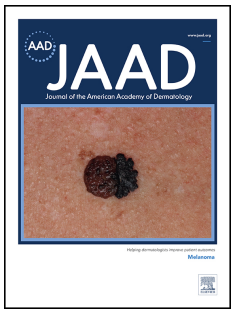
Journal Pre-proof



Cold atmospheric plasma device induces hair growth: a non-randomized, controlled study

Peter C. Friedman, MD, PhD, Gregory Fridman, PhD, Alexander Fridman, PhD

PII: S0190-9622(25)00538-9

DOI: https://doi.org/10.1016/j.jaad.2025.02.094

Reference: YMJD 19673

To appear in: *Journal of the American Academy of Dermatology*

Received Date: 21 October 2024

Revised Date: 22 February 2025

Accepted Date: 28 February 2025

Please cite this article as: Friedman PC, Fridman G, Fridman A, Cold atmospheric plasma device induces hair growth: a non-randomized, controlled study, *Journal of the American Academy of Dermatology* (2025), doi: https://doi.org/10.1016/j.jaad.2025.02.094.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2025 Published by Elsevier Inc. on behalf of the American Academy of Dermatology, Inc.

Journal Pre-proof

Article type: Brief report

Title: Cold atmospheric plasma device induces hair growth: a non-randomized, controlled study.

Peter C. Friedman, MD, PhD[1], Gregory Fridman, PhD[2], Alexander Fridman, PhD[3]

[1]The Skin Center Dermatology Group, 200 East Eckerson Road, New City, NY 10956

[2]AA Plasma, 3401 Grays Ferry Avenue, B197-221/223, Philadelphia, PA 19146

[3]C&J Nyheim Plasma Institute, Drexel University, 200 Federal Street, Suite 500, Camden, NJ 08103

Corresponding author:

Dr. Peter C. Friedman

Address: 200 E Eckerson Rd

New City, NY 10956

E-mail: pbc9@columbia.edu

Funding sources: None

Conflict of interest: non declared* see response to Associate Editor

IRB approval status: Reviewed and approved by the Western IRB; approval #20130084

ClinicalTrials.gov listing: NCT06149221

Patient consent: Not applicable

Reprint requests: Peter Friedman

Manuscript word count: 500

References: 5

Supplementary figure: Mendeley: doi: 10.17632/npjsksrjgc.1

Tables: 2

Keywords: clinical research; hair loss, cold plasma, non-thermal atmospheric pressure plasma

Journal Pre-proof

Journal Pre-proof

Body of manuscript: Minoxidil is widely used for various hair loss types, but there is a role for alternatives with better efficacy/tolerability profiles. Cold atmospheric pressure physical plasma (CAP) is a high energy, ionized gas containing reactive species, charged molecules.[1] In previous animal studies CAP improved hair growth via wnt/beta-catenin signaling[2,3] and by changing the interfollicular microenvironment.[4] We have reported the tolerability of applying CAP treated liquid medium to the scalp, but without measured parameters of hair growth.[5] In this study we compare the hair growth inducing effects of CAP and low dose oral minoxidil (LDOM), a known inducer of hair growth in different forms of alopecias. We used a novel, hybrid CAP treatment approach combining direct skin surface-generated plasma with simultaneous application of a liquid medium to act as a conduit for penetration by biologically active molecules of CAP.

20 male subjects with androgenetic alopecia, without history of other forms of hair loss were recruited. They had no prior exposure to LDOM, or any hair loss treatments 3 months prior to enrollment. The subjects self-selected to the LDOM or CAP group (n=10-10). The average age was 49 (34-59) for CAP and 38 (20-66) for LDOM. For CAP an 8X6 inch midline anterior hairline (n=6) or center vertex (n=4) treatment area was selected based on patient preference. The treated area was saturated with phosphate-buffered saline pH 7.2 solution (Thermo-Fisher Scientific, Inc., USA). CAP was delivered to the area using a floating-electrode direct-barrier discharge plasma device consisting of a quartz-covered copper electrode and a pulse generator supplying 20kV, 200 Hz pulse(FPG10- 01NM10, FID GmbH). The treated area was divided into three segments and the electrode was moved continuously over each segment for 5 minutes for a total of 15 minutes treatment time. The treatment was painless, no discomfort or other adverse events were reported. Treatment was performed every 2 weeks for 24 weeks. The LDOM group received oral minoxidil 2.5 mg daily for 24 weeks. Hair density and thickness were measured using a digital trichoscopy system (HairMetrix, Canfield Scientific, Inc., USA). Exact measurement site consistency was ensured using clinical photographs and anatomic landmarks. One LDOM-group patient was lost to follow-up.

Both treatment groups had improvement (Table 1.) and none of the subjects had any adverse effects. The average change of measured parameters in percentage and the results of a linear regression analysis of the post measurement data adjusted for the baseline measurement using the ANCOVA approach is shown in Table 2. In our sample, there was more improvement in the CAP treated group than in the LDOM group, for all three measures. Although this study was limited by small size, lack of randomization, pooled CAP treatment locations, our findings are in line with prior animal studies, and thus promising. The bi-weekly treatments may represent a barrier for some patients. If these results are verified in larger

Journal Pre-proof

studies, treatment parameters optimized (allowing longer time between treatment sessions), and device features are improved (treating larger scalp area), CAP may become a valuable treatment for hair loss.

Journal Pre-proof

Journal Pre-proof

Acknowledgements

The authors thank Kevin E. Thorpe, Assistant Professor, Dalla Lana School of Public Health, University of Toronto for performing the statistical analysis.

Journal Pre-proof

Journal Pre-proof

References

1. Friedman PC. Cold atmospheric pressure (physical) plasma in dermatology: where are we today? *Int J Dermatol*. 2020;59(10):1171-1184. doi:10.1111/ijd.15110
2. Babossalam S, Abdollahimajd F, Aghighi M, et al. The effect of nitrogen plasma on the skin and hair follicles: a possible promising future for the treatment of alopecia. *Arch Dermatol Res*. 2019. doi:10.1007/s00403-019-02020-w
3. Hwang JH, Lee HY, Chung KB, et al. Non-thermal atmospheric pressure plasma activates Wnt/β-catenin signaling in dermal papilla cells. *Sci Rep*. 2021;11(1):1-11. doi:10.1038/s41598-021-95650-y
4. Kim HJ, Choi EW, Choi EJ, et al. Non-thermal plasma promotes hair growth by improving the inter-follicular macroenvironment. *RSC Adv*. 2021;11(45):27880-27896. doi:10.1039/d1ra04625j
5. Khan A, Malik S, Walia J, Fridman G, Fridman A, Friedman PC. Tolerability of Six Months Indirect Cold (Physical) Plasma Treatment of the Scalp for Hair Loss. *J Drugs Dermatol*. 2020;19(12):1177-1180. doi:10.36849/JDD.2020.5186

Journal Pre-proof

Journal Pre-proof

Table 1. Subject characteristics and measurements

Age	Norwood scale	Fitzpatrick type	Scalp area treated*	Treatment group	Baseline terminal-vellus hair ratio	Treated terminal-vellus hair ratio	Baseline sum of hair width	Treated sum of hair width	Baseline hair count	Treated hair count
44	VII	III	Frontal[1]	CAP	21	68	8565	9104	124	129
34	III	VI	Frontal	CAP	1.5	3.5	5454	6222	134	139
46	IV	II	Frontal	CAP	7.7	8.9	8378	9190	123	140
59	VI	I	Vertex[2]	CAP	3.7	24	2411	3351	39	43
42	III	IV	Vertex	CAP	3.2	16.7	6843	9396	154	148
59	VII	I	Vertex	CAP	4.6	5.3	4010	5172	79	107
49	VI	II	Vertex	CAP	2	14	1760	2780	33	42
45	III	V	Frontal	CAP	5.6	17	8842	11132	130	151
59	V	II	Frontal	CAP	1.8	2.9	1814	3496	48	76
57	V	I	Frontal	CAP	14	6	2334	2733	43	58
47	IV	III	N/A	LDOM	13.3	21.3	7613	9635	160	187
61	III	II	N/A	LDOM	9.2	49	9862	8875	143	141
25	II	VI	N/A	LDOM	45	45	11437	12708	129	138
36	II	II	N/A	LDOM	9.4	31	11945	12111	205	179
40	II	II	N/A	LDOM	3.9	9.6	11672	11777	222	209
20	III	II	N/A	LDOM	34.5	40	15110	15380	200	230
66	VII	I	N/A	LDOM	3	4	623	518	12	11
25	II	III	N/A	LDOM	60	20	12207	12483	171	176
22	II	III	N/A	LDOM	6	2.6	10053	9753	216	244

Table 2. Subject characteristics are listed, subjects grouped by treatment group: cold atmospheric pressure physical plasma (CAP) and low-dose oral minoxidil (LDOM). Measurements obtained using digital trichoscopy at baseline and after completion of a 24 weeks treatment course are shown.

[1]Frontal indicates midline frontal hairline.

[2]Vertex indicates central vertex.

*For the CAP group measurements were obtained from the treated area, for the LDOM group measurements were obtained from the midline frontal hairline.

Journal Pre-proof

Table 2. Outcome analysis

6-month post-treatment measurements	Treatment modality		Regression analysis		
	CAP	LDOM	Lower 95 CI	Upper 95 CI	P-value
Terminal/vellus hair ratio increase	216% (p=0.03)	88% (p=0.28)	-3.494302	17.42061	0.1772332
Sum of hair width increase	33% (p<0.01	1.5% (p=0.16)	36.258080	2036.97090	0.0431179
Hair count increase	20% (p<0.01)	2.9% (p=0.18)	-13.786375	23.79192	0.5802800

Table 2. Digital trichoscopy measurements in the cold atmospheric pressure physical plasma (CAP) and low-dose oral minoxidil (LDOM) treatment groups after 6-months treatment, compared to baseline. Percentage changes in averages are shown. Regression analysis of the outcome measures was performed using the ANCOVA method. (CI: confidence interval)

Journal Pre-proof

Journal Pre-proof

Supplementary data

Mendeley Figure 1 Photo of the experimental device used in this study.

doi: 10.17632/npjsksrjgc.1

Journal Pre-proof