

# Quantification of Skin Elasticity Changes Associated With Pulsed Carbon Dioxide Laser Skin Resurfacing

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**Background:** While skin resurfacing using pulsed carbon dioxide lasers appears to have a skin-tightening effect clinically, the debate continues over its actual effects on dermal collagen.

**Objectives:** To provide quantitative measures of skin elasticity changes associated with pulsed carbon dioxide laser skin resurfacing and to introduce to the facial plastic surgery community the Cutometer SEM 575 skin elasticity meter, an instrument that is useful in the measurement of skin elasticity.

**Setting:** University-based facial plastic surgery clinic and wound healing laboratory.

**Design:** Intervention.

**Main Outcome Measures:** Measurements taken prior to and 6 months after procedure.

**Subjects and Intervention:** Thirty-two patients undergoing pulsed carbon dioxide full-face laser skin re-

surfacing participated. There were 12 test sites measured in 6 aesthetic units per participant. The Cutometer SEM 575 skin elasticity meter was used to measure skin elasticity changes accompanying this procedure. This device measures skin deformation with an accuracy of 10  $\mu\text{m}$ .

**Results:** The change in elastic recovery ( $U_r/U_e$ ) was determined. At all 6 of the facial sites, there was a statistically significant increase in skin elasticity ( $P < .001$ ). Overall, there was an 18.2% improvement in skin elasticity. Site-specific changes ranged from 9% (forehead) to 22% (prejowl and periorbital).

**Conclusions:** Skin resurfacing with the pulsed carbon dioxide laser produces a true skin-tightening effect. The Cutometer is a valuable instrument that permits accurate quantification of skin elasticity and may be useful in the evaluation of other facial plastic procedure results.

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**W**HILE SKIN resurfacing using pulsed carbon dioxide lasers appears to have a skin-tightening effect clinically, the debate continues over its actual effects on dermal collagen. There have been multiple histological evaluations of its effects, but it is unclear how this translates into substantive changes in skin elasticity.

Objective measures of results obtained from facial plastic surgery procedures are desirable. Uniform photographic documentation has improved, but there are still inconsistencies in patient position and lighting, which may lead to skepticism over viewing the presented results. Also, physician-based grading systems have inherent elements of subjectivity no matter how good the intentions. Quantification of results in a purely ob-

jective manner would be of great benefit for all facial plastic procedures. This need has been recognized with the use of cephalometric radiographs to monitor orthognathic procedures and grid systems to assess browlift results.

The Cutometer SEM 575 skin elasticity meter (Courage & Khazaka Electronic GmbH, Cologne, Germany) was used to measure skin elasticity changes accompanying pulsed carbon dioxide laser skin resurfacing (**Figure 1**). The Cutometer is an accepted dermatologic research tool for the evaluation of skin elasticity and has been used primarily to monitor conditions such as scleroderma.<sup>1</sup> The principle of the instrument is the application of a vacuum perpendicular to the skin surface and the measurement of the resulting skin deformation. The purpose of this study is to provide quantitative measures of skin elasticity changes associated with pulsed carbon di-

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## SUBJECTS AND METHODS

### SUBJECTS AND INTERVENTION

Thirty-two women undergoing pulsed carbon dioxide full-face laser skin resurfacing participated in our study. The procedure was performed at a university-based facial plastic surgery clinic; measurements were obtained at our wound healing laboratory. The mean age of the participants was 50 years (age range, 29-66 years). Indications for the procedure were fine to moderate rhytids, mild facial elastosis, actinic-damaged skin, shallow acne scars, or mild skin dyschromias. Exclusion criteria included active acne, psoriasis, eczema, allergic dermatitis, isotretinoin (Accutane) use in the previous 12 months, type VI sun-reactive skin type (**Table 1**), and facial skin resurfacing (chemical, laser, or dermabrasion) in the past 6 months. Smokers were not excluded.

The subjects stopped the use of skin products (including moisturizers and sunscreens) 3 weeks before their treatment. They were allowed to use a nonmoisturizing soap. Patients with type IV or V skin (such as persons of Asian or Hispanic descent, respectively) or in anticipation of a hyperpigmentation problem were pretreated with a combination cream containing 5% to 8% hydroquinone with 1% hydrocortisone and 0.05% to 0.1% tretinoin twice a day for 4 weeks.

The Luxar LX-20SP NovaPulse carbon dioxide laser (ESC Medical Systems, Yokneam, Israel) was used with a SureScan computerized pattern generator handpiece (ESC Medical Systems). Settings used were 6 to 7 W (360-420 mJ), program E-16, 0 density, with 1 to 2 passes. Problem regions, such as the perioral region, received additional passes as indicated.

A closed wound care system was used to promote moist healing while preventing an exudative phase.<sup>2</sup> The occlusive dressing was removed after 2 days. Routine postoperative medications included ciprofloxacin, 500 mg twice a day for 5 days, for *Pseudomonas* coverage. For herpes prophylaxis on all cases, valacyclovir hydrochloride, 500 mg twice a day (starting 2 days prior to treatment), was given until day 10. After reepithelialization, a UV-A/UV-B sunscreen with an SPF (sunlight protection factor) greater than 25 was applied.

### THE CUTOMETER SEM 575 SKIN ELASTICITY METER

As described by Elsner,<sup>3</sup> the Cutometer SEM 575 skin elasticity meter consists of a main unit and a handheld probe.

The main unit contains the vacuum pump, which generates a vacuum of up to 500 mbar, and the pressure sensor. The electronic circuit controls the pump and the analog-digital data conversion. The suction head is centered in the probe shield and has a 2-mm circular opening for application of the vacuum to the skin (**Figure 2**). Skin deformation is measured with an accuracy of 10  $\mu\text{m}$  and at a frequency of 100 Hz.<sup>3</sup> The Cutometer is linked to an IBM-compatible computer and controlled from the computer. Two measuring modes are available, a stress-strain mode and a time-strain mode. In the stress-strain mode, the vacuum is increased from 0 to 500 millibars (mbar) over a selected period, and the deformation (in millimeters) is displayed as a function of negative pressure (in millibars). In the time-strain mode, a selected vacuum is applied for a chosen period. Measurements can be made with a linearly increasing and decreasing vacuum. The deformation is displayed as a function of time.

### SKIN ELASTICITY MEASUREMENTS

There were 12 test sites measured in 6 aesthetic units per participant (**Figure 3**). Two measurements were taken at each site, and then the average was calculated. Measurements were obtained immediately prior to and 6 months after the procedure. All measurements were taken in an air-conditioned room (temperature, 20°C-21°C; air humidity, 55%-60%). The same person performed all measurements.

The Cutometer generates a graph (**Figure 4**) depicting immediate deformation or skin extensibility ( $U_e$ ), delayed distention ( $U_v$ ), final deformation ( $U_f$ ), and immediate retraction ( $U_r$ ), following the nomenclature proposed by Agache et al.<sup>4</sup> Certain ratios of these parameters do not depend on skin thickness and can be compared between sites and subjects.<sup>5,6</sup>

Using a 2-mm probe, a negative pressure of 400 mbar was applied to the skin for a period of 2 seconds, followed by a 2-second relaxation time for 2 cycles. The first deformation is considered to be the preconditioning phase and should not be evaluated. The deformation curve is composed of a fast deformation, representing a purely elastic part, followed by a viscoelastic part and finally a purely viscous part.<sup>3</sup>

### STATISTICAL ANALYSIS

The  $t$  test was used to determine the significance of differences detected before and after treatment. Differences at  $P \leq .05$  were considered statistically significant.

oxide laser skin resurfacing. Another goal is to introduce the Cutometer as an instrument to measure skin elasticity to the facial plastic surgery community.

## RESULTS

The change in elastic recovery ( $U_r/U_e$ ) was determined. Elastic recovery is represented by the ratio of immediate skin retraction ( $U_r$ ) to skin extensibility ( $U_e$ ). The mean  $U_r/U_e$  for each aesthetic unit was calculated. The preprocedure ratio was compared with the 6-month ratio. At all 6 of the facial sites, there was a statistically significant increase in skin elasticity ( $P < .001$ ). Site-specific

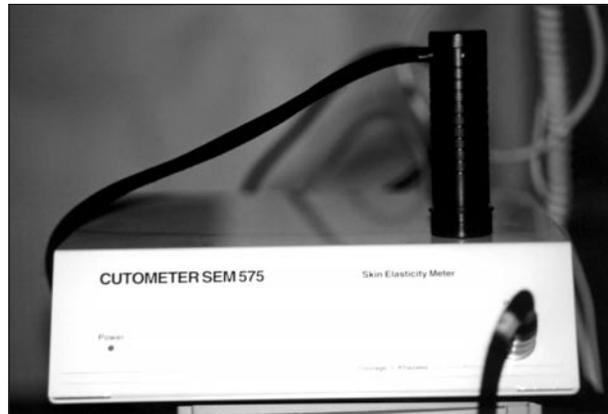
changes ranged from 9% (forehead) to 22% (prejowl and periorbital) (**Table 2**). Overall, there was an 18.2% increase in skin elasticity.

There was an 88% (28 of 32 patients) subjective patient satisfaction rate as determined by questionnaire 6 months after the procedure. This was not graded, but patient satisfaction was evaluated by the response to the question, "Were you satisfied with the results of your resurfacing procedure?" In addition, patients were monitored for postprocedural complications, including hyperpigmentation, hypopigmentation, scar formation, bacterial skin infection, herpetic outbreak, prolonged erythema (>3 months), ectropion, and skin sensory defi-

cits. One patient developed postinflammatory hyperpigmentation after exposure to direct sunlight 3 weeks after her procedure. Another patient had persistent hyperpigmentation (skin type V), which responded to bleaching agents. No patients had persistent erythema (>3 months). No other complications occurred.

**COMMENT**

The ratio of  $U_r/U_e$  is the parameter of choice for quantifying skin aging, since it represents elastic recovery (ie, the ability of the skin to recover after deformation) independent of skin thickness. Because immediate recovery decays with age, the index of elasticity ( $U_r/U_e$ ) de-



**Figure 1.** The Cutometer SEM 575 skin elasticity meter was used to measure skin elasticity changes accompanying pulsed carbon dioxide laser skin resurfacing. A vacuum is placed perpendicular to the skin surface and the resulting skin deformation is measured.

**Table 1. Fitzpatrick Sun-Reactive Skin Types**

Skin Type	Skin Color	Tanning Response
I	White	Always burns, never tans
II	White	Usually burns, tans with difficulty
III	White	Sometimes mild burn, tan average
IV	Brown	Rarely burns, tans with ease
V	Dark brown	Very rarely burns, tans very easily
VI	Black	Does not burn, tans very easily

creases with age. In this prospective study, the participants served as their own controls. The statistically significant increase in  $U_r/U_e$  ratios ( $P < .001$  for all) is even more impressive when considering that the  $U_r/U_e$  ratio decreases on its own because of aging during the 6-month interval.

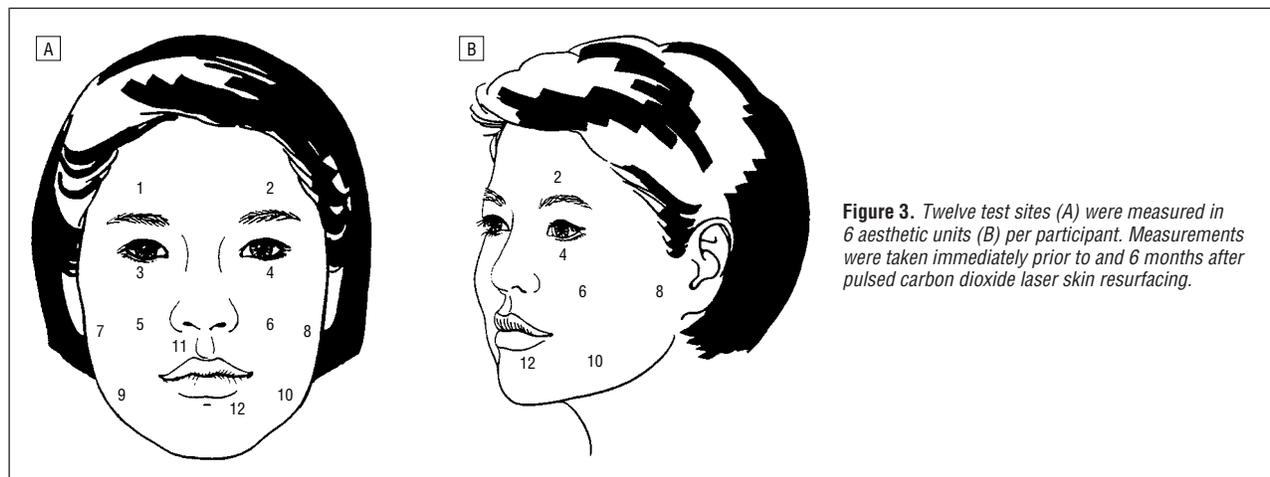
The  $U_v/U_e$  ratio (the ratio between delayed and immediate deformation) indicates the relative contributions of the viscoelastic, viscous, and elastic deformations to the total deformation.<sup>6</sup> The  $U_r/U_f$  ratio is the ratio of immediate retraction to the total deformation and is called *biological elasticity*.<sup>6</sup> The  $U_r/U_e$  ratio seems to closely parallel the  $U_r/U_f$  ratio.<sup>7</sup>

We did not perform a “number of passes” analysis with elasticity changes because we wanted to treat this subset of patients as we would normally treat any patient entering for laser resurfacing (ie, individualized treatment based on need). The correlation of the number of passes and especially fluence with elasticity changes warrants further study.

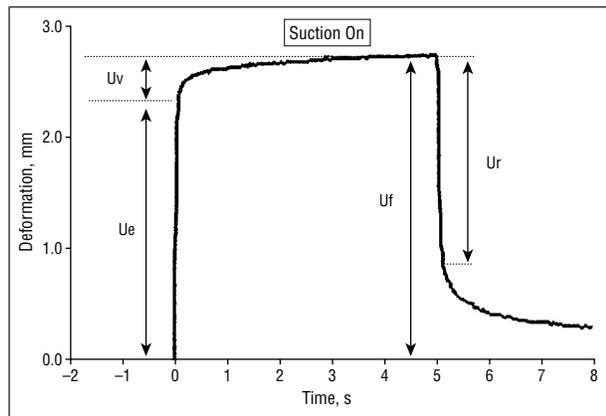
The Cutometer has several other possible indications in the quantification of facial plastic surgery results. These include evaluation of the tightening effects of the erbium-YAG (Er:YAG) laser and combined Er:YAG-carbon dioxide laser wavelengths<sup>7</sup> and the evalu-



**Figure 2.** The suction head of the Cutometer SEM 575 skin elasticity meter is centered in the probe shield and has a 2-mm circular opening for application of the vacuum to the skin. A negative pressure of 400 millibars was applied to the skin for a period of 2 seconds, followed by 2 seconds of relaxation for 2 cycles.



**Figure 3.** Twelve test sites (A) were measured in 6 aesthetic units (B) per participant. Measurements were taken immediately prior to and 6 months after pulsed carbon dioxide laser skin resurfacing.



**Figure 4.** Graph depicting immediate deformation ( $U_e$ ), delayed distention ( $U_v$ ), final deformation ( $U_f$ ), and immediate retraction ( $U_r$ ) of the tested skin.

**Table 2. Net Skin Elasticity Before and After Pulsed Carbon Dioxide Laser Treatment (N = 32)\***

Site	Mean (SD) $U_r/U_e$ Ratio†		Change in Skin Elasticity, %
	Before Treatment	6 Months After Treatment	
Forehead	0.64 (0.06)	0.70 (0.06)	9
Periorbital	0.59 (0.06)	0.72 (0.08)	22
Medial cheek	0.56 (0.07)	0.67 (0.07)	20
Lateral cheek	0.47 (0.07)	0.56 (0.08)	19
Prejowl	0.48 (0.06)	0.59 (0.07)	22
Perioral	0.70 (0.06)	0.82 (0.06)	17

\* $U_r$  indicates immediate retraction;  $U_e$ , skin extensibility.

† $P < .001$ .

ation of newer modalities, such as the nonablative dermal effects of the Nd:YAG laser and radiofrequency energy. The Cutometer may also be valuable in the preoperative assessment of lower eyelid laxity or in the predictive analysis of patients undergoing rhytidectomy. In other words, can we estimate the quality and duration of a face-lift result based on preexisting skin elasticity?

In conclusion, skin resurfacing with the pulsed carbon dioxide laser does produce a true skin-tightening effect. Also, the Cutometer is a valuable instrument that permits accurate quantification of skin elasticity,<sup>3,8-10</sup> and it may be useful in the evaluation of other facial plastic procedure results.

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