

# Hair reduction using a new intense pulsed light irradiator and a normal mode ruby laser

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Received 28 April 2000

Revised 12 September 2000

Accepted 14 September 2000

## Keywords:

adverse effects – hair removal  
– intense pulsed light – photo-  
depilation – ruby laser

**OBJECTIVE:** The main purpose of this clinical study was to compare the effectiveness of an intense pulsed light irradiator system (IPL) and a normal mode ruby laser for hair removal.

**MATERIALS AND METHODS:** Thirty-one patients were treated 3 times with a new IPL system on one side of the chin and neck and with a normal mode ruby laser on the other side. After 6 months, nine of the patients received 3 additional IPL treatments and 11 patients received 3 additional ruby laser treatments. All treatment intervals were 2 months. Hair reduction was measured by hair counts on close-up photographs.

**RESULTS:** Hair reduction was obtained by 93.5% of the patients

after 3 IPL treatments and by 54.8% after 3 ruby laser treatments. The average hair count was reduced by 49.3% after IPL treatments and by 21.3% after ruby laser treatments. Three additional IPL treatments following 3 IPL treatments resulted in only 6.6% further hair reduction – in total 55.9%, whereas 3 IPL treatments following 3 ruby laser treatments resulted in an additional 35.5% hair reduction – in total 56.8%.

**CONCLUSIONS:** The IPL was found to be 3.94 times more effective than the ruby laser for hair removal. In the chin and neck region, more than 3 treatments with the IPL did not improve the therapeutic result significantly.

*J Cutan Laser Ther* 2000; 2: 63–71

## Introduction

Both lasers and intense pulsed light irradiators (IPL) are currently used for optical depilation.<sup>1,2</sup> The effectiveness of different devices varies considerably, which theoretically may be due to different wavelengths, energy levels and pulse durations, as well as to biological variables such as anatomical location, epidermal pigmentation, duration of hair follicle cycle and androgen status.<sup>3–9</sup> The bio-

logical effects of both the IPL and the ruby laser are based on hair follicle damage by selective photothermolysis.<sup>10</sup> Although the primary target is melanin in the follicular epithelium and in the hair matrix, the ultimate goal is to destroy the surrounding hair follicle. A hair follicle can only be eliminated if a sufficient amount of light energy of the appropriate wavelength(s) and pulse duration is absorbed by the hair melanin and subsequently distributed, by thermal conduction, to reach temperatures that ensure denaturing of proteins in the surrounding follicle cells.<sup>11</sup> Both lasers and IPLs for hair reduction are being developed continuously, and significantly different treatment effects of these devices have been reported.<sup>2–5</sup>

In the present study an IPL was tested, using a right/left treatment design, against a classical ruby laser for reduction of unwanted hair growth in the chin and neck region. The study also included assessment of the possible additional gain of performing up to 6 consecutive treatments, and an evaluation of the effect of 3 IPL treatments following 3 treatments with a normal mode ruby laser.

## Patients and methods

### Patients

This study included 31 women with a mean age of 37.8 years (sd: 9.2 years). Fitzpatrick skin types and actual degree of pigmentation are shown in Tables 1a and 1b. All volunteers gave their written informed consent, and the study was approved by the Regional Ethics Committee.

### Irradiation devices

The following devices for optical depilation were used:

1. A normal mode ruby laser (Epitouch; ESC Sharplan, Tel Aviv, Israel), which emits pulsed laser irradiation at 694 nm with a fixed pulse duration of 0.9 ms, a spot size of 5 mm, and a repetition rate of 1 Hz.
2. An IPL (Ellipse Relax Light 1000; Danish Dermatologic Development, Hoersholm, Denmark), which emits an undulating train of pulses created by a xenon arc flash-lamp. The pulse duration can be adjusted between 5 and 40 ms to match the thermal relaxation time of both thin and thick hair follicles. The xenon arc light is conditioned by two types of optical filters: a water-containing filter which absorbs wavelengths longer than 950 nm (which would otherwise lead to non-specific heating of the tissue water in the skin as significant water absorption starts at 950 nm and increases strongly with longer wavelengths) and a long-pass filter which cuts off wavelengths shorter than 600 nm. The resultant filter combination has a clinically useful spectral range from 600 nm to 950 nm. The filtered light is guided to the skin surface by a 48 × 10 mm light conducting crystal with an optical design that partly recycles backscattered photons from the skin

surface. The optical coupling between the crystal and the skin is optimized by a thin layer of optical index matching hydro gel. Non-selective absorption in superficial cutaneous blood vessels is reduced by applying a firm mechanical pressure to the skin surface with the IPL system's optical light guide causing most blood to be removed from the treatment area during treatment.

### Experimental procedure

#### Experiment I

All 31 patients were first treated 3 times with 2-month intervals using the IPL on one side of the chin and neck and, during the same session, with the ruby laser on the contra lateral side.

#### Experiment II

Nine of the 31 patients were subsequently randomized to receive 3 additional IPL treatments with 2-month intervals. The first of these treatments was performed 6 months after completion of the first series.

#### Experiments III

Eleven of the 31 patients were randomized to a treatment series consisting of 3 ruby laser treatments (experiment I) followed by 3 IPL treatments, starting 6 months after the first series. All treatment intervals were 2 months. The follow-up period after the last treatment was 6 months for all experiments.

### Energy settings

The fluencies used were 19.2 J/cm<sup>2</sup> (sd: 1.64 J/cm<sup>2</sup>) for the ruby laser and 18.5 J/cm<sup>2</sup> (sd: 1.5 J/cm<sup>2</sup>) for the IPL system. The fluencies used for treatment of the individual patients were selected according to a pre-treatment clinical evaluation of skin colour followed by a series of test shots and inspection of the immediate physiological reaction. The aim was to determine the maximum tolerable treatment fluency for every treatment session. For both the IPL and the ruby laser treatments this fluency level produced perifollicular erythema and oedema visible within 5 minutes of the irradiation.

Skin type	I	II	III	IV	V
% patients	0	58.1	38.7	3.2	0

**Table 1a**

Distribution of patients according to the Fitzpatrick skin types.

Pigmentation	None	Light	Medium	Medium heavy	Heavy
% patients	33.3	30	30	0	6.7

**Table 1b**

Distribution of patients according to their actual skin pigmentary status.

## Treatment procedure

Clinical examination and close-up photography were performed before the first treatment. Hairs were counted in test areas on each photograph using specific landmarks (pigmented nevi, scars, comedones) on the skin surface to ensure that the exact same areas were used throughout the study. Hair counts were performed 2 months after the first 3 treatments as well as 6 months after the 3rd and 6th treatment.

## Adverse effects

1. Pain scores: The level of pain experienced by the patients during treatment was scored immediately after the treatment sessions on a 10-cm visual analogue scale.
2. Skin inflammation: The light induced acute inflammation was characterized by erythema, edema and occasionally leakage of interstitial tissue fluid from the orifice of the damaged hair follicles.

## Statistics

For statistical evaluations Wilcoxon's test for paired differences and the Mann-Whitney test were used. A significance level of 0.05 was accepted.

## Results

### Experiment 1: A Comparative study

Hair reduction was obtained in 93.5% of the IPL treated sites and in 54.8% of the ruby laser treated areas, indicating that 1.93 times more test area obtained hair reduction with the IPL than with the ruby laser (Figure 1). For treatment areas, in which hair reduction was actually obtained, the reduction was 49.3% (sd: 22.1%) after treatments with the IPL and 21.3% (sd: 16.2) after treatment with the ruby laser (Table 2), indicating a 2.32 times higher treatment effectiveness of the IPL compared to the ruby laser ( $P < 0.02$ ). When both of these factors are considered, the total relative effectiveness of the IPL is therefore 3.94 times higher than that of the ruby laser.

Increased hair growth was observed in a number of test areas after treatments with both IPL and ruby laser. After IPL treatments 6.5% of the patients experienced increased hair growth, on average 3.4% (sd: 1.7%), and after the ruby laser treatments 45.2% of the patients experienced hair growth, on average 16.7% (sd: 20.1) (Table 3). Both the percentage of test areas exhibiting hair growth and the magnitude of the hair growth observed after the 2 treatment modalities were highly statistically different ( $P < 0.0001$ ).

### The patients' subjective evaluation of treatment effectiveness

Hair reduction was also estimated by the patients after the initial 3 treatments. After the IPL treatments the patients assessed the hair reduction to 45.9% (sd: 29.8%)

	Intense pulsed light	Ruby laser
Hair reduction was obtained by % patients	93.5%	54.8%
Average hair reduction for responding patients	49.3%	21.3%
Standard deviation for responding patients	22.1%	16.2%

Table 2

Patients who obtained hair reduction after 3 treatments with either IPL or ruby laser, with 2-month intervals and follow-up period of 6 months.

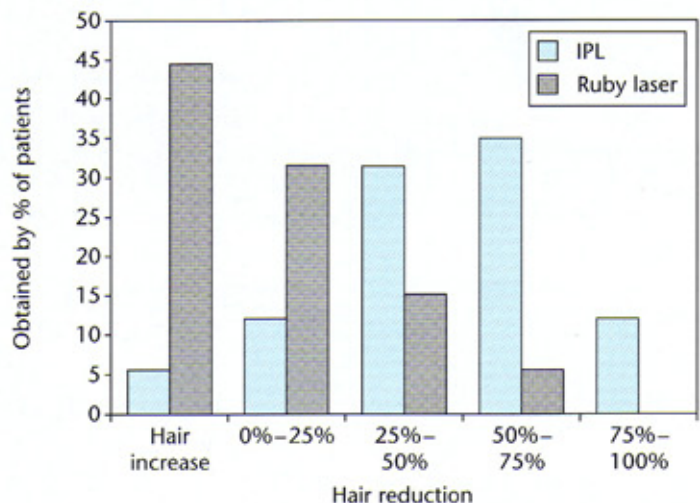


Figure 1

Hair reduction 6 months after the last of 3 treatments with an IPL and a normal mode ruby laser.

and after the ruby laser treatments to 24.0% (sd: 23.5%) ( $P < 0.0001$ ). The difference between the patients' evaluations and the objective hair counts were less than 4% for both treatment modalities (Table 4).

### Experiment 2: Effect of multiple IPL treatments

The effect of multiple IPL treatments is shown in Figure 2. Nine patients were initially treated 3 times with 2-month intervals. Six months after the last treatment 3 additional treatments, with 2-month intervals, were performed followed by a 6-month observation period. Hair reduction was 45.7% (sd: 35.2%) after the initial 3 treatments and 52.1% (sd: 20.1%) after 6 treatments. Only a modest increase of 6.4% in hair reduction was noted as a result of the last 3 treatments. The difference in hair reduction between the 3 treatment and 6 treatment regimes is not statistically significant ( $P > 0.9$ ).

	Intense pulsed light	Ruby laser
% of patients who obtained hair growth	6.5%	45.2%
Average % hair growth	3.4%	16.5%
Standard deviation for % hair growth	1.7%	20.1%

**Table 3**

Patients who obtained increased hair growth after 3 treatments with either IPL or ruby laser, with 2-month intervals and a follow-up period of 6 months. Insufficient damage to hair follicles may cause hair follicle synchronization leading to an increased number of hair follicles in the anagen phase.

	Intense pulsed light	Ruby laser
Efficiency estimated by patients	45.9 ± 29.8%	24.0% ± 23.5%
Measured efficiency	49.3 ± 22.1%	21.3% ± 16.2%

**Table 4**

The patients' subjective evaluation of treatment effect and objective hair counts.

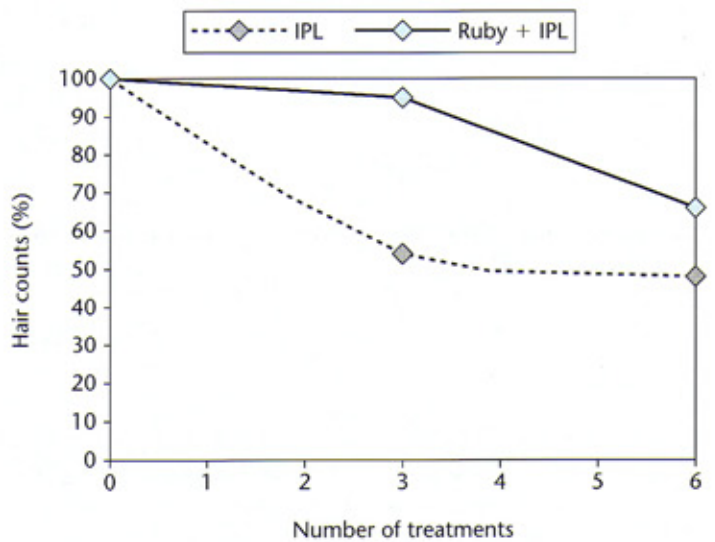
### Reduced light fluency leads to synchronization of the hair follicle growth cycle

The hair reductions after the individual treatments are shown in Figure 3. The second treatment was performed with a moderately reduced fluency setting averaging 2J/cm<sup>2</sup> on both devices. Due to the lower fluency a significant number of hair follicles suffered only partial damage and simultaneously turned into early anagen growing a new hair. This growth cycle synchronization of the hair follicles is clearly shown by a very low hair reduction of 7.2% (sd: 27.6%) compared to 53.5% (sd: 11.6%) after the first treatment.

### Experiment 3: Ruby laser treatment followed by IPL treatment

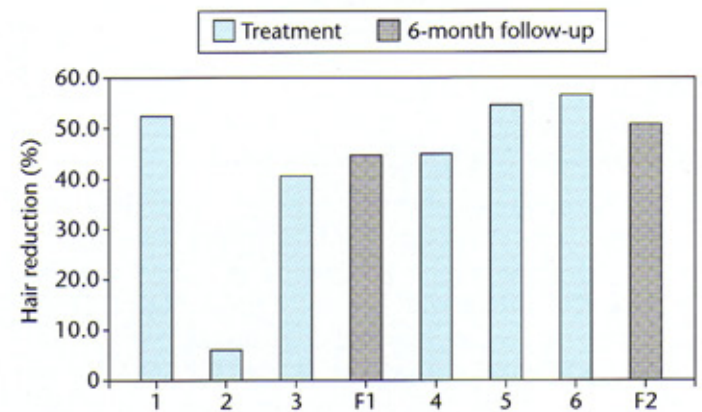
Following a series of 3 ruby laser treatments 11 patients were randomized to 3 additional IPL treatments with 2-month intervals. Only 6 of these 11 patients experienced any hair reduction after the initial 3 ruby laser treatments. For these 6 patients, the mean hair reduction was 25.4% (sd: 28.8%). The average hair reduction for the group was 6.6% (sd: 30.4%) (Figure 2).

After the additional 3 IPL treatments all 11 patients obtained hair reduction. The number of patients who obtained hair reduction after both ruby laser and IPL



**Figure 2**

The effect of multiple treatments. Six IPL treatments (solid line) with 2-month interval produced a good initial effect only becoming insignificant after more than 3 treatments. Three ruby laser treatments followed by 3 IPL treatments (dashed line) show insufficient effects from the ruby laser treatment and improvements following the IPL treatments. Hair counts were performed 6 months after each data point. (22 patients).



**Figure 3**

Cumulative hair reduction by IPL. F1 is the first follow-up 6 months after the third treatment. The treatments were continued after the first follow-up (F1) by treatment #4, #5, and #6. The second follow-up (F2) was performed 6 months after the last treatment. Treatment intervals were 2 months.

treatment was 1.83 times greater than the number who experienced hair reduction after ruby laser alone. The IPL induced hair reduction was 35.5% (sd: 15.0%). The total relative effectiveness of the IPL can therefore be calculated to be 2.56 times higher than with the ruby laser.

### Adverse effects

The patients evaluated the following adverse effects using a questionnaire: pain level during the treatments, duration of post-treatment discomfort, duration of skin texture changes after treatment and incidence of crust formation (Table 5).

### Pain level during treatment

Immediately after each treatment the patients scored the perceived pain on a visual analogue scale (range: 0–10 cm). The mean pain score was 4.9 cm (sd: 2.6 cm) for the IPL and 1.4 cm (sd: 1.2 cm) for the ruby laser. Thus, the pain level during IPL treatment was 3.5 times higher than the pain level experienced during ruby laser treatment ( $P < 0.0005$ ).

The pain level during treatment was evaluated as a function of the patients' Fitzpatrick skin type and also as a function of the patients' actual degree of skin pigmentation (Figure 4). For both IPL and ruby laser treatment, the pain score increased non-significantly with higher skin types, but was independent of the actual degree of pigmentation.

### Duration of discomfort after treatment

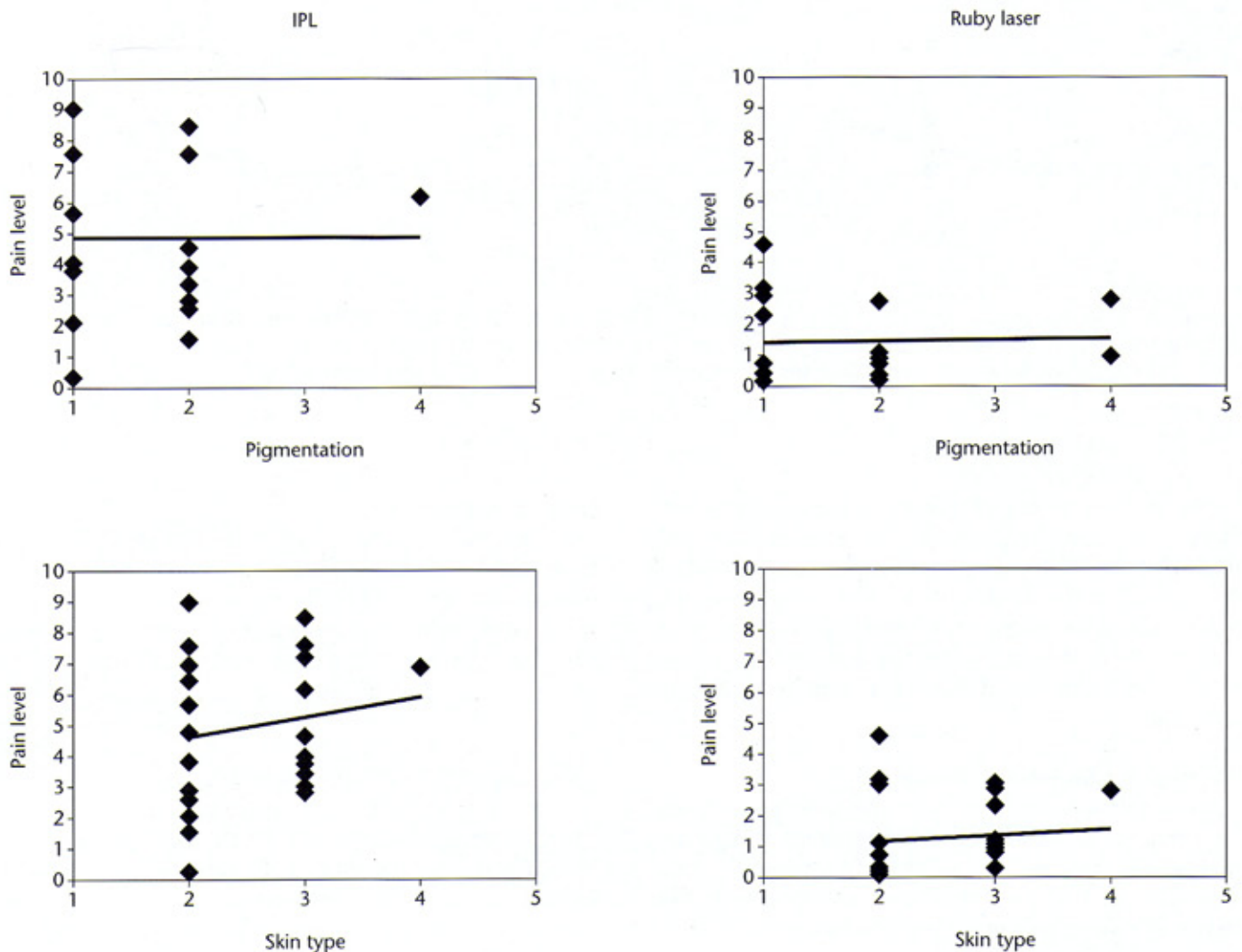
The duration of discomfort after treatment was reported by the patients to last significantly longer after the IPL

	Intense pulsed light	Ruby laser
Pain duration	14.2 ± 47.7 hours	7.8 ± 36.3 hours
Pain level (10–100)	49 ± 26	14 ± 12
Crust formation (% of patients)	21 ± 41%	11 ± 31%
Skin normal after	61.5 ± 80 hours	41.3 ± 70 hours

**Table 5**

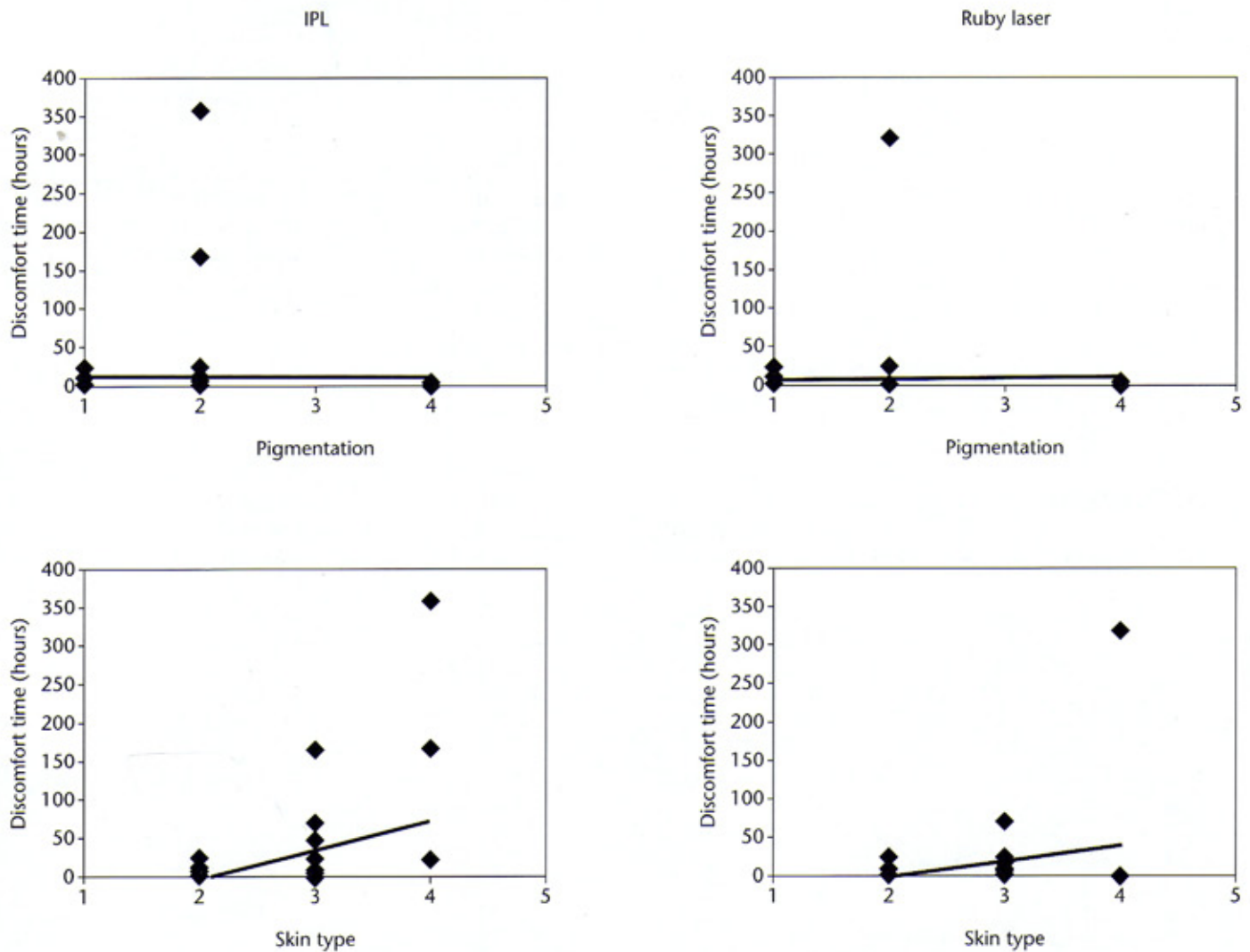
Adverse effects – the patients' evaluations.

treatments (14.2 h, sd: 47.7 h) than after the ruby laser treatments (7.8 h, sd: 36.3 h) (Figure 5). The difference in the mean pain score between the two treatment modalities was statistically significant ( $P = 0.016$ ).



**Figure 4**

The patients' subjective scores of pain during treatment (VAS 0–10). Left: IPL treatments, right: ruby laser treatments. Upper graphs show pain in relation to the patients' degree of skin pigmentation: none (1), light (2), medium (3), medium heavy (4) and heavy pigmentation (5). Lower graphs show pain in relation to Fitzpatrick skin types. (31 patients).



**Figure 5**  
 The patients' subjective evaluation of the duration of discomfort after treatments. Left: IPL treatments, right: ruby laser treatments. Upper graphs show the duration of discomfort in relation to the patients' degree of skin pigmentation: none (1), light (2), medium (3), medium heavy (4) and heavy pigmentation (5). Lower graphs show the duration of discomfort related to Fitzpatrick skin types. (93 treatments).

The duration of skin discomfort was evaluated in relation to the patients' Fitzpatrick's skin type and also to the actual degree of skin melanin pigmentation. For both the IPL and the ruby laser a trend towards a correlation between duration of discomfort and higher skin type was found (non-significant). There was no correlation between discomfort and the actual degree of skin pigmentation.

#### Duration of skin texture changes

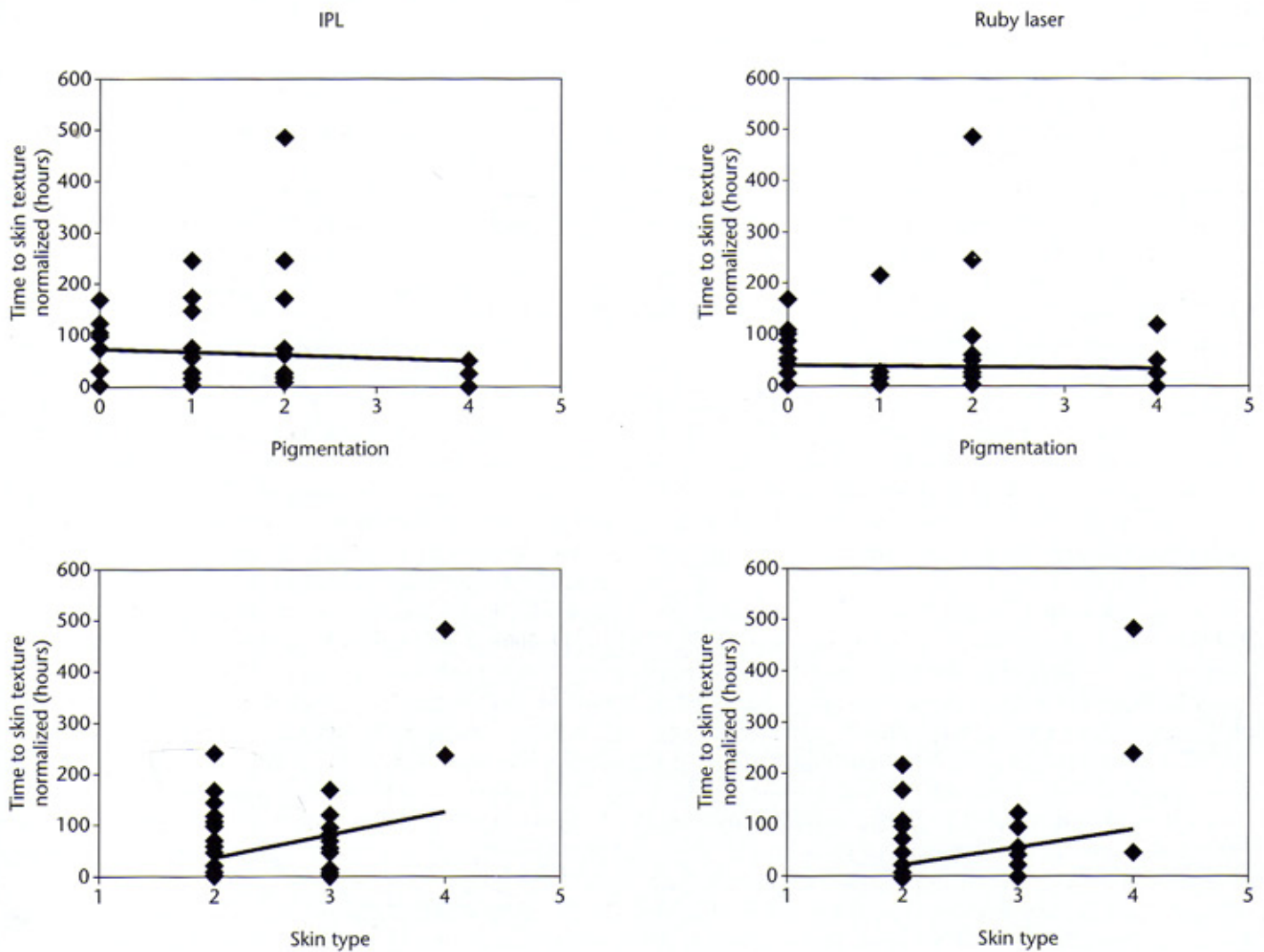
Textural changes, initially follicular oedema and later inflammation, induced by the treatments disappeared after an average of 61.5 h (sd: 80.0 h) following IPL treatment and after 41.3 h (sd: 70.0 h) following ruby laser treatment. The time until normalization of the skin was significantly shorter after ruby laser treatment ( $P=0.036$ ). The time until the skin felt normal correlated to the Fitzpatrick skin type of the patients (non-significantly) but not to the actual degree of skin pigmentation (Figure 6).

#### Crust formation

The formation of crusts due to leakage of tissue fluids from the hair follicle orifices was reported by 21% of patients (sd: 41%) after IPL treatments and by 11% (sd: 31%) after ruby laser treatments. Significantly more patients reported crusts after the IPL treatments ( $P<0.025$ ).

#### Discussion

The present study compares the effectiveness of an IPL system and a normal-mode ruby laser for hair removal. To date only a single study has evaluated the effect of the second generation IPL.<sup>2</sup> A mean hair reduction of 80.2% was found after 4 treatments of bikini line hairs in healthy women with a follow-up period of 12 months. Previous studies with other IPL systems have shown long-term hair reduction ranging from 37%<sup>12</sup> to 60%.<sup>5</sup> In comparison, the clinical efficacy of the ruby laser has



**Figure 6**  
 The duration of time until the patients perceived the skin as normal after treatments. Left: IPL treatments, right: ruby laser treatments. Upper graphs show duration in relation to the patients' degree of skin pigmentation: none (1), light (2), medium (3), medium heavy (4) and heavy pigmentation (5). Lower graphs show the duration in relation to Fitzpatrick skin type.  $n = 93$  treatments.

been more extensively studied, and hair reductions ranging from 20% to 60% have been reported.<sup>1,4,7-9</sup> The results from the present investigation, comprising 3 treatments with 2-month intervals and follow-up hair counts 6 months after the last treatment showed a significantly lower hair reduction efficacy after ruby laser treatments compared with IPL treatments. This may be due to the difference in pulse duration and wavelength spectra, and hence the amount of energy reaching the hair follicles.

The ruby laser emits pulses with durations of approximately 0.9 ms. Compared to the thermal relaxation time of hair follicles the ruby laser pulse duration may be too short. These short laser pulses induce a fast temperature rise in the hairs leading to evaporation. The hairs within a treatment area may be of different size and colour, containing different amounts of absorbing melanin. The hairs will therefore absorb different amounts of energy and evaporate after a variable period of time within the duration of the laser pulse. As soon as a hair is evaporated

the absence of the absorbing melanin in the hair shaft during the remaining part of the laser pulse will inhibit further heat accumulation and hence heat transfer to the hair follicle cells. An unknown and highly variable amount of heat is therefore delivered to the hair follicles in the case of hair shaft evaporation during the laser pulse. In contrast, the IPL emits substantially longer light pulses adjustable from 5 ms to 40 ms. Long pulses heat the hair shafts at a slower rate, allowing the heat to be transmitted to the surrounding hair follicle cells. Hair shaft temperatures do not reach the evaporation level, and the hairs do not disappear immediately during the treatment, but may remain for several days before shedding.

Light transmission through the skin is highly wavelength dependent. IPL emits a wavelength band of 600–950 nm with a mean wavelength of 820 nm. Part of the energy emitted by the IPL penetrates deeper into the skin and subcutaneous layers than the ruby laser wavelength of 694 nm. In the present IPL device, the wavelength

band is further limited to 950 nm while other systems emit wavelengths up to 1200 nm. At wavelengths above 950 nm tissue water and hair melanin have approximately the same absorption coefficient. If these longer wavelengths are not cut off a significant non-selective heating of all tissue components may occur. However, it has previously been stated that these very long wavelengths are important for effective hair removal due to their deeper penetration.<sup>6</sup> This could not be substantiated by the present study, which showed similar hair removal effectiveness for the 600–950 nm wavelength band compared to previous systems emitting wavelengths from 615 to 1200 nm.<sup>3,6</sup>

We found only a limited effect for more than 3 consecutive treatments with the IPL. The biologically optimal result may be reached after 3 treatments, and no further effect is therefore gained from additional treatments. This is supported by the present study, which showed that after a series of 3 less effective ruby laser treatments a substantial number of hairs are still accessible to subsequent IPL treatment.

Optical heat induced destruction of hair follicles is not pain free, and the intensity of pain varies with light fluency, wavelength, pulse duration, spot size, and skin pigmentation. The sensory nerve cells in the dorsal horn of the spinal cord which relay cutaneous nociception to central nervous centers also possess the ability to perform both spatial<sup>12,13</sup> and temporal<sup>14–16</sup> summation of cutaneous afferent pain signals. The term spatial summation implies that multiple sensory nerve inputs from larger treatment areas produce stronger pain sensations than sensory input from a few nerve endings within smaller treatment areas. Likewise, a series of shots delivered to adjacent skin areas with a fast repetition rate will cause the central nervous system to add the pain from the individual shots together. This phenomenon develops at pain stimulation rates higher than approximately 0.5 Hz, and it may become significant during treatment with laser systems, e.g. alexandrite and ruby lasers with repetition rates higher than 1 Hz.

The pain sensation reported by patients participating in the present study was higher after IPL treatment with a

large treatment area of 4.8 cm<sup>2</sup>/shot compared to the 0.2 cm<sup>2</sup>/shot area with the ruby laser. Also, the total energy delivered per shot by the IPL was 88.8 J compared to 3.8 J delivered by the ruby laser. Although the fluency (energy per cm<sup>2</sup>) was identical for the two devices, centrally acting spatial pain summation mechanisms are assumed to be involved in the different sensations perceived.<sup>16</sup>

Although the spot size of the IPL is approximately 24 times larger than the spot of the ruby laser, the pain reported is only 3.5 times higher than after a ruby laser shot indicating that the relationship between pain stimulus and subjective perception is not linear.

In the present study, light fluency was adjusted according to the actual skin colour for each patient in order to optimize the treatment efficiency and to minimize side effects. Accordingly, the patients' scores of pain during treatment, duration of discomfort and duration of texture changes were similar for the different skin colours treated. While the individual fluency adjustment ensured that the amount of light energy deposited in the skin was nearly the same for all skin colours, this was not the case for the different Fitzpatrick skin types. We observed a general, but non-significant trend towards higher scores of side effects in patients with higher Fitzpatrick skin types. A constitutionally higher reactivity to identical heat traumas of these darker skin types may be the reason for the observed effects.

No pigment disturbances or scars were observed after treatment with the IPL or the ruby laser, and we support previous findings that both the IPL and ruby laser are safe.<sup>6,17</sup>

The proportion of the patients who responded to IPL treatments was nearly double the number responding to ruby laser treatments (93.5% versus 54.8%). For the responding patients the amount of hair reduction was also double that of the ruby laser (49.3% versus 22.1%). The overall depilatory effectiveness of the IPL is thus approximately 4 times that of the ruby laser. The additional effect of more than 3 effective treatments is low (6.4% for the IPL) whereas additional treatments with an effective device can improve previous ineffective ruby laser treatment results.

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