

A sunblock based on bioadhesive nanoparticles

Yang Deng^{1 †}, Asiri Ediriwickrema^{1 †}, Fan Yang¹, Julia Lewis², Michael Girardi² and W. Mark Saltzman^{1*}

¹Department of Biomedical Engineering

Yale University

55 Prospect Street

New Haven, CT 06511

USA

²Department of Dermatology

Yale University

333 Cedar Street

New Haven, CT 06520

USA

[†]Y.D. and A.E. contributed equally to this work

*Email: mark.saltzman@yale.edu

Table S1. DLS size of NPs.

Nanoparticles	Diameter (nm)	PDI
BNPs	96	0.273
DiD/NNPs	120	0.211
DiD/BNPs	118	0.232
IR-780/BNPs	128	0.334
PO/BNPs	138	0.227

BNP - bioadhesive nanoparticle, DiD - 1,1'-dioctadecyl-3,3,3',3' -tetramethylindodicarbocyanine, 4-chlorobenzenesulfonate salt, DLS - dynamic light scattering, PO – padimate O, NNP - non-bioadhesive nanoparticle, NP - nanoparticle.

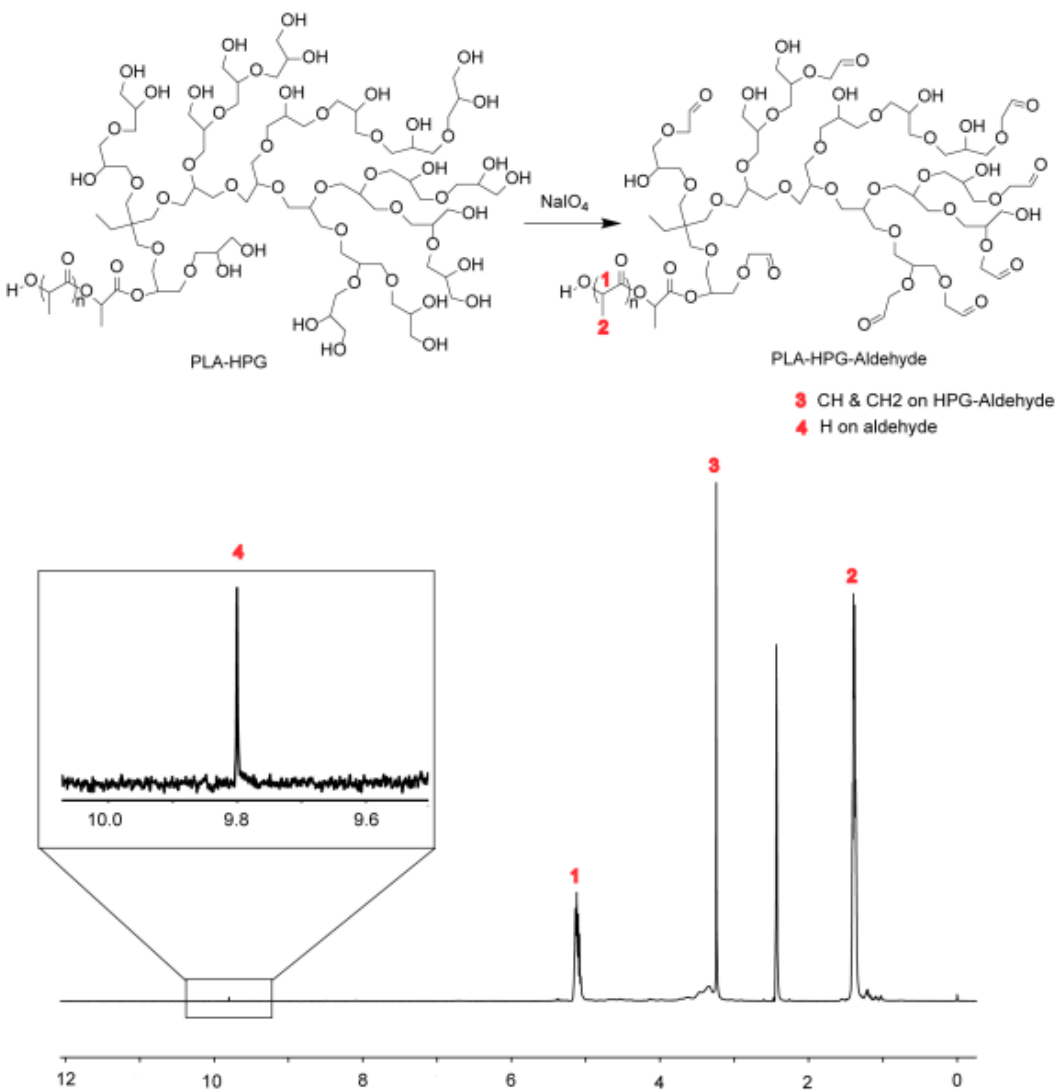


Figure S1. ¹H NMR spectrum of bioadhesive nanoparticles.

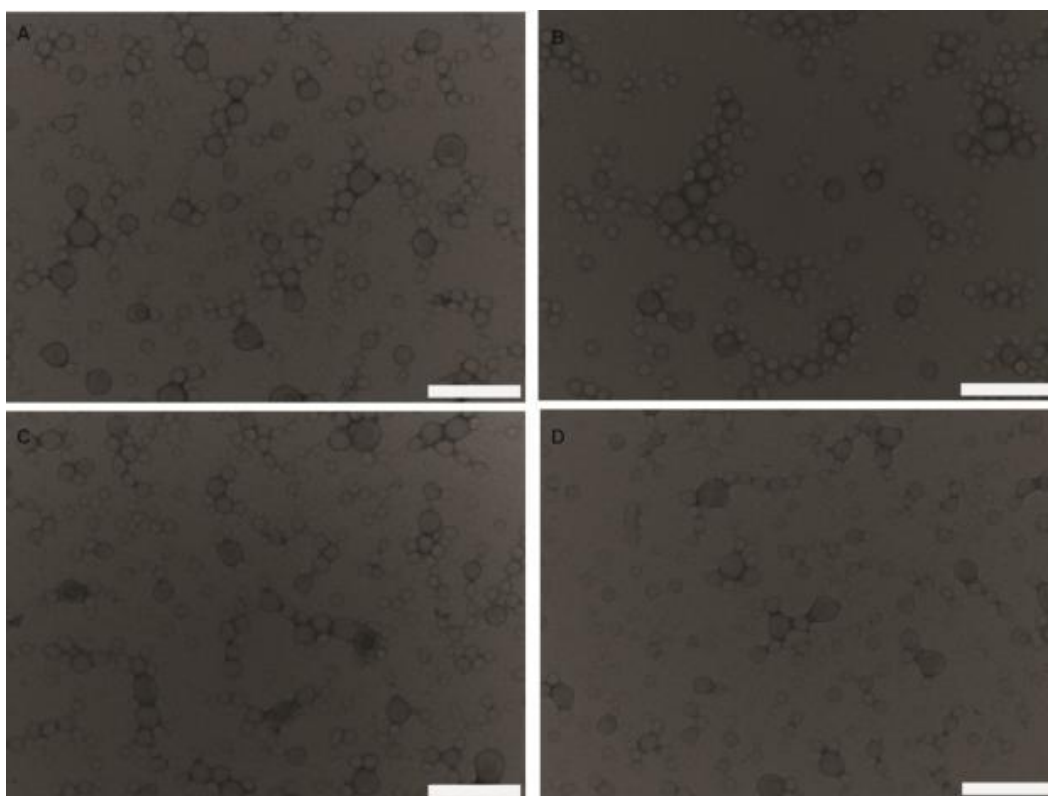


Figure S2. TEM images of BNPs. BNPs (A), DiD/NNPs (B), DiD/BNPs (C), IR-780/BNPs (D). The scale bar represents 200 nm. BNP - bioadhesive nanoparticle, DiD - 1,1'-dioctadecyl-3,3,3',3'-tetramethylindodicarbocyanine,4-chlorobenzenesulfonate salt, NNP - non-bioadhesive nanoparticle, TEM - transmission electron microscopy.

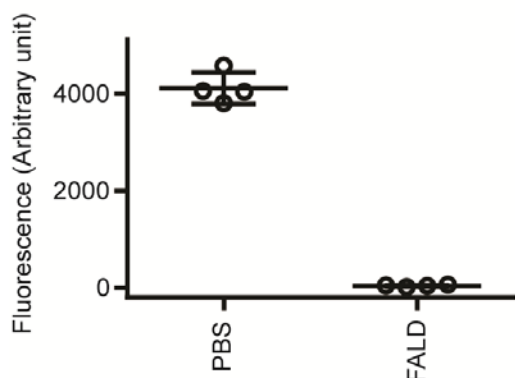


Figure S3. Surface adherence of BNPs on lysine coated slides as measured by DiD fluorescence in the absence or presence of formaldehyde. Co-treatment with formaldehyde competes with particles for lysine residue attachment and prevents particle adhesion. Data are shown as mean \pm SD (n = 4). BNP - bioadhesive nanoparticle, DiD - 1,1'-dioctadecyl-3,3,3',3'-tetramethylindodicarbocyanine,4-chlorobenzenesulfonate salt, FALD - formaldehyde, PBS - phosphate buffered saline.

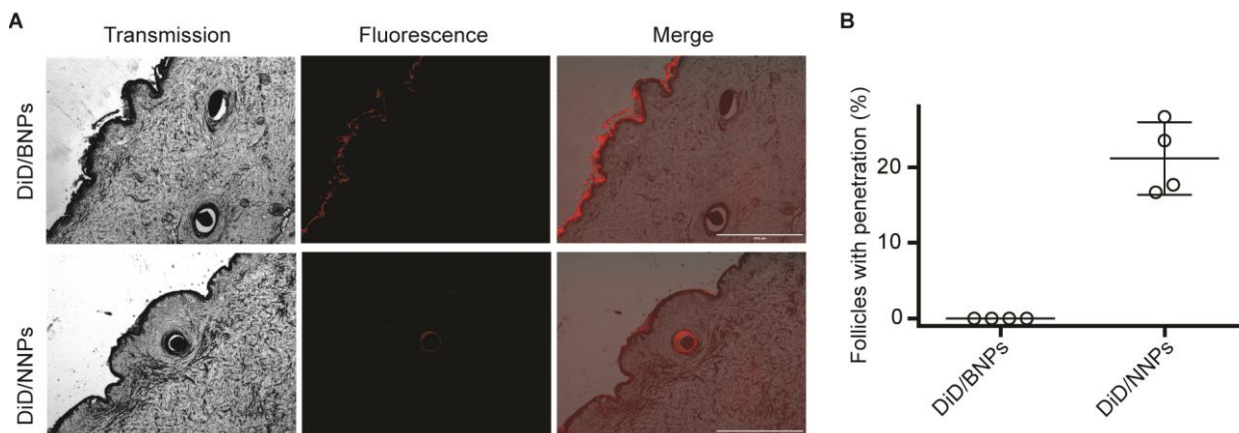


Figure S4. Evaluation of particle skin adhesion and penetration *ex vivo*. (A) Fluorescence images showing the penetration of NNPs and BNPs. NNPs penetrated into hair follicles after skin treatment, whereas BNPs remained primarily on the skin surface. (B) The percentage of follicles penetrated with nanoparticles for DiD loaded BNPs and NNPs. The scale bar represents 2 mm. BNP - bioadhesive nanoparticle, DiD-1,1'-dioctadecyl-3,3',3',3'-tetramethylindodicarbocyanine,4-chlorobenzenesulfonate salt, NNP - non-bioadhesive nanoparticle.

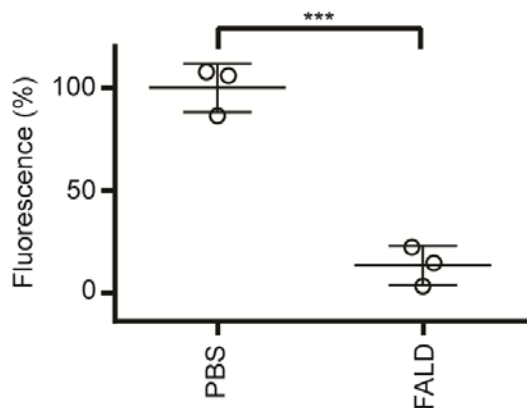


Figure S5. Particle skin adhesion as measured by DiD fluorescence. Skin surface BNPs were collected *via* tape stripping. Pig skin samples were pretreated with either PBS or PBS containing 2% formaldehyde, and subsequently incubated with DiD/BNPs in PBS or PBS with 2% formaldehyde respectively (***) $P < 0.001$). Co-treatment with formaldehyde competes with particles for skin surface attachment and prevents particle adhesion. BNP - bioadhesive nanoparticle, PBS – phosphate buffered saline, FALD - formaldehyde, DiD - 1,1'-dioctadecyl-3,3',3',3'-tetramethylindodicarbocyanine,4-chlorobenzenesulfonate salt.

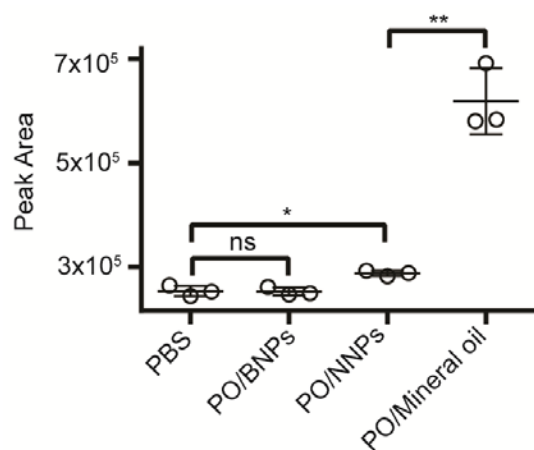


Figure S6. PO skin penetration in pig skin after topical treatment. Skin specimens were treated with PBS, PO/BNPs, PO/NNPs and PO/Mineral oil. After a 6 hour treatment, surface material was removed from skin specimens *via* tape stripping. The remaining PO was extracted and quantified using HPLC. BNP - bioadhesive nanoparticle, PBS – phosphate buffered saline, PO – padimate O, NNP - non-bioadhesive nanoparticle, FALD-formaldehyde. * $P < 0.05$, ** $P < 0.01$, NS - not significant.

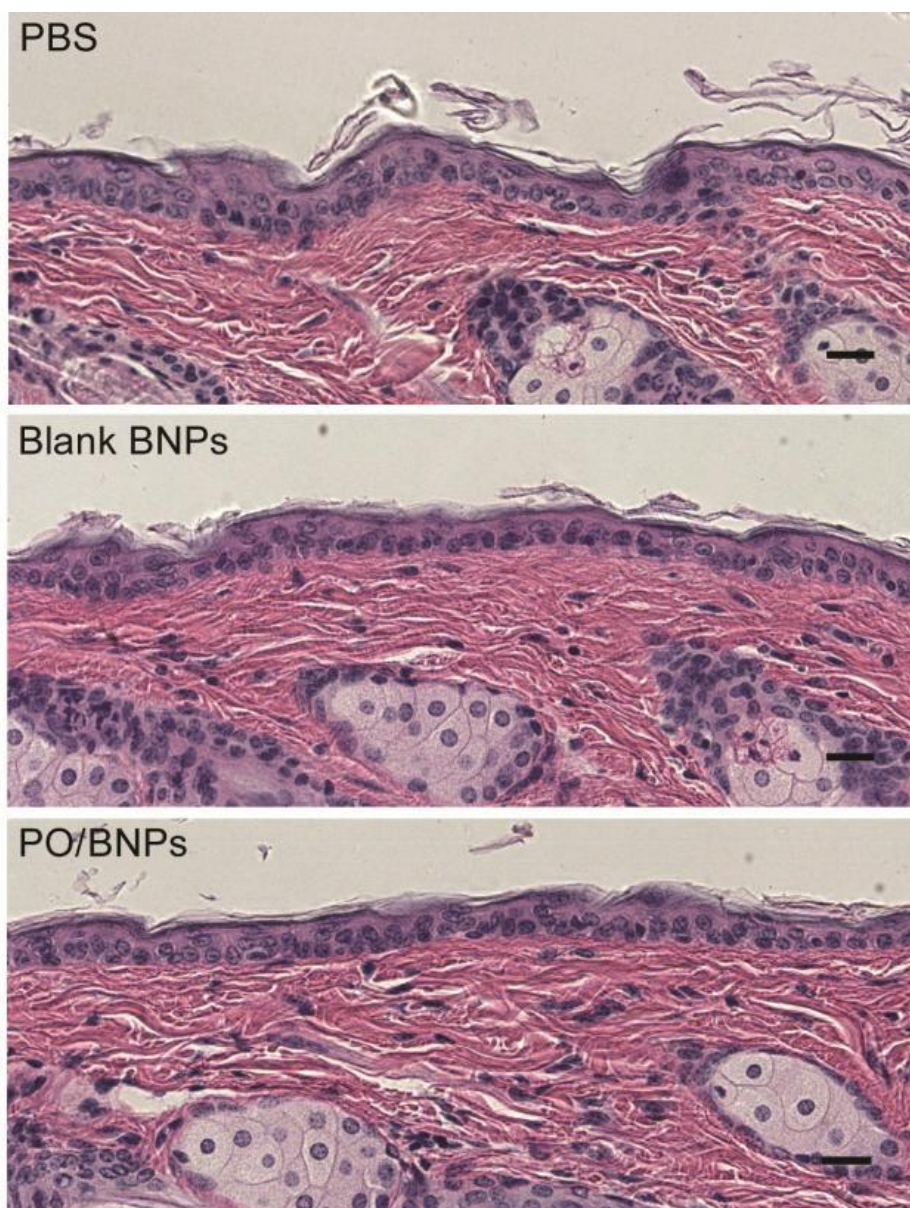


Figure S7. Evaluation of long term toxicity of PO/BNPs *in vivo*. Representative images of cutaneous histologic sections from FVB/NJ mice treated with PBS (n=3), blank BNP (n=4), or PO/BNP (n=4). Mice received treatment every other day for six total applications. Afterwards, skin treated with PO/BNPs and blank BNPs were indistinguishable from the PBS control. There was no histologic evidence of cutaneous irritancy, toxicity or inflammation. Bar = 20 μ m. BNP - bioadhesive nanoparticle, PBS - phosphate buffered saline, PO - padimate O.



Figure S8. Gross skin samples of mouse dorsal epidermis after receiving different topical interventions three days after high dose UV (2160 J/m²). Skin treated with both PO/BNPs and sunscreen contained no visible skin damage whereas the PBS and blank BNP controls shows significant erythema, edema, or ulceration. The scale bar represents 1 cm. BNP - bioadhesive nanoparticle, PBS – phosphate buffered saline, PO – padimate O.