Laser Hair Removal

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In 1994, we (M. Grossman, M.D., C. Dierickx M.D., and others) began to test the possibility of hair removal by laser light. We initially began research with a ruby laser system that was optimized for hair removal according to the principles of selective photothermolysis. That is, we chose a wavelength that was highly absorbed by melanin which was the target of the laser light, and we specified a pulse width as long as possible to match the thermal relaxation time of the hair shaft.

Given the deep depth to which the hair follicle extends, we determined that longer wavelengths—between 700 to 900 nanometers—were most appropriate. At these wavelengths, approximately 20% of the laser fluence at the epidermis will reach the hair bulb or dermal papillae.

Initial Study

The ruby system we started with had a wavelength of 694.3 nanometers, a 7 mm spot size, a pulse duration of 300 microseconds, and a unique convex sapphire lens which was cooled and was applied to the skin in a contact method. Our reasoning was that because the epidermis is melanin rich, cooling of the epidermis was important for protection of epithelial cells. After this study showed promising results, we optimized the laser parameters to extend the pulsewidth to 3 milliseconds. Although this was not the ideal exposure time, it was the longest that the ruby system could produce.

We then enrolled 50 patients at 2 sites and began the study. Each patient received 6 laser irradiations at each treatment. The 6 laser irradiations were done at different fluences, and areas were treated either once or twice to measure the effect of multiple treatments. From the beginning, we decided that the only way to accurately measure efficacy was through the actual counting of hairs. Although this is a difficult process, it is the only scientific way to measure hair count reduction. We used digital photography, and counted every hair at each irradiation site.

Temporary Hair Loss vs. Permanent Hair Reduction

From this study, we learned many things and noticed 2 effects – temporary hair loss which occurred in all patients and lasted for 1-3 months after treatment, and permanent hair reduction or a reduction in the number of regrowing hairs that was consistent at 6, 9, 12, and 24 months after treatment. It is important to note that all of the lasers approved by the FDA for hair removal – with the exception of 3 systems – are for temporary hair loss. Only the Palomar EpiLaser®, the Palomar E2000™, and the Coherent LightSheer™ are approved for permanent hair reduction. But what is the difference between temporary hair loss and permanent hair reduction?

"Permanent hair reduction" was defined and accepted by the FDA to be a significant loss of hair, which is quantitatively stable for a period longer than the complete hair growth cycle at a given body site. Although this definition is not perfect, it has proven so far to be reliable, based on data from thousands of laser test areas in hundreds of patients. Through the examination of over 4,000 digital pictures and hair counts of each image, we determined that the number of hairs regrowing at 6 months after the last treat-

ment is stable all the way to 24 months after treatment. For "temporary hair loss," clinical data must only support a reduction in the amount of hair for at least 90 days after the last treatment.

Multi-center Trial

We then expanded the ruby laser study, and in 1997 a multicenter clinical trial was performed in about 150 patients, treated with a 3 ms ruby laser (EpiLaser), 7-10 mm diameter spot size, 15-50 J/cm^2, up to 6 treatments given 1-2 months apart, and followed for at least 6 months after the last treatment. In this large study, 93% of the females and 80% of the males had significant permanent hair reduction after a mean of 4.2 treatments. Histologically, ruby laser treatment caused acute thermal and mechanical injury of the inner root sheath, matrix, and papilla, plus part of the outer root sheath, followed by miniaturization of terminal hair follicles.

Hair Loss Mechanism

We discovered that for temporary hair loss, the laser induces catagen in the hair follicle. TUNEL staining showed apoptosis of the lower portion of follicles beginning within hours after treatment. We also compared the hair growth cycle in mice and humans, and found great differences. In mice, we found and reported that anagen follicles are far more sensitive to laser injury, compared with telogen follicles. However, mice lose their intradermal follicular pigment during telogen, and humans do not. Furthermore, some human patients (about 10%) have complete, permanent hair loss after only one treatment. This would be impossible if only anagen hair were sensitive to laser hair removal. Therefore, C. Dierickx recently measured the effect of hair growth cycle on permanent hair reduction by ruby laser in humans, and found that both anagen and non-anagen follicles have equal sensitivity. By taking phototrichograms in 20 patients, clipping all hairs to 3 mm in length and then waiting 2 weeks, it was easy to identify growing anagen hairs and dead telogen hairs because the anagen hairs had grown several millimeters. Next, the areas were shaved and then laser irradiated. Six months later hair counts were performed, and it was clear that both anagen and telogen hairs had an almost equal probability of loss. Therefore, in humans, the hair growth cycle makes little or no difference on the effectiveness of laser hair removal by selective photothermolysis. As long as there are pigmented hairs present, laser hair removal can be effective.

Pulsewidth and Hair Loss

Pulsewidth has a very important connection to the mechanisms of hair loss, with short pulse widths causing the hair shaft to fracture, but with little or no damage to the outer root sheath of the hair follicle. Through short pulsewidths and fractured hair shafts, temporary hair loss is achieved for up to about 90 days. Longer pulsewidths, on the other hand (for example, in the 10s of milliseconds), have the ability to damage the inner and outer root sheath in the hair follicle, and it is damage to this area that gives permanent hair reduction. Our research and the comparison with mice showed that humans do not have a "bulge" area—or at least there is no bulging area in the hair follicle that is similar to what mice have. Rather, the equivalent stem cells which are responsible for hair regrowth surround the follicle in the outer root sheath in humans. These stem cells are about 10-15 cells in height, and are located approximately 1 mm below the skin surface. Histology studies show that the LightSheer can completely destroy the outer root sheath where these stem cells reside. Pulsewidths in the 1-3 millisecond range can fracture the hair shaft and thereby cause temporary hair loss, but have diminished ability to destroy the inner and outer root sheath where the stem cells reside. Stem cell damage is probably important for permanent hair loss, but the dermal papilla at the bottom of the hair follicles may also be important.

Study with the LightSheer

We continued our research and next worked with Coherent (Star) to develop and test the LightSheer diode laser device. A prospective dose-response study was done in 50 patients with all skin types, by C. Dierickx, M. Grossman, and V. Campos using this laser. Hair regrowth was measured for at least 1 year

after 1 vs. 2 treatments, in 8 sites per patient.

In patients with dark hair, the LightSheer produces permanent hair reduction very reliably. There was a mean of about 30% permanent hair loss per treatment at 30-40 J/cm^2, occurring in over 90% of the patients. The incidence of side effects (about 10%) was less than with ruby laser, and in practice, can be avoided by setting the fluence and pulsewidth appropriately. A fixed 30 ms pulsewidth was made available, which further reduces the risk of side effects in dark skin.

Patient Expectations

Done properly, laser hair removal is very effective and very safe. Patients with dark hair almost always achieve permanent hair reduction, and about half of them enjoy nearly complete, permanent hair loss after less than 6 treatments. The only patients I do not accept for laser hair removal treatment are those with white hair or extremely dark (black) skin. After many studies and over 1,000 patient treatments for hair removal, I have not seen even one case of scarring. Therefore, the incidence of scarring is less than about 0.1%. Suntanned skin should be treated after about 8 weeks of sun avoidance, with or without topical hydroquinone. I tell patients that they have a 90% chance for achieving noticeable, permanent hair reduction, and that 3-6 treatments will be needed, given about 2 months apart. Because of the combined temporary and permanent hair removal effects, it is sometimes difficult to predict how a patient is responding after only 1 or 2 treatments.

One useful trick is to save some of the original hair in the patient's chart, and then compare the diameter of whatever hair regrows when the patient returns. Those patients who fail to have permanent hair reduction regrow the same diameter of hair. Patients whose regrowing hair is obviously finer will almost always achieve good permanent hair reduction. This simple observation therefore helps to identify the best and least responsive patients early in their course of treatment.

Final Comments

Diode laser technology is highly advanced, and these lasers are now the most efficient light sources in the world. The combination of 800 nm diode laser wavelength and longer pulse duration (pulsewidth) is more ideal for hair removal and for protection of the epidermis. The ideal pulsewidth for hair removal is not known, but thought to lie between 5-100 ms, depending on the size of the hair follicle. This pulsewidth range has two advantages—far better protection of the epidermis by cold sapphire, and better heat conduction from the hair shaft to the epithelial stem cells of the outer root sheath, which are important targets for permanent hair reduction.

If I were treating Japanese patients, I would choose fluences with the LightSheer between 15-30 J/cm^2, and I would probably always use the 30 millisecond setting. For dark skin, the LightSheer diode laser at the 30 millisecond pulsewidth provides the best combination of safety and effectiveness.

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