

Basics in Dermatological Laser Applications

Volume Editors

Inja Bogdan Allemann Zurich

David J. Goldberg New York, N.Y.

56 figures, 53 in color, and 19 tables, 2011

KARGER

Basel · Freiburg · Paris · London · New York · New Delhi · Bangkok ·
Beijing · Tokyo · Kuala Lumpur · Singapore · Sydney

ENDYMED EXHIBIT 1020 - 1/10
EndyMed v Serendia
IPR2024-00842

Current Problems in Dermatology

Inja Bogdan Allemann, MD

Klinik für Plastische Chirurgie und
Handchirurgie
Universitätsspital Zürich
Rämistrasse 100
CH-8091 Zürich
Switzerland

David J. Goldberg, MD

Skin Laser & Surgery Specialists of
New York & New Jersey
115 E. 57th Street, Suite 710
New York, NY 10022
USA

Bibliographic Indices. This publication is listed in bibliographic services, including MEDLINE/Pubmed.

Disclaimer. The statements, opinions and data contained in this publication are solely those of the individual authors and contributors and not of the publisher and the editor(s). The appearance of advertisements in the book is not a warranty, endorsement, or approval of the products or services advertised or of their effectiveness, quality or safety. The publisher and the editor(s) disclaim responsibility for any injury to persons or property resulting from any ideas, methods, instructions or products referred to in the content or advertisements.

Drug Dosage. The authors and the publisher have exerted every effort to ensure that drug selection and dosage set forth in this text are in accord with current recommendations and practice at the time of publication. However, in view of ongoing research, changes in government regulations, and the constant flow of information relating to drug therapy and drug reactions, the reader is urged to check the package insert for each drug for any change in indications and dosage and for added warnings and precautions. This is particularly important when the recommended agent is a new and/or infrequently employed drug.

All rights reserved. No part of this publication may be translated into other languages, reproduced or utilized in any form or by any means electronic or mechanical, including photocopying, recording, microcopying, or by any information storage and retrieval system, without permission in writing from the publisher.

© Copyright 2011 by S. Karger AG, P.O. Box, CH-4009 Basel (Switzerland)

www.karger.com

Printed in Switzerland on acid-free and non-aging paper (ISO 9706) by Reinhardt Druck, Basel

ISSN 1421-5721

ISBN 978-3-8055-9788-3

e-ISBN 978-3-8055-9789-0

Contents

vii Preface

Bogdan Allemann, I. (Zurich); Goldberg, D.J. (New York, N.Y.)

Introduction

1 History of Lasers in Dermatology

Geiges, M.L. (Zurich)

Physical and Electronic Properties of Lasers

7 Laser Principles

Bogdan Allemann, I. (Zurich); Kaufman, J. (Miami, Fla.)

24 Laser-Induced Tissue Reactions and Dermatology

Weber, R.J.; Taylor, B.R. (Charleston S.C.); Engelman, D.E. (New York, N.Y.)

35 Laser Safety

Dudelzak, J. (Brooklyn, N.Y.); Goldberg, D.J. (New York, N.Y.)

Laser Applications in Dermatology

40 Ablative Skin Resurfacing

Chwalek, J. (Hackensack, N.J.); Goldberg, D.J. (New York, N.Y.)

48 Non-Ablative Lasers

Ciocon, D.H.; Doshi, D.; Goldberg, D.J. (New York, N.Y.)

56 Fractional Photothermolysis

Bogdan Allemann, I. (Zurich); Kaufman, J. (Miami, Fla.)

Indications for Laser Applications

67 Vascular Lesions

Ting, P.T.; Rao, J. (Edmonton, Alta.)

81 Benign Pigmented Lesions

Bogdan Allemann, I. (Zurich); Goldberg, D.J. (New York, N.Y.)

97 Tattoo Removal

Adatto, M.A. (Geneva/Bern); Halachmi, S. (Petah Tiqwa); Lapidoth, M. (Petah Tiqwa/Tel Aviv)

111 Hair Removal

Haedersdal, M.; Haak, C.S. (Copenhagen)

122 Photoaging

Grunebaum, L.D. (Miami, Fla.); Heffelfinger, R.N. (Philadelphia, Pa.)

131 Scars

Elsaie, M.L. (Miami, Fla./Cairo); Choudhary, S.; McLeod, M.; Nouri, K. (Miami, Fla.)

140 Acne Vulgaris

Läuchli, S. (Zurich)

147 Skin Tightening

Woolery-Lloyd, H. (Miami, Fla.); Kammer, J.N. (Miami, Fla./Philadelphia, Pa.)

153 Special Considerations for Darker-Skinned Patients

Chan, H.H.L. (Hong Kong/Boston, Mass.)

160 At-Home Laser and Light-Based Devices

Brown, A.S. (Hackensack, N.J.)

Non-Laser Technologies/Light-Based Systems

166 Intense Pulsed Light

Schoenewolf, N.L.; Barysch, M.J.; Dummer, R. (Zurich)

173 Light-Emitting Diode

Gold, M.H. (Nashville, Tenn.)

181 Photodynamic Therapy

Gold, M.H. (Nashville, Tenn.)

193 Author Index

194 Subject Index

Indications for Laser Applications

Bogdan Allemann I, Goldberg DJ (eds): Basics in Dermatological Laser Applications.
Curr Probl Dermatol. Basel, Karger, 2011, vol 42, pp 147–152

Skin Tightening

Heather Woolery-Lloyd^a · Jenna N. Kammer^{b,c}

^aDepartment of Dermatology and Cutaneous Surgery and ^bCosmetic Medicine and Research Institute, University of Miami, Miami Beach, Fla., and ^cDrexel University College of Medicine, Philadelphia, Pa., USA

Abstract

Skin tightening describes the treatment of skin laxity via radiofrequency (RF), ultrasound, or light-based devices. Skin laxity on the face is manifested by progressive loss of skin elasticity, loosening of the connective tissue framework, and deepening of skin folds. This results in prominence of submandibular and submental tissues. Genetic factors (chronological aging) and extrinsic factors (ultraviolet radiation) both contribute to skin laxity. There are many RF, ultrasound, and light-based devices directed at treating skin laxity. All of these devices target and heat the dermis to induce collagen contraction. Heating of the dermis causes collagen denaturation and immediate collagen contraction in addition to long-term collagen remodeling. Via RF, light, or ultrasound, these skin tightening devices deliver heat to the dermis to create new collagen and induce skin tightening. This chapter will provide an overview of the various skin tightening devices.

Copyright © 2011 S. Karger AG, Basel

Skin laxity on the face is manifested by progressive loss of skin elasticity, loosening of the connective tissue framework, and deepening of skin folds. This results in prominence of submandibular and submental tissues [1]. Skin laxity on the body occurs with normal aging on the upper arms, thighs, and legs. Skin laxity on the body is also commonly observed after significant rapid weight loss. In

addition, abdominal skin laxity can occur after pregnancy. Inherent genetic factors (chronological aging) and extrinsic factors (ultraviolet radiation) contribute to skin laxity. Unlike photoaging, skin laxity is a cosmetic complaint observed in all skin types.

There are many radiofrequency (RF)-, light-, and ultrasound-based devices directed at treating skin laxity. All of these devices are based on the notion that collagen contracts when heat is applied. Heating of the dermis causes collagen denaturation and immediate collagen contraction, in addition to long-term collagen remodeling [2, 3]. Via RF, light, or ultrasound, these skin tightening devices deliver heat to the dermis to create new collagen and induce skin tightening. Some of the available skin tightening devices on the market are listed in table 1.

Patient Selection

Patient selection is very important in treating skin laxity. Older patients with excessive skin laxity are less likely to achieve the results that a younger patient with mild-to-moderate skin laxity will achieve. Also, patients with significant fat underlying the loose skin are less likely to get

Table 1. Skin tightening devices

Technology	Device
Infrared light (1,100–1,800)	Cutera (Titan)
Infrared light (850–1,350 nm)	Palomar (Lux IR and Lux Deep IR)
Infrared light (800–1,400)	Sciton (SkinTyte)
RF: monopolar	Thermage (Theramcool)
RF: bipolar with vacuum	Lumenis (Aluma)
RF: bipolar with optical energy	Syneron (ReFirme)
RF: unipolar and bipolar	Alma (Accent)
Ultrasound	Ulthera P (Ulthera)

optimal results. Predictability of patient response to treatment has been a concern with skin tightening procedures. It is clear that the level of patient response can vary widely and be difficult to predict. Therefore, appropriate selection of patients and managing realistic patient expectations are fundamental considerations to ensure satisfaction with results. It is important to note that it can take up to 6 months to achieve the best results and this aspect of skin tightening treatments should also be discussed with patients [4]. As with all cosmetic procedures, management of patient expectations is essential. Patients must realize that results can be noticeable, but often are subtle. Since the changes are gradual and the patient sees themselves every day, before and after pictures can be helpful.

Technologies

All skin tightening devices work via a similar mechanism. They all strive to deliver enough heat through ultrasound, RF, or light-based energy

deep into the dermis, causing an initial contraction of the collagen fibers followed by dermal remodeling and in the end neocollagen synthesis. Several light-based, ultrasound, and RF devices have been introduced.

Laser Devices: CO₂ and Er:YAG Lasers

Many studies have shown that treatments with ablative CO₂ and Er-YAG lasers selectively heat dermal collagen, resulting in a dermal neocollagen formation and tightening of the facial skin [5–7]. However, the major disadvantage of ablative treatment methods is epidermal damage, resulting in a recuperation period of many weeks. Additionally, there are potential risks such as hyper- or hypopigmentation, infections, and scarring [5, 8, 9]. For this reason, non-ablative skin rejuvenation has become popular over the recent years.

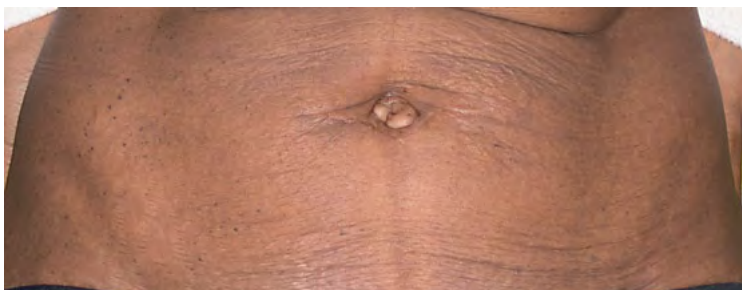
Infrared Tightening

Infrared skin tightening utilizes infrared light to heat the dermis. One of the first infrared tightening devices introduced was the Titan (Cutera, Inc., Brisbane, Calif., USA). It utilizes a long pulse of infrared light with a spectrum of 1,100–1,800 nm, with the greatest intensity in the range of 1,400–1,500 nm. The penetration depth is 1–2 mm, which is best for targeting the reticular dermis [10]. Light is emitted in multisecond cycles in order to sufficiently heat the dermis while providing appropriate cooling of the epidermis. Like other skin tightening devices, it is designed to thermally induce immediate collagen contraction, followed by the induction of collagen remodeling and the synthesis of new collagen. Water is the target chromophore which allows for uniform heating of the targeted area. The procedure causes mild-to-moderate discomfort and mild temporary erythema. The epidermis is protected through contact cooling with a sapphire tip. The procedure is associated with minimal downtime and is safe to use on all skin types. Two initial passes are performed over the entire designated treatment area,

Fig. 1. Baseline.



Fig. 2. After 3 treatments with an infrared tightening device.



with additional passes over areas of great concern. A series of 3–4 treatments, 4–6 weeks apart, are recommended for the best results. Although an immediate tightening effect is achieved, the full effect is observed 6 months after the last treatment [11] (fig. 1, 2).

In an open-label trial in 21 Asian patients, skin tightening was observed in 86% of patients as measured by 3 independent physician observers. This improvement ranged from mild to excellent (mild 29%, moderate 38%, excellent 19%) [12]. Variable response rates with skin tightening technologies may be due to the patient selection, energies used, and overall skin quality [13].

Another infrared device, the SkinTyte (Sciton, Inc., Palo Alto, Calif., USA) delivers infrared light in the range of 800–1,400 nm. It utilizes uniform targeted deep dermal heating to achieve

skin tightening. Continuous cooling of the epidermis is achieved with thermoelectric sapphire plates.

The LuxIR and the LuxDeep IR (Palomar Medical Technologies, Inc., Burlington, Ma., USA) deliver infrared light in the range of 850–1,350. The LuxDeepIR Fractional Infrared Handpiece (Palomar Medical Technologies) utilizes fractional infrared light and was designed to deliver infrared deep light extending up to 4 mm into the dermis and fat layer without damaging the epidermis. The LuxDeep IR Handpiece safely delivers more effective heat to greater depths, and offers longer pulse durations. The energy is delivered through a sapphire crystal with contact cooling to prevent epidermal injury. Several treatments are required. Various clinical trials have demonstrated improvement in skin tightening [14–16].

Radiofrequency

RF devices heat, lift, and tighten dermal tissue to treat skin laxity [17]. RF energy is an alternating current that runs from the tip of an electrode to tissue that it contacts [13]. In contrast to direct current, with alternating current, the flow of electrons cycles back and forth at a certain frequency. The frequency of the alternating current in RF devices is typically 0.3–10 MHz [18]. These devices generate dermal heating, denature collagen, and induce collagen remodeling. Wound healing mechanisms trigger wound contraction, which enhances the appearance of mild to moderate skin laxity. RF devices are either monopolar (unipolar), bipolar, or both.

Monopolar Radiofrequency

In monopolar RF systems, current flows from the electrode in contact with the treatment area to a grounding electrode on the skin at a distant site. The current flows from the electrode contact area through the body to the grounding pad. Most of the heat is generated just beneath the treating electrode. One of the first monopolar RF devices ThermaCool (Thermage, Inc., Hayward, Calif., USA) was developed to specifically tighten deeper dermal structures without damaging the epidermis. The benefit of monopolar RF devices is that the current penetrates to the deeper layers of skin [18, 19]. RF treatments can be mild-to-moderately painful and patients may require some pain management [19].

The ThermaCool (Thermage) is a non-ablative monopolar RF device that heats the deep tissues utilizing a capacitive coupling membrane. The capacitive coupling causes volumetric tissue heating, allowing large amounts of energy to be distributed over a three-dimensional volume of dermal tissue. This device uses monopolar RF with a grounding pad placed on the patient to deliver heat deep in the dermis (volumetric

deep dermal heating). In addition to the dermis, monopolar RF energy delivers heat to the fibrous septae within the fat. A cryogen system simultaneously cools the epidermis. Disposable single-use tips are available in different sizes to treat different body parts. Originally, high energies were delivered in 1–2 passes to achieve clinical results. Later treatments evolved to utilize lower energies with multiple passes to improve tolerability. Fat necrosis, which had been originally described as a possible adverse effect, is now rare with the newer parameters [20]. Clinical studies show efficacy in treating skin laxity with monopolar RF in all skin types [3, 21, 22].

Bipolar Radiofrequency

Bipolar RF devices use two electrodes positioned at fixed distances from each other, and both electrodes are in contact with the area being treated [11]. Alternating current enters the skin and passes only through the tissue between the two electrodes. In these devices, the penetration depth of the electrical current is approximately half the distance between the electrodes [18]. With bipolar systems the distribution of current can be controlled, but the depth of the treatment is less than that with monopolar RF. For this reason, many bipolar RF devices have been coupled with other modalities to address this issue.

Bipolar Radiofrequency: Vacuum-Assisted

The Aluma (Lumenis, Santa Clara, Calif., USA) uses its bipolar RF energy with an accompanying vacuum apparatus, which allows energy to selectively target the deep dermis. With this system there is little or no pain associated with the procedure, and it utilizes less energy because the vacuum brings the electrodes closer to the dermal tissue. The disposable treatment tip can be used for multiple treatment sessions. Clinical trials have demonstrated safety and efficacy for skin tightening [19, 23].

Combined Unipolar and Bipolar Radiofrequency
The Accent (Alma Lasers, Inc., Ft. Lauderdale, Fla., USA) RF system includes both a unipolar handpiece for volumetric deep heating and a bipolar handpiece for superficial heating of the dermis. One of the first studies demonstrated its effectiveness in reducing the appearance of cellulite and also confirmed its effect on tissue tightening [24]. Since then, a number of reports have verified its safety and efficacy in treating wrinkles and skin laxity [25, 26].

Combined Bipolar Radiofrequency and Optical Energy

The ReFirme (Syneron Medical Ltd., Yokneam, Israel) is a combined bipolar RF and optical energy device (700–2,000 nm infrared light). The theory is that with these combined energy sources, less RF energy is necessary. A grounding plate is not required. The RF energy is more superficial and the cooling apparatus is in the handpiece. Clinical studies have demonstrated improvement in skin laxity with this device [27, 28]. In one study, blinded evaluation of treated subjects revealed statistically significant improvements in the cheeks, jowls, and nasolabial folds [28].

Ultrasound Tightening

Intense ultrasound is an energy that can propagate through tissue up to several millimeters. Ultrasound waves induce a vibration in the molecules of a target tissue during propagation, and the thermoviscous losses in the medium lead to tissue heating [29]. When the beam is directed to focus on the tissue at a certain depth, it produces thermal coagulative necrosis, leaving the superficial layers unaffected.

The Ulthera P (Ulthera, Mesa, Ariz., USA) ultrasound device utilizes intense focused ultrasound energy to achieve skin tightening. Epidermal injury is minimized, and thermal energy is directed into the reticular dermis and subcutis, where immediate tissue contraction and delayed remodeling are believed to collectively cause tightening. It

has been developed specifically for treating facial soft tissues and targeting the superficial musculoaponeurotic system [30].

It is a micro-ablation device that non-invasively treats multiple layers of tissue. The device uses standard ultrasound to visualize the target layers of the sub-epidermis immediately before the therapeutic level of focused ultrasonic energy is delivered. This gives the clinician the ability to visualize and target the desired treatment level of the skin. The outer epidermal layer of skin is spared, while deeper treatment immediately triggers the body's natural healing effect, resulting in a gradual lifting and tightening of the face and neck. This procedure can be painful and typically requires pain management. Clinical studies have demonstrated improvement in skin laxity in addition to brow elevation [31].

Conclusion

Non-invasive skin tightening is a highly sought after procedure and new devices in this arena continue to be developed. There are many commercially available devices that have offered patients effective results without surgery. However, ultrasound, laser, and light-based devices do not deliver surgical results and patient selection is key. Furthermore, assessing of the action of tightening is difficult, as there is no standardized measure available. Photographic evaluations are sometimes helpful but can be challenging, as a minor change in position will alter the results. Additionally, it is difficult to measure if slight tightening occurs, especially if it occurs over a long period of time. There is a definite need for more blinded controlled trials to assess these technologies more thoroughly. In addition it is still uncertain how long the results will last before maintenance therapies are necessary. Further long-term clinical trials are warranted to look into the skin tightening longevity with the current tightening devices available.

References

- 1 Alexiades-Armenakas M: Assessment of the mobile delivery of infrared light (1,100–1,800 nm) for the treatment of facial and neck skin laxity. *J Drugs Dermatol* 2009;8:221–226.
- ▶ 2 Zelickson BD, Kist D, Bernstein E, et al: Histological and ultrastructural evaluation of the effects of a radiofrequency based nonablative dermal remodeling device. *Arch Dermatol* 2004;140:204–209.
- ▶ 3 Fitzpatrick R, Geronemus R, Goldberg D, et al: Multicenter study of noninvasive radiofrequency for periorbital tissue tightening. *Lasers Surg Med* 2003;33:232–242.
- 4 Gold MH: Tissue tightening: a hot topic utilizing deep dermal heating. *J Drugs Dermatol* 2007;6:1238–1242.
- ▶ 5 Fitzpatrick RE, Goldman MP, Sotir NM, et al: Pulsed carbon dioxide laser resurfacing of photoaged skin. *Arch Dermatol* 1996;132:395–402.
- ▶ 6 Kauvar AN, Geronemus RG: Histology of laser resurfacing. *Dermatol Clin* 1997;15:459–467.
- ▶ 7 Majaron B, Kelly KM, Park HB, et al: Er:YAG laser skin resurfacing using repetitive long-pulse exposure and cryogen spray cooling. I. Histological study. *Lasers Surg Med* 2001;28:121–130.
- ▶ 8 Greve B, Raulin C: Professional errors caused by laser and IPL technology in dermatology and aesthetic medicine: preventive strategies and case studies. *Dermatol Surg* 2001;28:156–161.
- ▶ 9 Nanni CA, Alster TS: Complications of carbon dioxide laser resurfacing: an evaluation of 500 patients. *Dermatol Surg* 1998;24:315–320.
- ▶ 10 Dierickx CC: The role of deep heating for noninvasive skin rejuvenation. *Lasers Surg Med* 2006;38:799–807.
- ▶ 11 Sadick NS: Tissue tightening technology: fact or fiction. *Aesthet Surg J* 2008;28:180–188.
- ▶ 12 Chua SH, Ang P, Khoo LS, Goh CL: Nonablative infrared skin tightening in type IV to V Asian skin: a prospective clinical study. *Dermatol Surg* 2007;33:146–151.
- ▶ 13 Bunin LS, Carniol BJ: Cervical facial skin tightening with an infrared device. *Facial Plast Surg Clin North Am* 2007;15:179–184.
- ▶ 14 Dierickx C, Altschuler G, Erofeev A, et al: Skin tightening with Palomar's StarLux IR deep dermal, fractional heating. *Lasers Surg Med* 2008;40:1–132.
- ▶ 15 Weiss R: Fractional infrared light for skin tightening: six month prospective study. *Lasers Surg Med* 2007;39:15–34.
- 16 Dierickx C, Altschuler G, Childs J, et al: Dermal/hypodermal junction as a new target for deep fractional thermal treatment. *Lasers Surg Med* 2007;39:1–14.
- ▶ 17 Alster TS, Lupton JR: Nonablative cutaneous remodeling using radiofrequency devices. *Clin Dermatol* 2007;25:487–491.
- ▶ 18 Sadick NS, Makino Y: Selective electro-thermolysis in aesthetic medicine: a review. *Lasers Surg Med* 2004;34:91–97.
- 19 Montesi G, Calvieri S, Balzani A, et al: Bipolar radiofrequency in the treatment of dermatologic imperfections: clinicopathological and immunohistochemical aspects. *J Drugs Dermatol* 2007;6:890–896.
- ▶ 20 Dover JS, Zelickson B: Results of a survey of 5,700 patient monopolar radiofrequency facial skin tightening treatments: assessment of a low-energy, multiple-pass technique leading to a clinical point algorithm. *Dermatol Surg* 2007;33:900–907.
- ▶ 21 Alster TS, Tanzi E: Improvement of neck and cheek laxity with a nonablative radiofrequency device: a lifting experience. *Dermatol Surg* 2004;30:503–507.
- ▶ 22 Kushikata N, Negeshi K, Takeuchi K, Wakamatsu S: Nonablative skin tightening with radiofrequency in Asian skin. *Lasers Surg Med* 2005;36:92–97.
- ▶ 23 Gold MH, Goldman MP, Rao J, et al: Treatment of wrinkles and elastosis using vacuum-assisted bipolar radiofrequency heating of the dermis. *Dermatol Surg* 2007; 33:300–309.
- 24 Emelia del Pino M, Rosado RH, Azuela A, et al: Effect of controlled volumetric tissue heating with radiofrequency on cellulite and the subcutaneous tissue of the buttocks and thighs. *J Drugs Dermatol* 2006;5:714–722.
- ▶ 25 Freidman DJ, Gilead LT: The use of hybrid radiofrequency device for the treatment of rhytides and lax skin. *Dermatol Surg* 2007;33:543–551.
- 26 Mayoral FA: Skin tightening with a combined unipolar and bipolar radiofrequency device. *J Drugs Dermatol* 2007;6:212–215.
- 27 Sadick NS: Electro-optical synergy in aesthetic medicine: novel technology, multiple applications. *Cosmet Dermatol* 2005;18:201–206.
- ▶ 28 Yu, CS, Yeung CK, Shek SY, Tse RK, Kono T, Chan HH: Combined infrared light and bipolar radiofrequency for skin tightening in Asians. *Lasers Surg Med* 2007;39:471–475.
- ▶ 29 Kennedy JE, terHaar GR, Cranston D: High intensity focused ultrasound: surgery of the future? *Br J Radiol* 2003;76:590–599.
- ▶ 30 White WM, Makin IR, Barthe PG, Slayton MH, Gliklich RE: Selective creation of thermal injury zones in the superficial musculoaponeurotic system using intense ultrasound therapy: a new target for noninvasive facial rejuvenation. *Arch Facial Plast Surg* 2007;9:22–29.
- ▶ 31 Alam M, White LE, Martin N, Witherpoon J, Yoo S, West DP: Ultrasound tightening of facial and neck skin: a rater-blinded prospective cohort study. *J Am Acad Dermatol* 2010;62:262–269.

Heather Woolery-Lloyd, MD
 University of Miami Department of Dermatology and Cutaneous Surgery
 1295 Northwest 14th Street
 South Building, Suite K
 Miami, FL 33125 (USA)
 Tel. +1 305 243 6704, E-Mail woolerylloyd@yahoo.com