

Duke University Medical Center

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Jan. 12, 1990

PENETRATION OF POLARIZED LIGHT THROUGH SKIN

Bruce Klitzman, Ph.D.

There are several proposed mechanisms of action of polarized light. For each of these, the depth of penetration of the polarization could influence the efficacy of the light. It is not known to what degree the polarization is maintained as the light penetrates the skin. Therefore, the purpose of this study was to quantify the extent to which the Bioptron polarized light maintains its polarization after penetrating pig skin of various thicknesses.

METHODS

A hand held model Bioptron lamp was positioned so that the emitted light transilluminated only the optical components (sham) or the optical components plus pig skin or wound dressing samples on a Zeiss ACM compound microscope. No condenser was used. The light was collected by a Zeiss UD6.3 objective (magnification=4X, numerical aperture=0.12). A polarizing barrier filter was placed in the optical axis of the microscope beyond the objective to filter the transmitted light. The filter was rotated in 10° increments from the original position (0°) through a total of 180°. A photometer recorded the light intensity of transmitted light beyond the polarizing filter for each angular position. The percent polarization was calculated as:

$$\% \text{ Polarization} = \frac{100 (\text{Max Intensity} - \text{Min Intensity})}{\text{Max Intensity}}$$

Full thickness skin samples were harvested from 40kg pigs using sharp surgical dissection. The samples were then pinned flat onto a special support which had a raised center. An air driven dermatome was used to harvest skin samples of four different thicknesses. The goal was samples of 0.1, 0.3, 1.0, and 3.0 mm. The skin samples were then placed between two glass microscope slides and positioned on the microscope with the incident light striking the epidermal surface. Samples were measured within three hours of harvesting.

Three of the skin samples of each thickness were fixed in 10% buffered formalin and measured. In addition to the skin samples, measurements were made through three common wound dressings: Adaptic, Opsite, and Tegaderm.

For most of the measurements, the transmitted light was filtered with a 525nm bandpass filter (10nm band width) or a 590nm long pass filter (all wavelengths longer than 590nm), in addition to measurements with no filter. In a second series with the 0.3mm thick skin sample only, the relation between wavelength and polarization maintenance was assessed by using either a 490nm bandpass filter or a 590nm long pass filter.

RESULTS

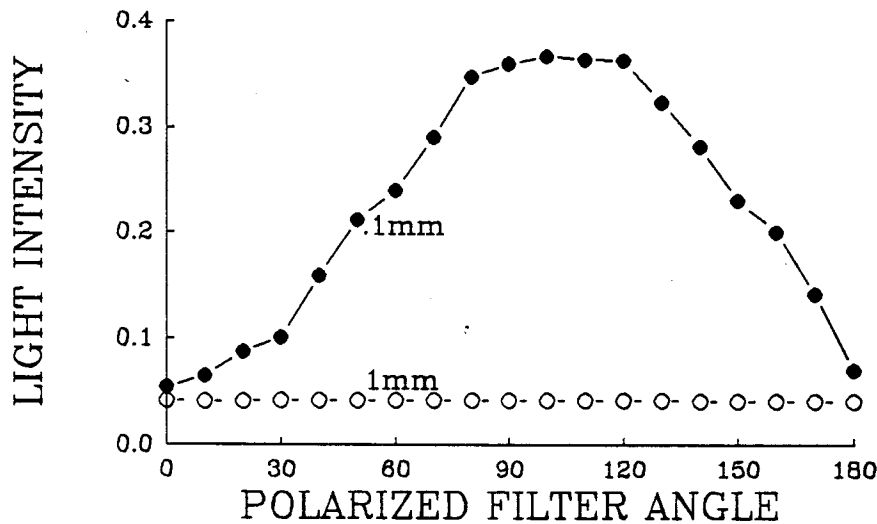
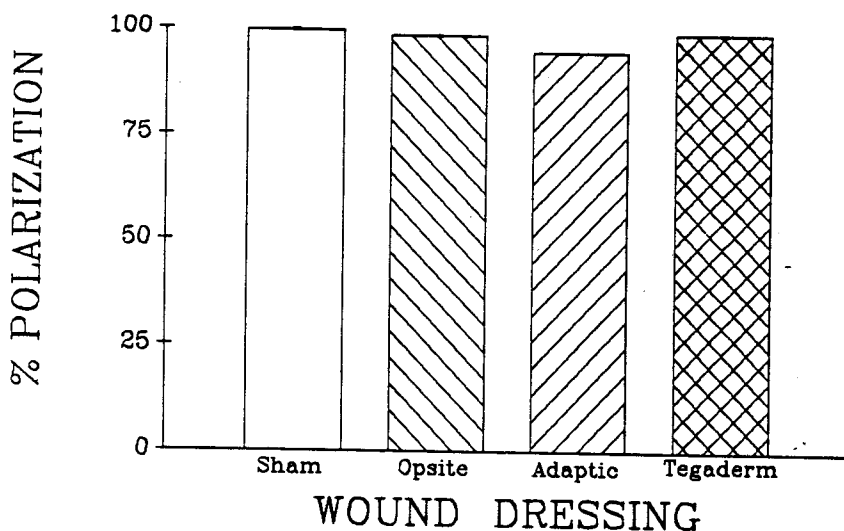
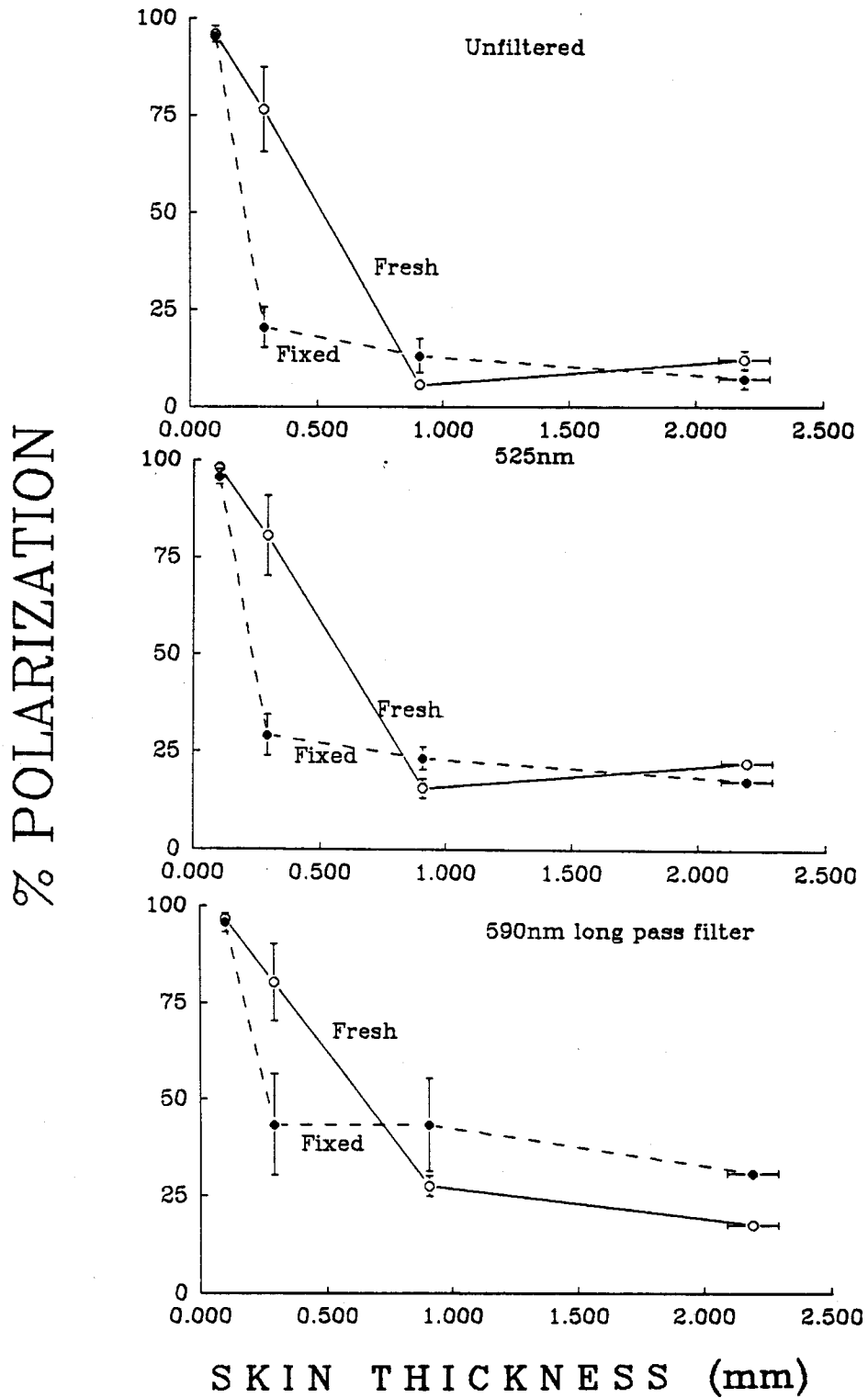


Figure 1 shows an example of the variation in light intensity with polarizing filter angle for skin of 0.1mm and of 1mm thickness. There is a 99% variation in light intensity for the 0.1mm sample as the polarizer rotates from being perpendicular to the orientation of the incident light to parallel. The sham measurements indicated that approximately 99% of the incident light was polarized at any of the wavelengths tested.



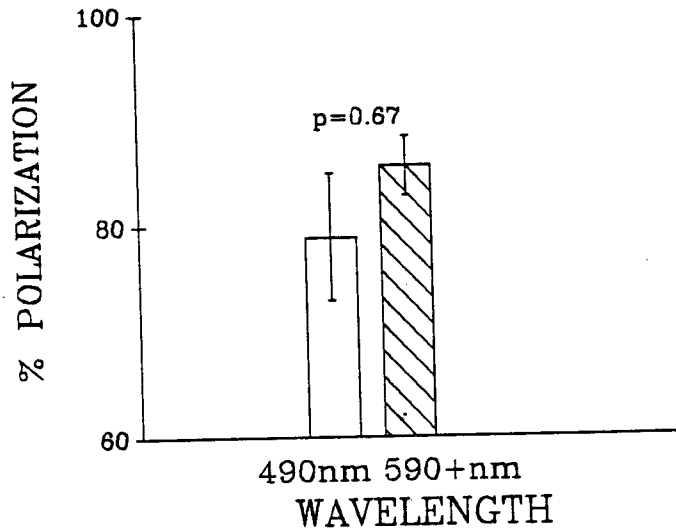
As shown in Fig. 2, the disorientation of the light was not substantial for any of the wound dressings tested.

The mean \pm SE (n) of the skin sample thicknesses were 0.10 \pm .01mm (7), 0.29 \pm .01mm (7), 0.91 \pm .03mm (7), and 2.19 \pm 0.10mm (8). Each of the thicknesses was significantly ($p < .01$) different from the other thicknesses.



As shown in Fig. 3, approximately 96% of the polarization is maintained through a depth of 0.1mm for all samples and

wavelengths. Between 0.1 and 0.3mm, significant disorientation is observed. There is considerable variability, particularly between fresh and fixed skin of 0.3mm thickness. Through 0.9mm, only approximately 20% of the polarization is maintained. Through 2.2mm, 15% polarization is measured.



The effect of wavelength is shown in Fig. 4. No significant difference was measured between 490nm (blue-green color) and 590+nm (red color).

DISCUSSION

The Bioptron light is highly polarized and does not seem to be effected substantially by the common wound dressings tested. However, skin does have a significant effect on the degree of polarization. Almost 80% of the polarization is lost within 1mm of skin depth. Surprisingly, there was not a significant difference in polarization penetration between 490nm and 590+nm light. However, thicker skin samples and wider wavelength differences were not tested. There was considerable variability in the measurements, particularly with the 0.3mm and 0.9mm thicknesses. As can be seen in Fig. 2, the thin and thick samples were more reproducible. It is possible that factors such as hydration state of the skin influenced the measurements somewhat. In summary, the polarization is well maintained through the surface layers of the skin, but is poorly maintained into the deeper layers.

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SUMMARY STATISTICS: Mean \pm SE n

Measured Skin Thicknesses

0.10 \pm .01 7
0.29 \pm .01 7
0.91 \pm .03 7
2.19 \pm .10 8

<u>Thickness</u>	<u>Tissue</u>	<u>Percent Polarization</u>			<u>n</u>
		<u>Unfiltered</u>	<u>525nm</u>	<u>590+nm</u>	
	Sham	99.6 \pm .3	99.1 \pm .2	98.8 \pm .2	3
	Opsite	98.4 \pm .2	98.9 \pm .1	98.3 \pm .2	3
	Adaptic	94.6	97.7	98.7	1
	Tegaderm	99.0 \pm .2	97.8 \pm .4	98.5 \pm .3	3
.1	fresh	95.9 \pm 2.1	98.0 \pm 0.7	96.7 \pm 1.2	7
.1	fixed	95.3 \pm 1.7	95.7 \pm 2.0	95.6 \pm 2.5	3
.29	fresh	76.5 \pm 10.8	80.5 \pm 10.3	80.2 \pm 9.9	7
.29	fixed	20.4 \pm 5.2	29.2 \pm 5.3	43.4 \pm 13.1	3
.91	fresh	5.6 \pm 1.6	15.7 \pm 2.4	27.5 \pm 2.6	7
.91	fixed	13.1 \pm 4.4	23.3 \pm 2.9	43.3 \pm 12.0	3
2.19	fresh	12.0 \pm 2.5	22.4 \pm 1.1	17.6 \pm 1.1	7
2.19	fixed	7.3	17.8	30.8	1

In a separate test of the 0.29mm thick skin sample, polarization at 470 \pm 20nm was 78.9 \pm 6.0% (6) and at 590+nm (long pass filter) was 85.6 \pm 2.8% (4, p = 0.67) thus, there was no significant polarization difference over the wavelengths tested.

Thicknesses (mm)

2.55	.85	.32	.08
2.45	.90	.28	.13
2.40	.85	.34	.13
2.45	.95	.	.10
1.90	1.05	.25	.10
1.95	.90	.30	.10
1.85	.90	.25	.08
2.00	.	.28	.

<u>Wavelnth</u>	<u>min</u>	<u>max</u>
470	4.3	46.5
470	4.3	48.3
470	8.4	107.7
470	5.3	21.6
470	8.4	21.5
470	10.6	28.4
590	.035	.395
590	.023	.104
590	.016	.110
590	.033	.273

<u>Materl</u>	<u>Thick</u>	<u>Unfilt</u>		<u>525nm</u>		<u>590+nm</u>	
		min	max	min	max	min	max
Sham	0	.2	19.5	.07	12.4	.025	2
Fresh	3	.0348	.0360	.0195	.0240	.0036	.0045
Fixed	3	.0478	.0516	.0282	.0343	.0045	.0065
Fresh	1	.0415	.0420	.0241	.0275	.0045	.0065
Fixed	1	.029	.035	.016	.022	.002	.005
Fresh	.3	.0475	.0543	.0279	.0349	.0048	.0061
Fixed	.3	.077	.105	.042	.064	.005	.016
Fresh	.1	.0552	.367	.0113	.228	.0047	.0463
Fixed	.1	.325	23.2	.182	15.6	.023	2.60
Adapt	9	.894	16.41	.307	13.59	.0270	2.13
Sham	0	.038	29.1	.25	19.94	.05	3.27
Sham	0	.052	28.9	.19	20.0	.03	3.40
Tegaderm	9	.14	17.64	.17	9.61	.03	1.69
Tegaderm	9	.20	15.65	.3	11.3	.02	1.7
Opsite	9	.04	2.86	.02	1.94	.006	.32
Opsite	9	.053	2.94	.023	1.93	.005	.32
Fixed	1	.023	.028	.015	.02	.003	.006
Fixed	1	.022	.023	.014	.017	.004	.005
Fixed	.3	.071	.079	.044	.054	.009	.012
Fixed	.3	.056	.074	.034	.052	.007	.011
Fixed	.1	.095	1.585	.049	1.297	.008	.27
Fixed	.1	.163	2.39	.126	1.6	.029	.314
Fresh	3	268	303	156	201	26	32
Fresh	3	293	388	173	221	32	38
Fresh	3	268	315	137	191	28	36
Fresh	1	642	686	392	502	61	86
Fresh	1	683	743	377	514	58	83
Fresh	1	637	734	370	431	63	103
Fresh	.3	.096	1.00	.053	.957	.015	.142
Fresh	.3	.092	1.072	.074	2.079	.014	.14
Fresh	.3	.114	1.426	.069	.761	.016	.214
Fresh	.1	.048	2.34	.072	1.98	.013	.345
Fresh	.1	.073	2.02	.052	1.71	.0098	.288
Fresh	.1	.252	3.36	.028	1.37	.0083	.371
Fresh	3	293	320	173	224	36	42
Fresh	3	287	322	168	218	38	45
Fresh	3	298	332	178	222	36	43
Fresh	1	544	558	325	365	58	71
Fresh	1	554	582	344	381	53	68
Fresh	1	518	533	314	365	56	73
Fresh	.3	.1194	.559	.1058	1.228	.0095	.1531
Fresh	.3	.1453	.783	.0765	.346	.0154	.1092
Fresh	.3	.208	1.848	.0621	.822	.013	.1104
Fresh	.1	.00661	3.36	.00374	2.51	.0079	.593
Fresh	.1	.00458	3.71	.00358	1.476	.011	1.083
Fresh	.1	.00732	3.90	.00326	3.09	.0058	.536

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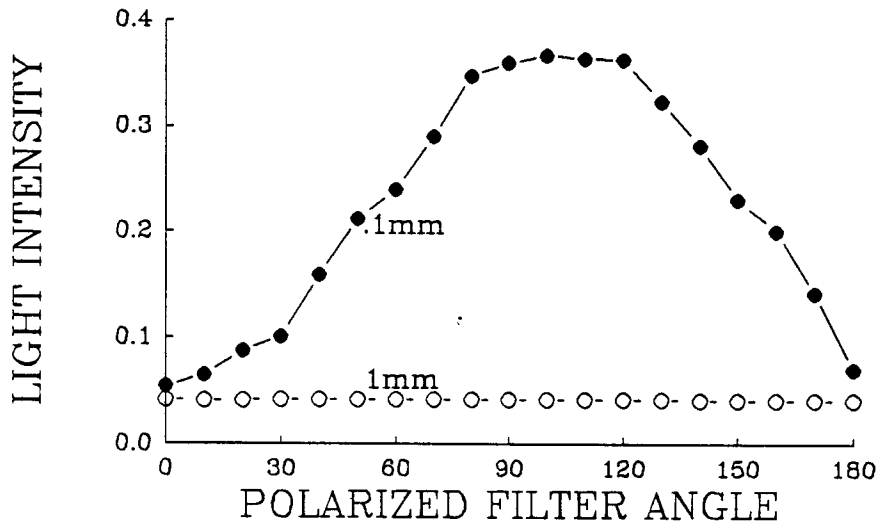
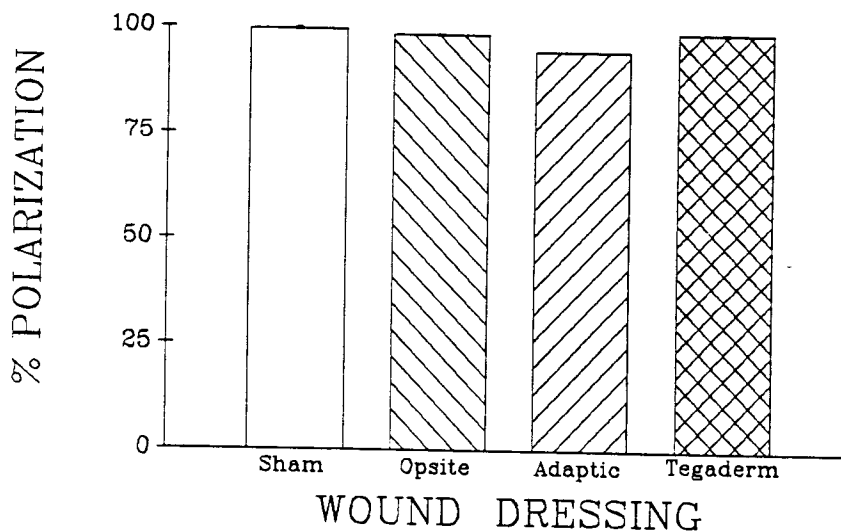
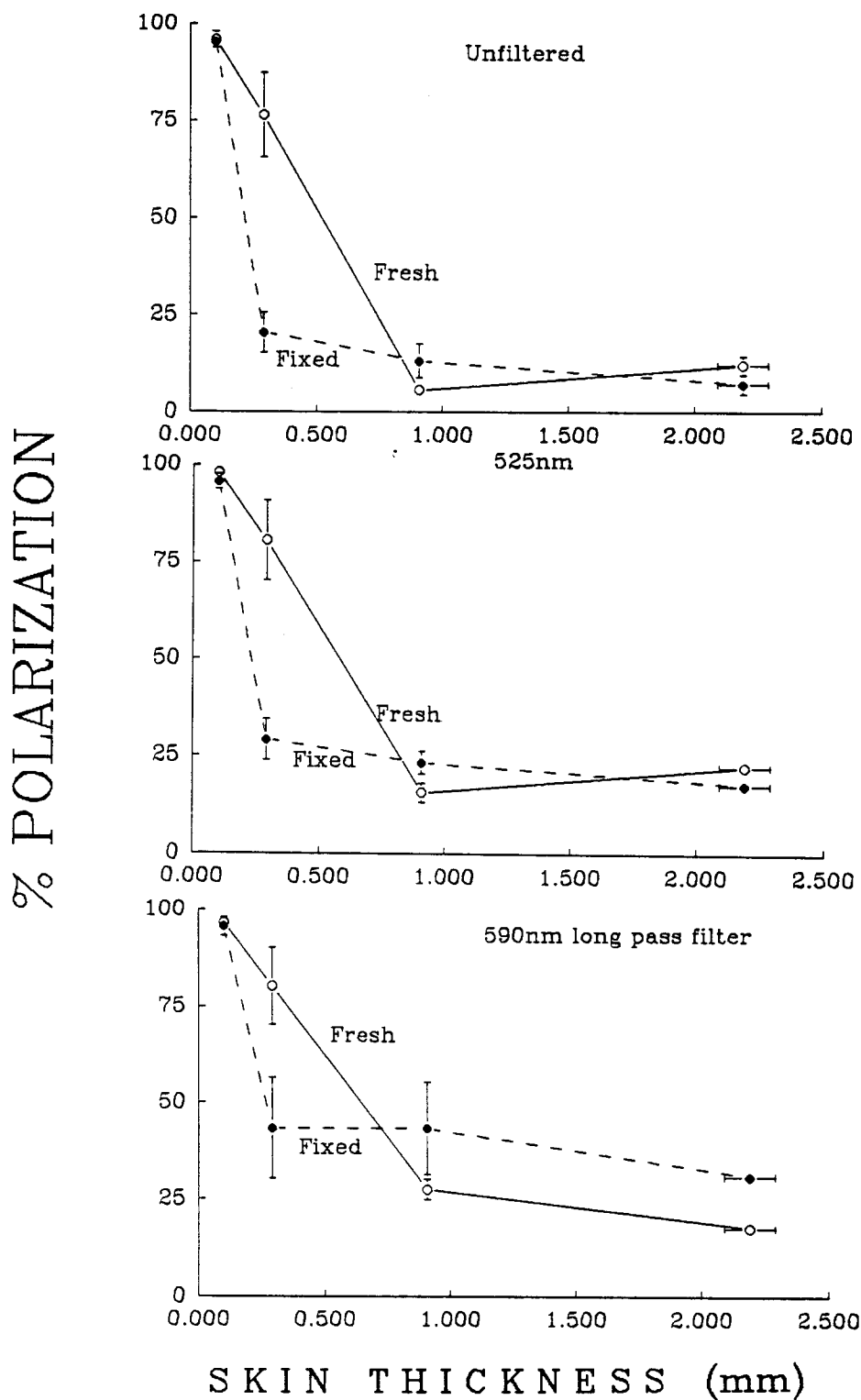


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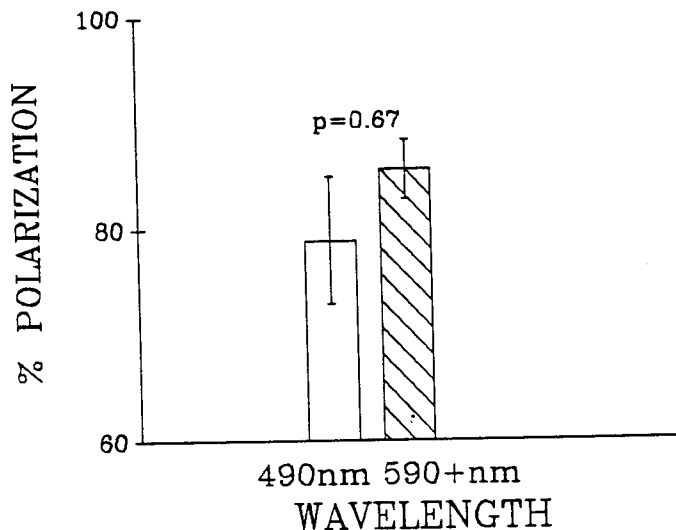
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Fresh	.3	.208	1.848	.0621	.822	.013	.1104
Fresh	.1	.00661	3.36	.00374	2.51	.0079	.593
Fresh	.1	.00458	3.71	.00358	1.476	.011	1.083
Fresh	.1	.00732	3.90	.00326	3.09	.0058	.536