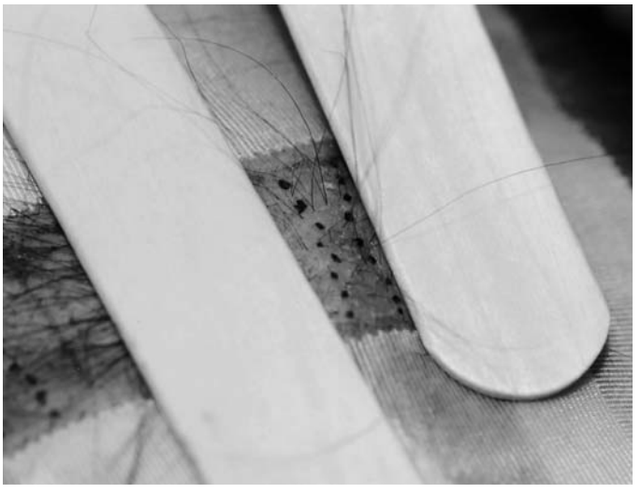


Figure 11C1-7 Two tongue depressors holding down hairs in the zones adjacent to the central zone, which is being counted.

Once the first zone has been counted, a second tongue depressor, different from the one held by the assistant, is laid over it (Fig. 11C1-7). Forceps are used to separate hairs within the second zone from those in the third zone. The same sequence of steps is carried out in the second zone, until each of the zones has been counted and the study box total tallied. The count is then repeated to ensure a precise measurement. This method has been used to count in boxes of up to 50 FU/cm^2.

HAIR COUNTS: ALTERNATIVE METHODS

While the above technique works very well, at higher densities, it can be difficult to partition the study box into longitudinal zones. In such cases, a modified method can be used, provided that study hairs are longer than 3 cm. Instead of partitioning the study box using dotted lines, forceps can be used to separate off a narrow column of the hairs, while the rest of the study box is occluded with a tongue depressor. Once counted, these hairs are pulled off to the side and covered with a second tongue depressor, while the first tongue depressor is then moved laterally to free a second longitudinal group of hairs. This process continues until the entire box has been counted. An alternative method of counting high-density study boxes is to clip the hair contained within the box to a very short length and then take a magnified photo. A count can then be manually performed from the digital image, or automatically calculated using software. In the author's experience, however, patients are reluctant to allow their hair to be trimmed.

CONCLUSION

Performing hair growth studies, both to scientifically advance the field of hair restoration and to pursue office quality improvement, is an important part of every practice. The methods described in this chapter provide a reliable way of creating and counting study boxes that can be easily applied to any office setting.

11C2. THE CROSS-SECTION TRICHOMETER

Bernard H Cohen

BACKGROUND

Office-based physicians lack a reliable and rapid means for measuring hair loss and growth. The proper assessment of both parameters requires the measurement of hair caliber and density, and not density alone. A recently introduced medical device, the cross-section trichometer, fills this need.

HAIR MASS

In 2001, Arnold introduced the concept of hair mass. He measured the circumference of a bundle of hairs isolated from a defined area of the scalp in order to evaluate how much hair was present (1). In the past, physicians tended to focus solely on hair density when making this judgment, but Arnold appreciated the important influence that hair diameter had on appearance (2). Hair mass incorporates both density and diameter, and although a change in either will affect hair mass, changes in hair diameter would have the more significant influence. If hair density is reduced by half, hair mass will be reduced by a factor of 2; in contrast, if hair diameter is reduced by half, hair mass will reduce by a factor of 4, since the cross-sectional area of a hair is a product of the square of its radius ($3.14 \times r^2$).

THE CROSS-SECTION TRICHOMETER

An extension of the concept of hair mass is the hair mass index (HMI), which defines hair mass as mm^2 of hair per cm^2 of scalp. The cross-section trichometer is a novel device, which is specifically designed to measure the HMI of a bundle collected from a premeasured area of the scalp. The original stainless steel prototype was patented in 2006 (3,4) (Fig. 11C2-1). In 2008, peer-reviewed articles confirmed that the cross-sectional area of a hair bundle, as measured by the cross-section trichometer, was directly correlated to hair diameter, hair density, dry weight of the bundle, and global assessments of hair loss (5,6). Moreover, they concluded that the device provided a reliable substitute for current instruments and methods used to measure the parameters of hair loss and growth, including dry hair weight measurement—the industry gold standard. One commentator suggested that it generated more meaningful data than hair counts and global photography, which are the standard measurements used by the Food and Drug Administration (FDA) when considering the approval of new medications and devices used in hair loss therapy (7).

APPLICATIONS OF THE CROSS-SECTION TRICHOMETER

The cross-section trichometer has three important applications. The first is that it can be used to identify early patterned hair loss, as recognized by hair miniaturization, before such changes are clinically visible. Surprisingly, a man must lose almost 50% of his hair mass before that loss can be seen with the naked eye (8). By contrast, the trichometer can recognize as little as 5% loss by comparing the HMI in an area typically affected by patterned hair loss (the frontal region) to the HMI in the permanent fringe (the occipital region).

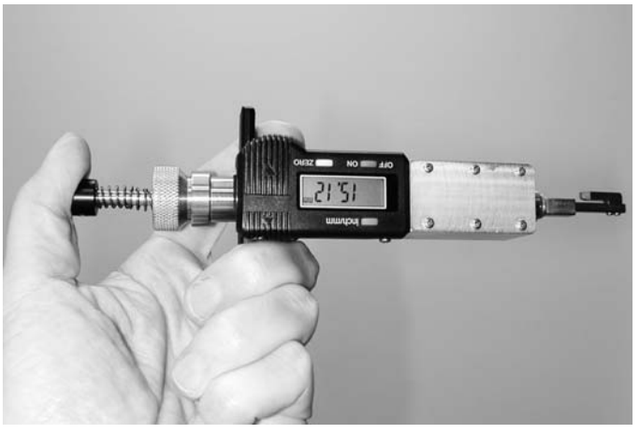


Figure 11C2-1 The stainless steel prototype of the cross-section trichometer.

Figure 11C2-2 The commercially available version of the cross-section trichometer.

Consequently, the progression of hair loss can be tracked over years, and medical intervention introduced in a timely fashion. The second application is that the cross-section trichometer can be used to measure hair growth over time, as quantified by the HMI. This information can be used to evaluate patient response to medical and surgical interventions for hair loss, in either a clinical or research setting (9). A final application is that it can detect and measure hair breakage, a common, but unrecognized cause of hair loss that results from using hair driers, hair irons, colorants, straighteners, and perm agents. Cohen showed that a significant number of women, who had been diagnosed with telogen effluvium or female pattern balding, were in fact suffering from hair breakage (6). The cross-section trichometer provides a means of reliably identifying these cases based on the principle that over the lifetime of an anagen hair, which is constantly growing, the distal hair shaft is subject to a great number of repetitive traumas than the proximal hair shaft. Consequently, the distal shaft is more likely to break when combed or brushed. By virtue of this, the HMI will be higher proximally than distally, where the ends of hairs are broken off. If the distal HMI is divided by the proximal HMI, the percentage of broken hairs can then be calculated and reported as the hair breakage index (HBI).

Using the Cross-Section Trichometer

The cross-section trichometer is available in research and commercial models. The commercial model, HairCheck, is a handheld, plastic device with a pair of contoured, spring-loaded levers (Fig. 11C2-2). The distal end has a slotted J-hook and anvil contained in a disposable cartridge.

MEASURING HAIR LOSS AND GROWTH

To quantify hair loss and growth, repeated HMI measurements in the same region of scalp are required. A locator strip, included with the device, enables the return to a previously measured area (Fig. 11C2-3). The strip is attached to the nosepiece of an eyeglass frame, and laid along the midline of the scalp. A four-legged inked template is placed above one of the numbered tabs on the locator strip (Fig. 11C2-4).

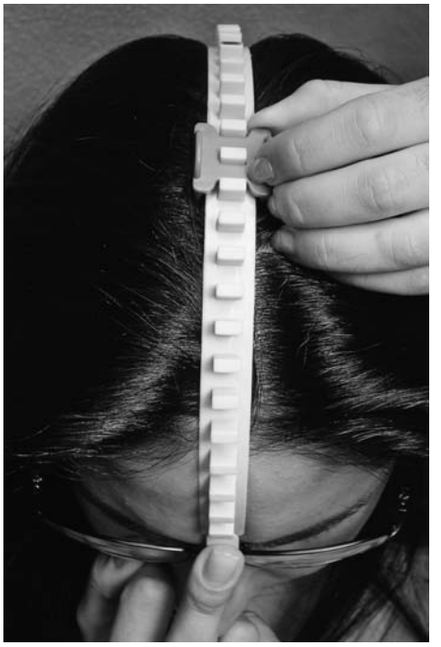


Figure 11C2-3 A locator strip is attached to glasses worn by the patient, and placed along the midline of the scalp. This permits subsequent measurements to be made at the same location.

The template leaves four ink dots on the scalp that form a 2 $\times$ 2 cm square, with a 4 cm^2 area. The number on the tab is recorded, and the same site may be relocated in the future by returning to the same tab.

After defining this area, loupe magnification should be used to isolate hairs within the demarcated area. Hairs at the perimeter of the box, which could be inadvertently included in the measurement, are immobilized with tape. Then hair within the box is gathered into a bundle and its cross-section

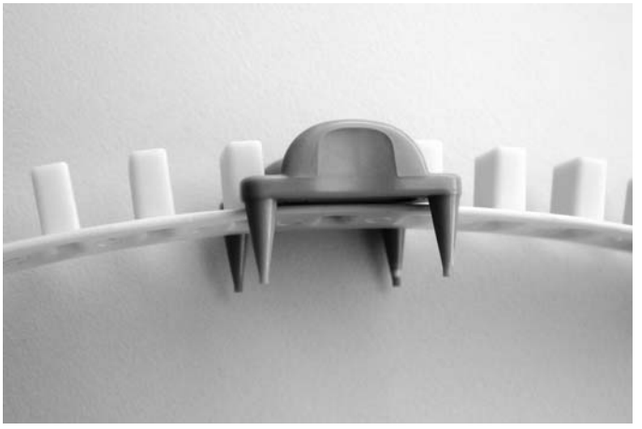


Figure 11C2-4 A four-legged inked template is placed above one of the embossed numbers on the locator strip. The feet of the template leave four ink dots on the scalp, which are used to identify the corners of the area that will be measured.

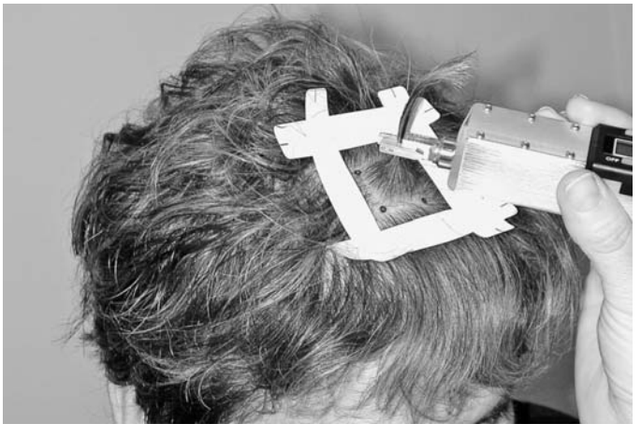


Figure 11C2-5 Tape is used to isolate the area of the scalp where the measurement will be performed.

measured using the device (Fig. 11C2-5). Hairs should be at least 2.5 cm long, in order to span the distance from the scalp to the cartridge. To perform the measurement, the proximal end of the hair bundle is placed in the slot of the J-hook. When the levers are squeezed, the bundle is compressed within a rectangular chamber with a precise, predetermined force, which compacts the bundle, but does not damage the individual fibers (Fig. 11C2-6). An LED screen on the device will then display the HMI. In patients with an average density of 100,000 hairs or 230 hairs per cm^2, the HMI range is 75–100, which reflects normal variability in hair diameter. Hair miniaturization or loss is reflected by a reduction in HMI. If measuring growth, be aware that newly emerging hairs may be insufficiently long to be captured by the device, and thus measurements should be deferred until the new hairs are anticipated to have grown at least 2.5 cm.

Figure 11C2-6 A hair bundle is compressed within the HairCheck device. The hair bundle is gathered from an area of 4 cm^2, to which the device is calibrated. Hair can be wet or dry, provided that it is in a similar condition during subsequent measurements.

Measuring Hair Breakage

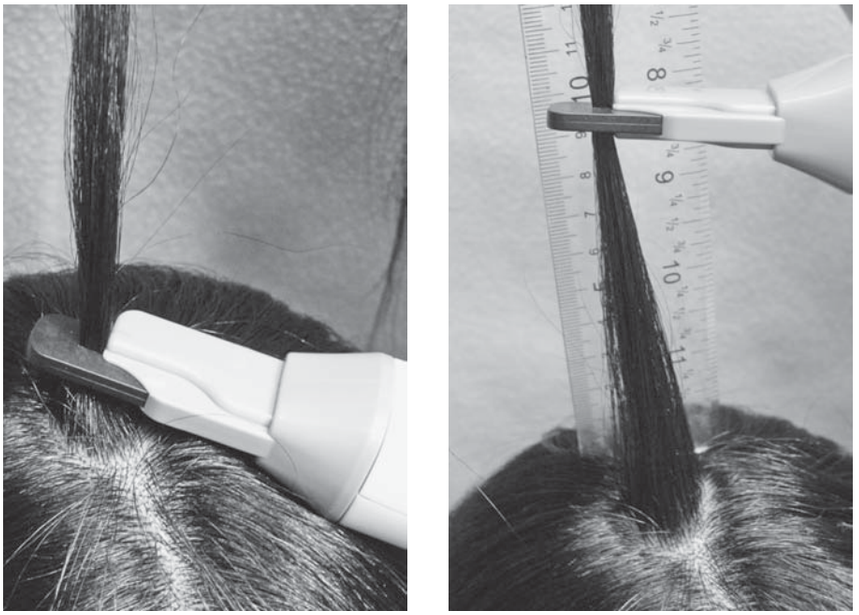
To measure the HBI, a random-sized bundle of hairs are gathered from an area of suspected breakage. A proximal HMI measurement is performed, as previously described, and placed into memory by pressing the "HBI" button on the device (Fig. 11C2-7a). A second HMI measurement, usually 10 cm distal to the scalp, is performed and similarly placed into memory (Fig. 11C2-7b). Finally, by pressing this same button a third time, the HBI value is generated. This is expressed as the percent of broken hairs at a fixed distance from the scale, since the HBI can be calculated at any distance along the hair shaft, depending on the need.

Layered haircuts will give a false-positive reading for breakage if the distal measurement is taken at a distance less than the shortest layer of hair. In addition, a false-positive reading can occur in the months following an episode of shedding, when short, newly growing anagen hairs, might be misinterpreted as broken.

OTHER ADVANCED MEASURING INSTRUMENTS

While the cross-section trichometer is the subject of this chapter, it is worth mentioning another measuring device, the TrichoScan®, which has similar precision and accuracy. The TrichoScan uses enhanced digital imagery to generate values for hair density and diameter. The test site must be shaved, uniformly dyed, digitally photographed, and then analyzed with software designed for the system. Measurements of hair diameter are subsequently used to classify hairs as either terminal or vellus. The system is available in either a simple (TrichoScan SMART) or a sophisticated research version, both of which require a trained technician for operation.

The TrichoScan has advantages and disadvantages when compared to the cross-section trichometer. Its primary benefit is that hair diameter and hair count can be separately measured. Moreover, all hairs, including vellus and anagen hairs, are included in its measurements, whereas the trichometer is not capable of measuring hairs less than 2.5 cm long. On the other



(**a**) (**b**)

Figure 11C2-7 (**a**) When measuring the hair breakage index (HBI), the first measurement is made at the proximal end of the hair bundle. (**b**) The second measurement required to calculate the HBI is made toward the distal end of the hair shaft. In this case, a ruler was used to identify a point 10 cm distal to the root of the hair follicle.

hand, the TrichoScan is not capable of measuring hair breakage, it requires specially trained staff to operate, it is considerably more time-consuming and expensive, and it requires that an area of hair is cut and dyed, which most patients are reluctant to do. Thus, in the author's opinion the cross-section trichometer is a preferred instrument for most clinical settings.

CONCLUSION

Since its introduction, the cross-section trichometer has been adopted by the health and beauty industry to evaluate the efficacy of hair care products. A newer version of the trichometer, commercially named HairCheck, has been designed specifically for the office evaluation of hair loss. Its application in clinical settings promises to help improve the evaluation and treatment of hair loss.

11C3. ENHANCED PATIENT SELECTION: A NEW METHOD FOR MEASURING HAIR GROWTH PARAMETERS—THE TrichoScan®

Jerzy R Kolasinski

INTRODUCTION

In the treatment of alopecia, it is important to have objective ways of evaluating hair loss. Hair loss can be described in terms of hair counts, hair diameter (terminal vs. miniaturized hairs), and stages in hair cycle (anagen vs. telogen hairs). Specific parameters particularly useful when evaluating hair loss include the following:

- Anagen hair count—Hair in its active growth phase characterized by hair growth of approximately 1 cm/month.
- Telogen hair counts—Hair in its nongrowing resting phase.
- Terminal (large diameter) hair counts—hair greater than 40 µm in thickness. These can be anagen hairs or telogen hairs.
- Small-diameter hair counts—hairs below 40 µm in thickness. These can be either miniaturized hairs, androgen-type alopecia (AGA), or vellus hairs.

Evaluating the density and relative percentages of the above hair types is valuable for the correct diagnosis of alopecia; the correct selection of patients for surgery; monitoring therapeutic effectiveness; and comparative evaluation in scientific studies.

A variety of methods for evaluating hair loss exists and is listed in Box 11C3-1 and Appendix 4D-1. All these methods, although effective, have a fundamental shortcoming. Namely their precision is totally dependent on the experience and subjective visual assessment of the examiner and thus it is vulnerable to human error and variability. For example, it is the examiner's judgment that will determine if a hair, borderline in diameter, is classified as a terminal or a miniaturized hair.

The TrichoScan® is a new evaluation technique that attempts to overcome this subjectivity and potential for human error. It combines high-quality digital imaging (Fotofinder DERMA, Teachscreen Software, Bad Birnbach, Germany) with

Box 11C3-1 Various Methods to Evaluate Hair Loss

Noninvasive methods: macroscopic visual evaluation (densitometer, etc.) (1,2); microphotography—visual analysis of magnified images—phototrichogram (3–5)
Semi-invasive methods such as trichogram (6) or microscopic analysis of hairs plucked from a selected scalp area
Invasive methods (7) or examination of biopsied scalp-skin samples

Box 11C3-2 Parameters Measured with TrichoScan®

Total hair density (hr/cm^2)
Hair diameter (μm)
Hair growth rate (mm/day)
Anagen hair count (%)
Telogen hair count (%)
Terminal hair count (%)
Small-diameter hair count (%)
Ratio of anagen to telogen hair
Ratio of terminal hair to small diameter hair (i.e., miniaturization grade)

sophisticated computer software (TrichoScan software, Tricholog GmbH, Freiburg, Germany) that measures and analyzes modest differences in hair diameter and hair length (8,9). Digital images are obtained at 20 times magnification and the TrichoScan software can distinguish between 5 μm in hair thickness and length. This method makes it possible to objectively assess hair growth parameters, useful in the evaluation of hair loss, such as those listed in Box 11C3-2.

HOW TO PERFORM A TrichoScan

Preparing and Shaving the Sites

The patient arrives three days before evaluation with the TrichoScan. At this point, two pairs of fields measuring 1.8 cm^2 are selected and shaved (Fig. 11C3-1a–c).

One field in each pair is situated in the balding recipient area (usually the frontal area) and the other field is placed in the nonbalding donor area (usually the occipital area). This enables the comparison of donor and recipient hair characteristics.

In addition, one pair of fields is shaved to 1.5 mm above the skin surface while the other is shaved flush with the skin surface. This difference in shaving length determines which of the parameters the program will be able to measure from each pair of the fields.

The patient should grow his hair a little longer before having the examination in order to hide these fields.

Dyeing the Sites

Three days after shaving the patient returns for the actual TrichoScan. The sites are dyed immediately before imaging in order to increase the contrast between the color of hair and scalp. Dyeing also increases the quality of the photos (Fig. 11C3-2). The dye must remain on the shaven sites for 12 minutes. Longer dyeing periods lead to the blackening of the scalp skin, shorter lead to inadequately dyed hair. Both results are equally unsuitable for later evaluations. After dyeing, the area should be thoroughly cleansed using an alcohol-based solution.

Imaging

Digital images are taken of the dyed sites with an epiluminescent camera ELM (Fotofinder DERMA). The sites remain wet throughout the examination and the correct distance between the camera and skin surface is kept by constant contact of the camera lens with the skin (Fig. 11C3-3).

Analysis and Interpretation

The images are loaded into the computer where the TrichoScan software automatically proceeds with the measurements and analysis (Fig. 11C3-4). The software is able to distinguish between 5 μm in hair diameter. It objectively recognizes every hair less than 40 μm in diameter as a miniaturized or small diameter hair. The program measures a different set of parameters for each pair of fields as described in the following sections.

Analysis: First Pair of Fields Shaved 1.5 mm Above the Skin

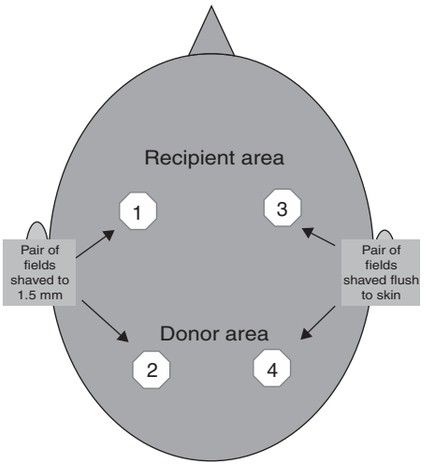
In the first pair of fields, the computer calculates the total hairs/cm^2 as well as the absolute and relative numbers of anagen and telogen hairs. Anagen hair is characterized by constant growth, which results in its lengthening over the three days as compared with telogen hair, which does not grow. The TrichoScan sensitivity allows it to capture this difference in length and therefore can differentiate between anagen and telogen hairs. The results are presented in both absolute numbers and in percentages. Agreement on the normal percentage of telogen hairs varies, but from a practical standpoint anything greater than 20% telogen (or less than 80% anagen) strongly points to a telogen effluvium type of alopecia (10,11).

Because fields were made in both the recipient area and the donor area, the anagen counts in both these areas can be compared. A significant difference between these two areas, where the recipient area shows a reduced anagen count and increased miniaturization when compared to the donor areas, points toward a patterned alopecia like AGA. If the decrease in anagen count and percent miniaturization is similar in both areas, then this is a strong indication for diffuse unpatterned alopecia (DUPA).

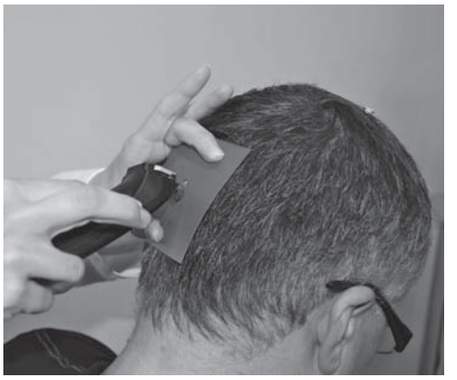
Analysis: Second Pair of Fields Shaved Flush to Skin

In the second pair of fields, the computer specifically calculates anagen hair density. Telogen hairs are not seen by the program as their length does not increase over the three-day period and they remain below the surface. Only the anagen hairs become visible to the program. The program also calculates the ratio of large-diameter (over 40 μm) anagen hairs to miniaturized anagen hairs (below 40 μm). An increase in miniaturized hairs indicates AGA. Agreements on the normal amount of miniaturized hair also vary, but miniaturization greater than 20% is accepted as being high.

These measurements can also be used to follow the results of medical treatment. In AGA, hair is miniaturized. Treatment with a finasteride (Propecia) frequently reverses this miniaturization. A TrichoScan performed at the beginning and repeated three months into the treatment can be used to follow-up on the effectiveness of the treatment. Diminished miniaturization after 3 months suggests a beneficial effect.



(**a**)



(**b**)

(**c**)

Figure 11C3-1 (**a**) Choosing pairs of fields in the recipient and donor area. One pair of fields is shaved to 1.5 mm 3 days before and one pair of fields is shaved flush to skin 3 days before. (**b**) The hair is exposed through a template and shaved with an electric razor. (**c**) After shaving.

Figure 11C3-2 Application of the dye.

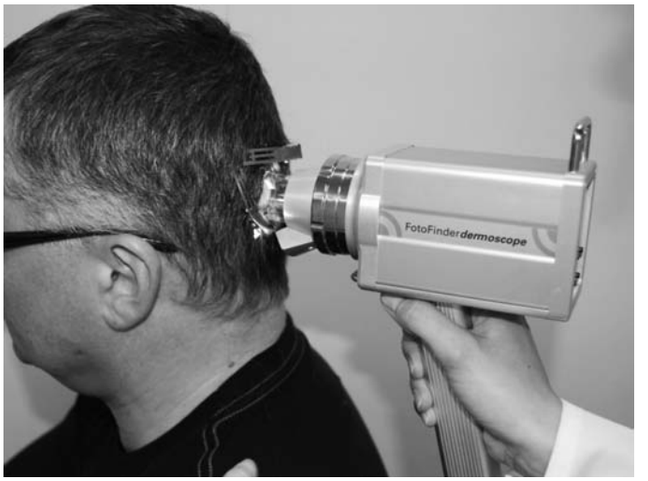


Figure 11C3-3 Photograph is taken with an epiluminescent camera ELM.

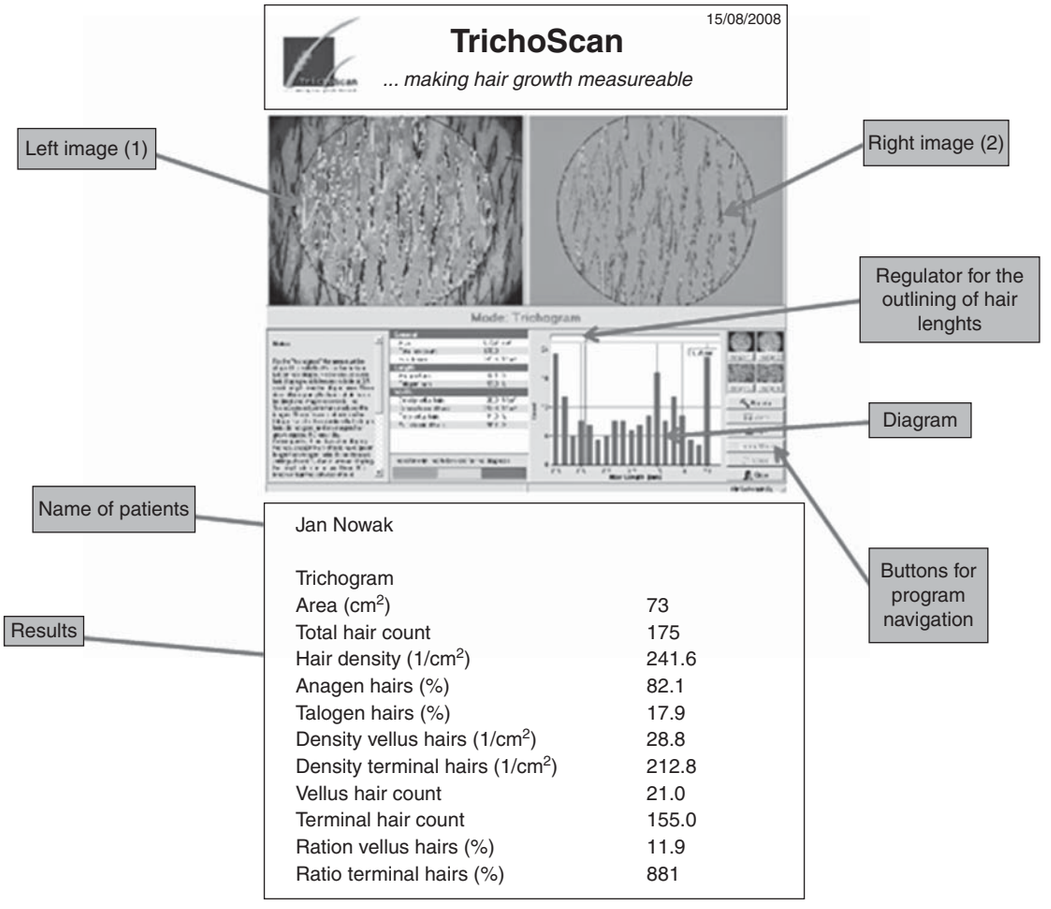


Figure 11C3-4 Results of TrichoScan analysis.

In hair transplant surgery, an analysis of miniaturization in the donor area allows for a more precise selection of patients for surgical treatment (12). Based on our experience (13) and data from literature (14), it can be assumed that patients with less than 10% miniaturization in the donor area are good candidates for surgery. Miniaturization of 10% to 15% should begin to create caution in selecting patients for surgical treatment. However, miniaturization exceeding 15% to 20%, especially in young men, should signify a real "red flag" for surgery. The ability to visualize results with the TrichoScan makes it easier to explain to your patient the concerns that you have about surgical treatment of his/her hair loss. This is especially important in managing younger patients below 25 years of age.

Using the TrichoScan Without Preshaving Three Days Before

Not all patients can be seen three days in advance. In this situation, a practical, although less accurate, alternative is to shave the fields and do the TrichoScan on the same day. Only one pair of fields is shaved to a length of 1.5 mm in this situation. The program measures total hair density and the ratio of terminal to small-diameter hair (i.e., miniaturization grade). In a normal scalp, there is approximately 91% to 95% of terminal hair, and 9% of miniaturized hair (15). The results of this immediate analysis are flawed due to the presence of telogen hairs among terminal hairs. However, the ease of its application makes it a test of choice when patients cannot come in three days in advance. Results are interpreted similarly to those of the second (shaved-to-skin) pair of fields described earlier, keeping in mind that terminal hair count is higher than anagen count thus reducing percentages of miniaturized hair by 5% on an average.

11C4. COMMENTARY

Walter P Unger

Readers are also referred to chapter 4D—Enhanced Patient Selection: The Folliscope®—for another device that can be used to study hair survival and growth.

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