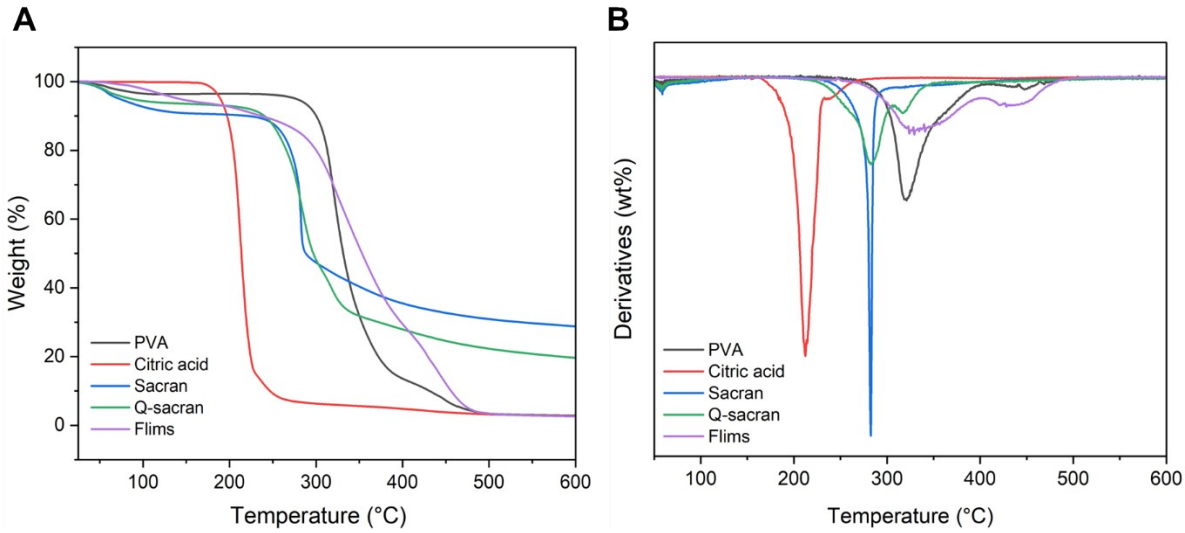

Figure S3. A) Thermogravimetric curves (TGA) of poly(vinyl alcohol) (PVA), citric acid (CA), sacran, quaternised-sacran, and film settings; B) derivative thermogravimetric (DTG) analysis curves.

Table S1. Penetration percentage of Parafilm® layer under pressure**.**

Layer	A1	A2	B1
1	100	100	94
2	100	100	75
3	100	100	53
4	67	89	33
5	3	45	0
6	0	3	0
7	0	0	0
8	0	0	0

Table S2. Cumulative drug-release profile from microneedle patches at different time points.

Time (min)	Total Drug Released per Patch (µg/mL)			Total Drug Released per Needle (µg/mL)		
	A1	A2	B1	A1	A2	B1
5	0.47±0.2	0.41±0.1	1.62±0.5	0.01±0.01	0.01±0.01	0.04±0.02
10	1.00±0.2	0.98±0.2	2.24±0.5	0.03±0.01	0.03±0.01	0.06±0.02
15	1.75±0.2	1.87±0.3	2.97±0.6	0.05±0.01	0.05±0.01	0.08±0.03
30	2.65±0.1	2.97±0.3	3.89±0.6	0.07±0.01	0.08±0.01	0.11±0.03
60	3.84±0.2	4.43±0.3	5.08±0.7	0.11±0.01	0.12±0.01	0.14±0.03
90	4.84±0.3	5.82±0.4	6.01±0.7	0.13±0.01	0.16±0.02	0.17±0.02
180	5.79±0.5	7.10±0.6	6.87±0.5	0.16±0.01	0.20±0.02	0.19±0.02
360	6.54±0.5	7.81±0.6	7.69±0.5	0.18±0.02	0.22±0.01	0.21±0.01
720	7.38±0.8	8.37±0.3	7.87±0.4	0.21±0.02	0.23±0.01	0.22±0.02

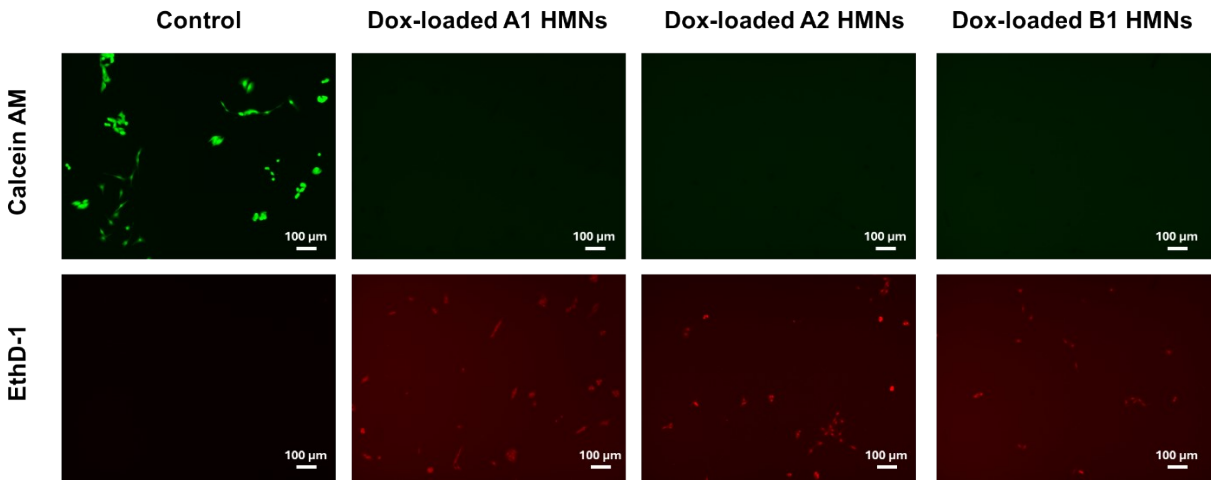

Figure S4. Live/dead cell staining of B16F1 melanoma cells after treatment with different doxorubicin (Dox)-loaded hydrogel microneedle (HMN) formulations. The upper row shows Calcein AM staining (green fluorescence), indicating live cells, whereas the lower row shows EthD-1 staining (red fluorescence), indicating dead cells. The control group exhibited a strong green fluorescence, indicating high cell viability. In contrast, the Dox-loaded A1, A2, and B1 HMN groups showed minimal green fluorescence and increased red fluorescence, indicating significant cell death due to the cytotoxic effects of the released Dox.