Follicular Map: A Novel Approach to Quantitative Trichoscopy

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Abstract

Background: Trichoscopy (hair and scalp dermoscopy) is gaining importance as an easy-to-use diagnostic and monitoring tool in various hair and scalp conditions. **Objective:** The demand for a method to identify exactly the same site on scalp skin for subsequent examinations is growing constantly. **Methods:** In total, 40,000 trichoscopic images of 70-fold magnification were analyzed. Graphical pattern recognition was used to identify hair shafts in trichoscopy images and to derive the coordinates of all follicular orifices. Determination of the relative positions of hair follicle orifices formed the Follicular Map (FMap). Processing and matching of FMaps involves conceptually simple but computationally complex numerical algorithms. **Results:** FMaps were shown to be unique for specific locations on the scalp in each human individual. The follicular patterns were not affected by natural hair cycling processes and remained unchanged over the course of time. It has been tentatively verified that FMaps remain unaffected by noncicatricial alopecia. **Conclusions:** The

concept of FMap presents a novel approach to qualitative trichoscopy, allowing precise evaluation of treatment efficiency, clinical trial quality control, validation of diagnostic tools, and potentially other applications still to be discovered. The FMap enables the location of hair follicles to be precisely measured and recorded.

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Introduction

Trichoscopy is a dermoscopy-based, noninvasive diagnostic technique used for the evaluation of hair and scalp disorders. It is a valuable tool for diagnosing and monitoring various hair disorders, their natural course, as well as therapeutic outcomes [1, 2]. This quick, noninvasive, and cost-efficient method of diagnosing hair conditions is gaining importance.

Trichoscopic evaluation may consist of qualitative and quantitative hair assessment. The currently used quanti-

The work was conducted at TrichoLAB.

Fig. 1. Healthy scalp. The depicted pigmented lesion enables easy visual matching of two trichoscopy images presenting the same scalp area (rotated by 50°).

tative analysis and presentation standards concentrate on overall statistical measurement of hairs in the selected areas. Most frequently, assessed parameters include average hair density, average hair-shaft thickness, percentage of one-hair units, two-hair units, and multiple-hair units, as well as percentage of thin ($<30\ \mu\text{m}$), medium ($30\text{--}50\ \mu\text{m}$), and thick ($>50\ \mu\text{m}$) hairs.

Comparison of the frontal area to the occipital area is often implemented, especially in the diagnosis of androgenetic alopecia (AGA) [3–5]. Although statistical measures are very useful and practical, they represent only some aspects of the raw data. The goal of this study is to evaluate a novel approach to trichoscopy raw-data analysis: the Follicular Map (FMap).

A literature search has revealed no dedicated dermatology articles on the subject, although many publications on cicatricial alopecia disorders indicate that scarring processes lead to significant modifications of the follicle distribution pattern, mostly through loss of follicle orifices [6]. There is significant literature on planning target graft locations in hair transplantation to produce a natural look, as inadequate planning results in poor resemblance of natural follicle distribution. Despite some reports from the cosmetic industry on hair regrowth therapies that result in genuinely new follicle formation, there is no scientific evidence confirming these claims. Non-dermatology literature states that follicle patterns may be used for identification purposes [7, 8]. Some attempts have been made to use the vellus hair pattern on the dorsal aspect of a hand to

authenticate the user of a computer system, but no successful implementation of this concept is known so far. The distribution and orientation of hair follicles have been studied to test various models of intercellular molecular signalling and cell network evolution [9–11].

Methods

Derivation of FMaps from Trichoscopy Images

For derivation of the FMap, trichoscopy images are used. The relative positions of follicle orifices, which are expected to be unique in these images, create the FMap (Fig. 1). The positions are then derived using computer-pattern recognition software and are presented in graphical form (Fig. 2). For the purpose of visualization, the trichoscopy photos are modified: hair shaft images are removed, and follicular orifices are marked with dots and labelled with numerical indexes.

The original images may be compared with the FMap matching results. FMap matching may help to identify minute differences between trichoscopy images and analysis inefficiencies (Fig. 3).

The FMap Matching Procedure

FMap matching has been developed to compensate for the following effects:

(1) Different positioning of the videodermoscope camera (shifts and rotations) on the scalp during subsequent examinations; (2) the precise location where hair emerges from follicular orifices is quite ambiguous (due to skin transparency) and it is measured with an uncertainty of at least $100\ \mu\text{m}$; (3) hair follicles are “anchored” below the skin surface; rearranging hair in a different direction may pull follicular openings along to some extent, up to $200\ \mu\text{m}$; and (4) scalp skin displays a certain degree of elasticity and it is often pulled,

Fig. 2. Healthy scalp. FMaps were obtained by hair images removal and labelling follicular orifices with number indexes (only few indexes are presented for clarity). Matching of FMaps revealed minute differences between images.

Fig. 3. Healthy scalp. Hairs without identified counterparts in the corresponding image were labelled with red indexes. The blue lines outline overlapping areas of the presented images.

stretched, or tilted due to hair parting and pressing the videodermoscope lens against the scalp (may introduce shifts of up to 1 mm).

FMaps can be matched numerically by calculation of biometric vectors, derivation of approximate rotation and shift, or graphical transform function. A detailed description of these processes exceeds the spatial limits of this work.

Statistical Properties of FMaps

A successful match does not require all individual hairs to be matched. A successful match was defined as one with more than

50% of the hair shafts successfully matched in the corresponding image of an overlapping area.

Evaluation of Invariance of FMaps in Time

In six patients with age-related hair loss on monthly platelet-rich plasma treatment, FMaps were created with a six-month interval.

We also made a similar comparison between images registered with a 2-year interval in 5 untreated patients with AGA. In all mentioned cases, a successful match was found for over 80% of the hair

shafts, despite an increase in hair density in patients treated with platelet-rich plasma and a significant hair-density reduction in untreated AGA patients. In all cases, the major FMap pattern remained unchanged.

It has therefore been concluded that the human scalp FMap most probably does not change significantly over time and is basically invariant to nonscarring hair-loss conditions and nonsurgical hair treatments. In the case of massive hair loss or complete baldness, it seems clear that derivation of the FMap from the trichoscopy image is not possible. In those cases, however, the pattern of empty follicle openings most probably remains intact.

Evaluation of FMap Uniqueness to an Individual

A test using a TrichoLAB database of over 3,400 trichoscopy examinations and 40,000 images was conducted. The sample included images of frontal, temporal, and occipital areas registered with $\times 70$ magnification. Trichoscopic images had been obtained with different versions of FotoFinder Medicam (500, 800 HD, and 1,000). All hair shafts were identified in images, and proximal hair ends were identified to derive the FMaps. The process underwent stringent quality assurance by qualified operators. To prove that FMaps are unique to the individual, an attempt was made to find a match among 50 randomly selected trichoscopic images.

The study results showed that in no case did the percentage of matched hairs in randomly selected images exceed 30%. A minimum value of 50% is considered to be needed for a successful match, and the results obtained were significantly below this value.

It can therefore be stated that unless very small images with just a few hairs are used, the FMap is unique to an individual and to the area on the scalp.

Discussion

The concept of the proposed FMap is based on an observation of the hair follicle pattern, which seems to be unique to each individual. Retrospective and prospective observations of this phenomenon in healthy individuals show stability of a FMap in a certain individual in a chosen area.

The FMaps also seem invariant to nonscarring hair-loss conditions and nonsurgical treatments. This noninvasive, innovative tool therefore seems to have promising potential for detailed pre- and post-treatment monitoring, assessing hair-loss patterns in different types of alopecia, quality assurance of clinical trials, and validation of diagnostic methods. Future applications, such as personal identification for security purposes, or in criminology if fingerprint data is missing and the individual's previous trichoscopy examination is available, may also appear.

The disadvantages of this method include the need for patient cooperation during the procedure. This factor makes it hard to apply in young children or in patients with tremor and similar disorders. Appearance of post-traumatic scars or fibrosing conditions (i.e., scleroderme en coup de sabre), as well as the use of skin-tension modifying

procedures such as expanders or flap techniques in skin surgery, may limit the usefulness of this diagnostic method.

Aims of future research include elucidating correlations between the hair-loss pattern in scarring and non-scarring alopecias. This includes, for example, early identification of the frontal fibrosing alopecia subtype, which is helpful in determining disease course and prognosis [12]. The implications of this novel approach and other possible applications need further investigation.

Statement of Ethics

The basic images derive from trichoscopic examinations performed as a part of a diagnostic process in patients with hair loss disorders or as a check-up procedure in people interested in the condition of their hair and scalp. Informed consent for the performed trichoscopic examination had been obtained from all patients.

Our research does not violate regulations for human studies.

Disclosure Statement

Michał Kasprzak and Justyna Sicińska have no conflicts of interest to disclose.

Antonella Tosti is a consultant for P&G, DS Laboratories, Monat, and Fotofinder; serves as a principal investigator for Incyte and Nutrifol; is an advisory board member for Pfizer; receives author royalties from Springer & Verlag and Taylor & Francis; is Editor-in-Chief of *Skin Appendage Disorders*, Karger; and is on the scientific board for the National Alopecia Areata Foundation.

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