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Hair Removal With the Long Pulsed Nd:YAG Laser: A Prospective Study With One Year Follow-Up

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Background and Objective: The aim was to investigate the efficacy, side effects, and the long-term results of a long pulsed Nd:YAG-Laser for hair removal in different hair colors and skin types.
Study Design/Materials and Methods: We performed a prospective clinical study with 29 volunteers. Treatment was performed on the lower leg with a long pulsed Nd:YAG-Laser. Five test areas were treated 1–5 times in monthly intervals; one served as control. Follow-up investigations were performed at each session, and 3, 6, and 12 months after the last therapy. No depilatory treatment except shaving was allowed during the time of follow-up. Percentual hair loss, short- and long-term side effects, and pain during the treatment were evaluated.
Results: After one month, a hair loss of greater than 50% was found in 44.9% of the areas treated once. With up to five treatments, this percentage increased up to 71.5%. One year after therapy, a greater than 50% hair reduction was still present in 40% of the five-treatment-areas and in 0% of the areas treated only once. There were no permanent side effects despite one small scar after a folliculitis.
Conclusions: The long pulsed Nd:YAG is suitable to remove hair for more than 12 months effectively, although 4–5 sessions are necessary for these results. Blond hair can also be removed, although much less effective. No lasting side effects could be seen. Darker skin types or tanned skin can also be treated without side effects. A cooling may be advisable due to the pain reported by the volunteers. Lasers Surg. Med. 30:127–134, 2002.

Key words: thigh; clinical standardized study; selective photothermolysis; epilation

INTRODUCTION

Laser assisted hair removal has become one of the most competitive fields in laser medicine. The longing for an almost perfect body has led to the wish also to remove so called normal body hair and even blond hair. The necessity of a laser device, which can remove hair successfully, long lasting, nearly without side effects and also in dark skin has become even more important due to dermatology's switch towards aesthetically-oriented patients.

So far long pulsed ruby, alexandrite and diode lasers, and non-coherent intense light sources have been used to remove unwanted hair [1–9]. Nevertheless, only a few studies were conducted with a long-term follow-up of more than 6 months [1,5,7,9].

Infrared light with a wavelength of 1064 nm, like that of the Nd:YAG laser, can penetrate the skin to a depth of 5–7 mm [10]. Even if the light absorption by water in human tissue is higher at 1064 nm than at visible wavelengths, this is compensated by a lower scattering coefficient that lets a Nd:YAG laser beam penetrate deep into the skin. This deep penetration could represent the greatest advantage of the Nd:YAG laser, since the target structures (hair follicles and their bulge) are mostly located several millimeters deep in the skin [11,12].

On the other hand, the absorption by melanin at 1064 nm is lower than at shorter wavelengths (532, 694, 755, and 810 nm), but it seems still to be sufficient to permit a relatively selective absorption, which is necessary to achieve selective photothermolysis of the pigmented hair follicle [13,14]. The relatively low melanin absorption seems to be the main disadvantage of the Nd:YAG laser, but on the other hand, is advantageous to reduce the thermal damage of the melanin-containing epidermis, and hence, the side effects, permitting even the therapy of dark skinned patients [1,15].

Since the theoretical relaxation time of hair follicles is approximately 90 milliseconds [13,16], long-pulsed Nd:YAG lasers have recently been developed with pulse lengths in the millisecond range. Till now, only one study has been published using this laser for hair removal. Bencini et al. [1] showed good results with different hair colors using a long pulsed Nd:YAG laser with a pulse length of 4 milliseconds. The aim of our study was to evaluate the efficacy, side effects, and duration of hair removal with a 4 milliseconds Nd:YAG laser under standardized conditions and with sufficient follow-up.

MATERIALS, VOLUNTEERS, AND METHODS

Twenty-nine volunteers (7 male, 22 female) were treated in five hair-bearing areas on the lower leg after signing

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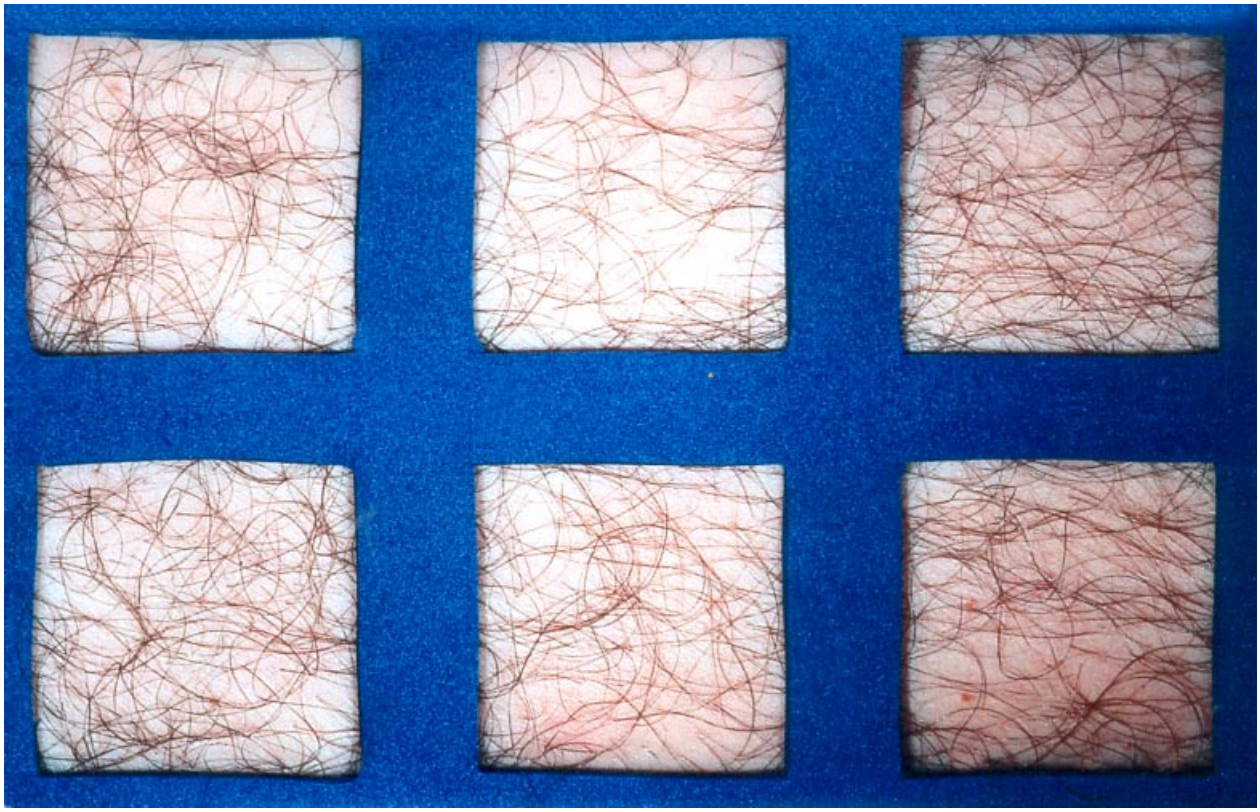

Fig. 1. Template in position on the lower leg before the first treatment. Control area in the left lower edge. Area to be treated five times in the right upper edge.

informed consent. The age ranged from 22 to 40 years with a mean age of 31 years. Fitzpatrick skin types were present as follows: 3 Type I, 19 Type II, 5 Type III, and 2 Type IV. Those with skin Type IV got tanned during the study. Five volunteers had blond hair, twenty-one brown hair, and three had black hair.

With a template (Fig. 1), we marked six areas on the lower leg of 3 cm × 3 cm each. As position markers we used moles or lentigines in the lower leg and/or points painted on the skin with a water resistant felt pen. The pretreatment procedure consisted of a shaving and a thin layer of ultrasonic contact gel applied on the treatment areas. The long-pulsed Nd:YAG laser (1064 nm, 4 milliseconds, 4 mm spot size) was used with 40 J/cm^2 and without a cooling device.

One area remained untreated as control. In the first therapy session, all five areas were treated. In intervals of four weeks, 4, 3, 2, and at last 1 area were treated again with the same parameters, resulting in one control area and five areas treated one to five times, respectively (Fig. 2). Follow-up examinations were performed at each therapy session and 3, 6, and 12 months after the last (5th) treatment resulting in the differing follow-up times as presented in Figure 2.

During the follow-up period, the only method allowed to remove hair was shaving, with an interval of at least 2 weeks prior to the next follow-up.

Evaluation and photographs of all sites were performed at each consultation by the staff of the outpatient laser clinic using the same template, camera, and films. Treatment outcomes were evaluated comparing terminal hair counts using the pretreatment values as baseline. Results were ranked into 5 categories: 0 = bad (< 25% hairs removed), 1 = moderate (25–50% hairs removed), 2 = good (50–75% hairs removed), 3 = very good (75–95% hairs removed), 4 = excellent (more than 95% of the hair removed).

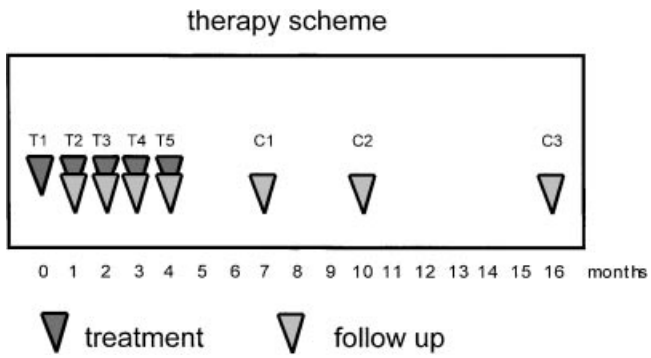

Fig. 2. Therapy scheme.

A questionnaire asked for immediate therapy sequelae and pain, as well as longer lasting discomfort or any other sensations. Side effects were documented as hypo-, hyperpigmentation or scar formation (atrophic or hypertrophic).

For statistical analysis, MS Excel™ and Jandel Scientific Sigma Stat™ were used. Due to the relatively low number of volunteers, the Mann-Whitney-U Rank Sum Test (MWR) was used. We defined the results to be significant at $P < 0.05$.

RESULTS

Hair Reduction (All Hair Colors)

Score, 2 or more, representing a greater than 50% hair reduction, could be attained in 44.9% of the areas 1 month after a single treatment. With two treatments, it was possible to increase this percentage to 71.5%. By more than two treatments, the mean results could not be improved further. Figure 3 presents a detailed subdivision of the 1 month results. The differences of the 1 month follow-up results between one or multiple treatments were highly significant (MWR; all $P < 0.001$). In the control areas, which were only shaved, no hair reduction could be seen throughout the entire follow-up time.

With multiple treatments, there was not only an improvement in the short term effectiveness of hair removal (1 month follow-up), but also in the duration of epilation success. In the case of only one or two treatments, the results lasted only 2 months, but increased to more than 4 or 12 months for areas treated four and five times (Table 1 and Fig. 4). Even between four and five treatments, the long-term results were different, though not significantly (MWR; $P = 0.218$). At 13 (four treatments), and 12 months (five treatments) of follow-up, the rate of excellent results ($> 95\%$ hair removed) increased from 4% after four treatments to 12% after five treatments.

The long-term follow-up investigations showed unexpected chronological dynamics. Figure 4 shows the mean scores of the different treatment groups during the follow-up. All areas showed a two peak, two valley design. For single treatments the two peaks were located at month 1 and 10 and the first nadir was reached at 4, the second at 16 months; multiple treatments shortened the interval between the two peaks (Fig. 4). After the second peak, the follow-up results of a single or double treatment worsened with poor results in the long-term follow-up (Fig. 4). The long-term follow-up of the four/five treatment areas showed an tendency towards a stabilization at a mean moderate to good result (Fig. 4). For example, after five treatments, the results of more than 50% hair reduction (score 2) improved from the 3-month- (42.8%) to the six-month- (57.2%) follow-up and stabilized at 40% after 12 months (Fig. 4). Figure 5 shows the same volunteer as in Figure 1 demonstrates a marked hair reduction 12 months after the last treatment. The results are significantly better (MWR; $P = < 0.001$) 12 months (resp. 13) after five and four treatments than at 10 and 16 months after one treatment.

Hair Reduction (Hair-Color Dependent)

Brown and black hair showed the best epilation results. The mean score for brown hair 12 months after the 5th treatment was 1.5 (SD $\pm$ 1.47). For black hair, the median was 2. Due to the small number of individuals with black hair ($n = 3$), no further significance tests were performed.

For blond hair, the median long-term score after five treatments was 0.5. Although it took two treatments to attain a score 2 (50–75%) in three of five cases and four treatments to attain at least one time a hair reduction of more than 95% (score 4) in the one month follow-up, at least this laser device could attain a hair reduction in blond hair. The long-term follow-up showed in two of four cases reduction rates between 25 and 50% 12 [13] months after the 5th (4th) treatment.

Therapy Sequelae and Side Effects

With increasing number of treatments, the volunteers increasingly reported unpleasant sensations such as tingling, warmth, burning, prickling, or "small bursts under the skin." There were also two cases of perifollicular edema that lasted about 10 min, and one case of formation of small perifollicular urticae. Remarkably all our volunteers reported the treated areas felt dryer than the untreated skin.

No temporary or permanent side effects like hypo- or hyperpigmentation and scars were seen in our study group, not even in the strongly suntanned volunteers. One female subject developed a folliculitis after a single treatment session, with the formation of a small, atrophic scar in the treated area. This reaction was classified as nonspecific since this volunteer reacted the same way to other laser devices used for hair removal (long pulsed ruby and diode laser). Table 2 shows the therapy sequelae and side effects in detail.

COMMENT

Laser epilation studies with long-term follow-up are infrequent [5,9], and till now do not exist for the long pulsed Nd:YAG laser. The only epilation study with this laser, conducted by Bencini et al. [1], involved an heterogeneous group of subjects (normal body hair, hypertrichosis, hirsutism, transsexuals) with various hair colors (from white to black) treated with a 4 milliseconds Nd:YAG laser at 23–56 J/cm^2. The authors reported that 3–8 treatments were necessary for complete hair removal, depending on hair type and thickness, and that every hair type and color could be treated, except white hair. However, since follow-up examinations were not conducted, the duration of the depilation remained open. No side effects other than a burning sensation with higher fluences and temporary erythema were reported.

The aim of our study was to examine the long-term effectiveness of hair removal under controlled conditions and in one body area. As to our knowledge, this is the first study with the long pulsed Nd:YAG laser with 12 months or more of follow-up.

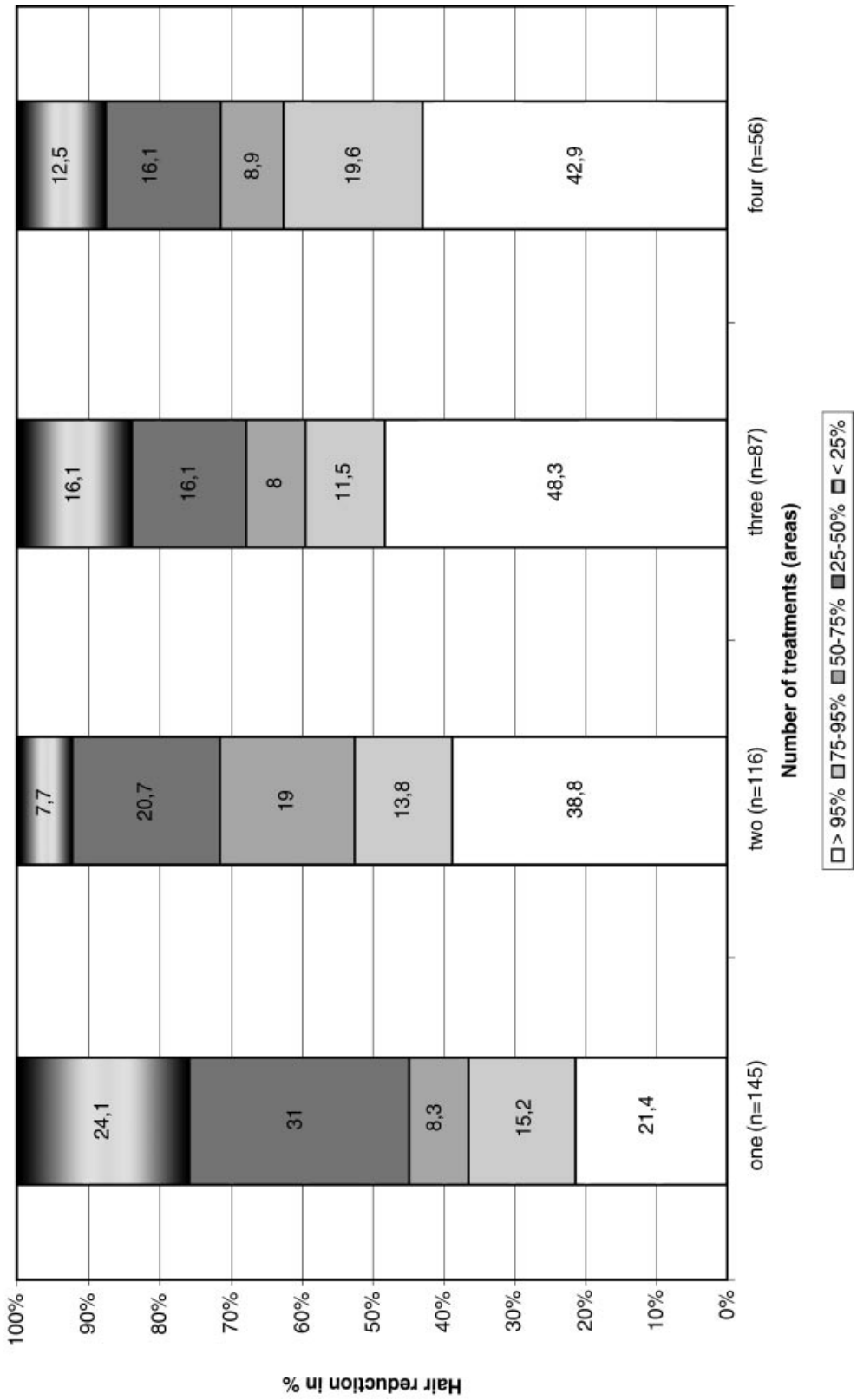

Fig. 3. One month follow-up.

TABLE 1. Hair Reduction Scores According to Number of Treatments and Follow-Up Period

		Months of follow-up															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of treatments	Score	Hair removal in %															
1		N = 145	N = 29	N = 29	N = 28			N = 28			N = 28						N = 25
	4	21.4	0.0	0.0	0.0			0.0			7.1						0
	3	15.2	0.0	0.0	0.0			0.0			3.6						0
	2	8.3	10.3	3.4	0.0			0.0			0.0						0
	1	31.0	37.9	10.3	3.6			0.0			0.0						0
	0	24.1	51.7	86.2	96.4			100			89.3						100
2		N = 116	N = 29	N = 29			N = 28			N = 28						N = 25	
	4	38.8	13.8	0.0			0.0			7.1						0.0	
	3	13.8	6.9	7.1			0.0			7.1						0.0	
	2	19.0	20.7	7.1			3.6			10.7						0.0	
	1	20.7	17.2	7.1			7.1			10.7						4.0	
	0	7.8	41.3	78.5			85.7			64.3						96.0	
3		N = 87	N = 28			N = 28			N = 28						N = 25		
	4	48.3	3.6			0.0			7.1						0.0		
	3	11.5	39.3			7.1			10.7						0.0		
	2	8.0	17.9			10.7			17.9						8.0		
	1	16.1	17.9			7.1			17.9						8.0		
	0	16.1	21.4			75.0			46.4						84.0		
4		N = 56			N = 28			N = 28						N = 25			
	4	42.9			0.0			14.3						4.0			
	3	19.6			3.6			14.3						4.0			
	2	8.9			14.3			21.4						16.0			
	1	16.1			25.0			7.1						24.0			
	0	12.5			57.1			42.8						52.0			
5				N = 28			N = 28						N = 25				
	4			10.7			17.9						12.0				
	3			7.1			17.9						16.0				
	2			25.0			21.4						12.0				
	1			17.9			7.1						20.0				
	0			39.3			35.7						40.0				

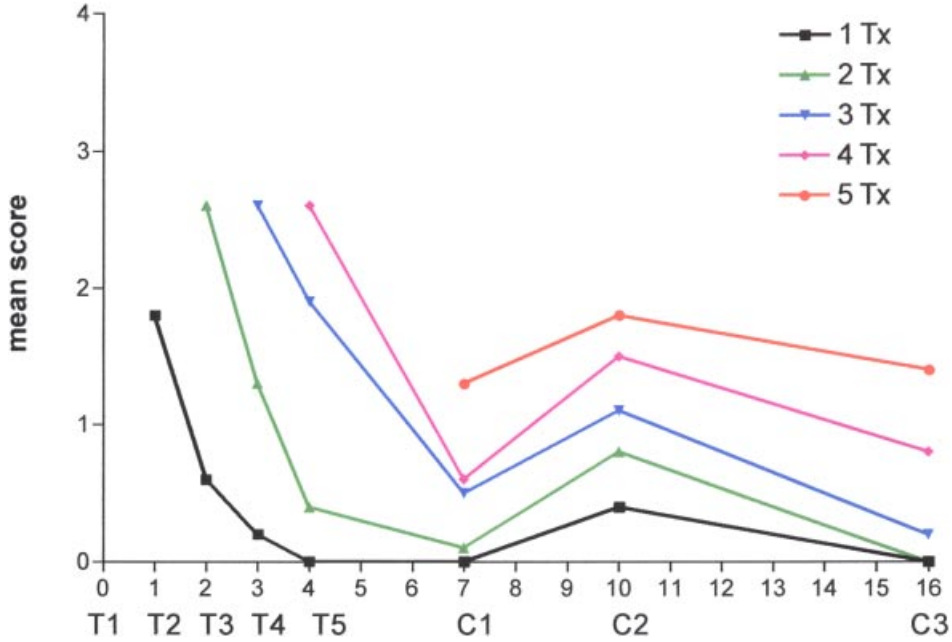

Fig. 4. Mean scores after one to five treatments. T_1–T_5 = treatment sessions; C_1–C_3 = follow-up examinations.

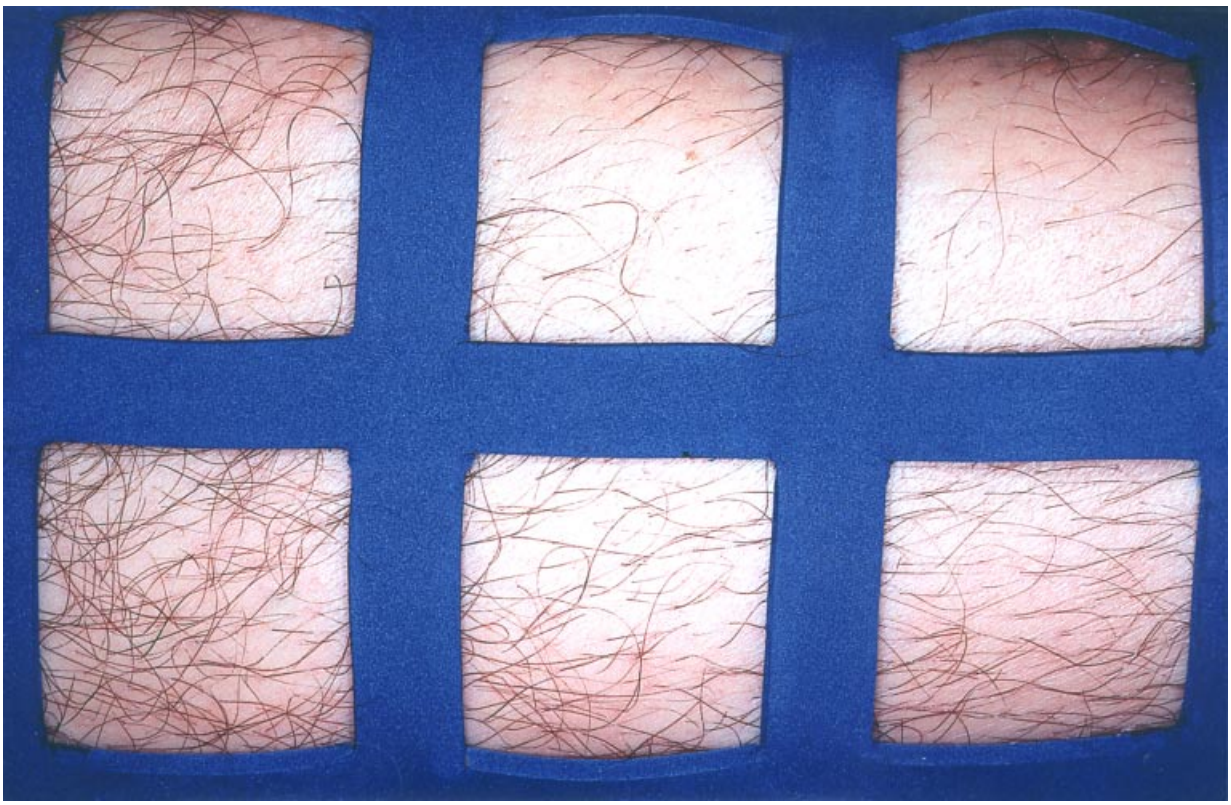

Fig. 5. Areas 12 months after the 5th treatment. Area five shows more than 75% hair removal.

TABLE 2. Therapy Sequelae Reported by the Volunteers

	Treatment no.				
Therapy sequelae n = 19	1	2	3	4	5
Dry skin	3	3	3	2	2
Urticae during treatment	1	1	1	1	1
Burning sensation during water contact	2	1	1	1	1
Tingling when a follicle is hit by the laser beam	1	1	1	1	1
Small perifollicular vesiculae	0	1	1	1	1
Tickling through dry skin	2	2	2	2	1
Heavy pain in the ankle	1	0	0	0	0
Superinfection, scarring, hyperpigmentation	0	0	0	1	0
Eczema aggravation in atopic dermatitis (1 volunteer)	(2 weeks duration)			(3 days)	0

With 4 (resp. 5) treatments, at 12 months follow-up, a hair reduction greater 75% could be achieved in 8% (resp. 28%) of the volunteers. A hair reduction of 50–75% was achieved in another 16% (four treatments) and 12% (five treatments). This demonstrates that this laser device with 1064 nm, 4 milliseconds, 40 J/cm^2, and 4 mm spot size can produce reduction of unwanted hair lasting for 12 months.

These results have to be compared to the few long-term epilation results reported with other lasers. Repeated treatments (1–4) with a ruby laser (694 nm, 5 milliseconds, 6 mm, 17.5–35 J/cm^2; n = 74) lead to a hair reduction of more than 75% in 11.9% six months after the last treatment [9]. For the alexandrite laser (755 nm, 5/10/20 milliseconds, 10 mm, 15–20 J/cm^2; n = 36) an average hair count reduction of 4% has been reported 6 months after one treatment [7]. In the diode laser study (800 nm, 5–30 milliseconds, 9 mm × 9 mm, 10–40 J/cm^2) of Lou et al. [5], a hair reduction of 34–53% could be reached in the long-term follow-up after two treatments (up to 20 months; n = 19) and fits well to our results with the long pulsed Nd:YAG laser.

Lin et al. [14] and Richards and Meharg [17] postulate that follicles treated in the telogen phase show only a growth delay for weeks, whereas, when treated in the anagen phase, the follicles are either damaged lethally, have a growth delay, or switch into telogen phase. This could partly explain the growth dynamics we saw in our study: repeated treatments could lead to a synchronization of the anagen phase by induction and/or shortening of the telogen phase, which could increase the effectiveness of hair removal with each consecutive treatment. Another explanation might be that the follicle is not destroyed immediately, but shows a growth arrest after one (shortened) anagen cycle. This fits well to the results, which Lou et al. [5] reported with the diode laser where a plateau could be seen in the follow-up.

Unlike with long pulsed ruby and alexandrite lasers [7,9], we could show an noteworthy effectiveness even in blond hair, although with less efficacious results than in darker hair.

This might be caused by the higher penetration depth of the 1064-nm wavelength and the consecutively higher fluences at the bulge even of blond hair [11,12].

Different to other lasers, that can cause adverse effects and perhaps even scarring [18], the long-pulsed Nd:YAG laser shows little to no hypo- and hyperpigmentation [1], making it particularly suitable for dark skinned subjects, as is confirmed by the US FDA approval of long pulsed Nd:YAG laser for use in hair removal on Fitzpatrick skin phototype 6. This is certainly due to the low melanin absorption at 1064 nm, which does not lead to a thermal damage of the epidermis, but nevertheless seems sufficient to induce follicular damage. Although a cooling device seems not absolutely necessary, its use, in our opinion, would reduce the pain or heat sensations and could greatly improve the acceptance of this laser, especially for facial treatment. Regarding the skin dryness reported by the volunteers, further investigation of the effect on sweat glands or sebum excretion rates as performed for the ruby laser [19] are necessary and already in progress.

In conclusion, the long-pulsed Nd:YAG laser can be considered a safe and effective device for hair removal. The results of our research, conducted on the legs of volunteers, cannot easily be transferred to other body areas. On the legs, 62–88% of hairs are usually in the telogen phase with the telogen phase lasting 4–6 months and the anagen phase lasting 3–6 months in this area, which makes it difficult to treat [20].

However, on most parts of the body where hair removal is clinically important, especially the face, the telogen rates are substantially lower and the total duration of the hair growth cycle is shorter [20] than on the shins. The epilation efficacy in these areas could be even better, and consecutive clinical trials in patients are under progress.

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