A novel integrated database system for follicular units transplantation, based on micro-photos image analysis and statistical inference

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Objective

In this study, a novel integrated system is presented which includes a fully organized relational database and an image analysis system with statistical inference for hair transplant procedures.

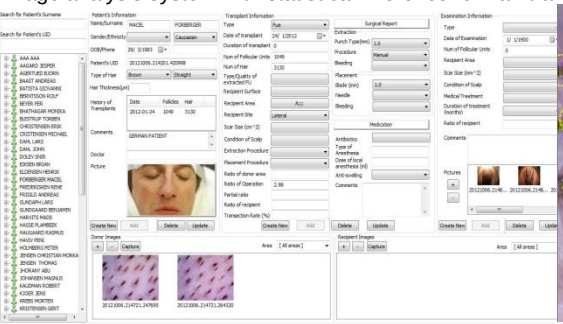

Fig. 1 Overview of the database module

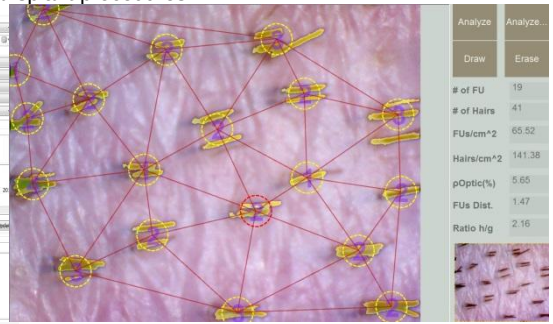

Fig. 2 The image analysis module with the calculated image parameters

Material/Methods

Database module: A patient based tree-like database structure was created with three top-down levels. The top level contains detailed information regarding patient demographics and scalp condition(Fig 1). The next level corresponds to the hair transplant procedure performed on each patient. Information about surgical procedure is also gathered. The final level concerns follow-up examinations post-operatively.

Image Analysis Module: Contrast enhancement filters were applied to increase the separability of hair follicles compared to the background. Segmentation algorithms were utilized to correctly separate the follicular units from the skin. The detected units were connected by using the Delaunay triangulation algorithm and the mean intra-follicular distance in millimeters was calculated(Fig 2). An automatic hair assignment algorithm was implemented. In this way, parameters such as, a) density of donor and recipient area (follicular units and hairs per square centimeter), b)mean number of hairs per follicular unit, c) the intra-follicular distance, were measured. Additionally, an advanced method for automatic calculation of the recipient area surface from macro images was included taking into consideration the curvature of the area(Fig. 3). Specific mathematic formulas were embodied into the system which automatically calculates the number of grafts or hair follicles which should be placed into the recipient area in order to increase the density up to a given level.

Statistical Inference Module: The system includes statistical procedures to perform comparisons between the donor and the recipient area calculated parameters. In this way, intra-patient correlations between the image analysis results are extracted to characterize the transplant outcome in a quantitative way(Fig 4).

Fig. 3 Surface and curvature calculation

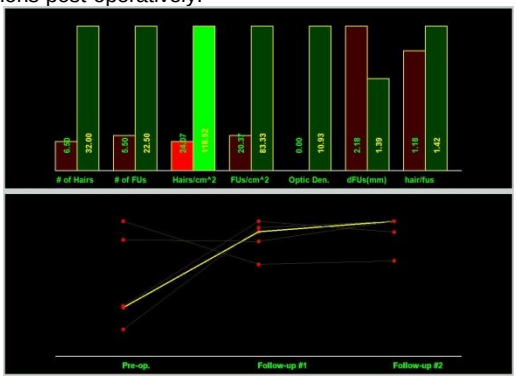

Fig. 4 Statistical comparison and time line trend

Results/Discussion

The accuracy of the algorithm, was evaluated on 56 micro-photos (Bodelin ProScope HR2 at 640x480 pixels) taken from different patients. The sensitivity of the algorithm in correctly detecting follicular units position was 97.5% (mean) with 3.8 standard deviation. The precision of the algorithm had a mean of 98.6% with 3.1 standard deviation. Pre-operatively, the system helps the physician to precisely calculate both the surface and the grafts needed for an optimal coverage of the recipient area without wasting the donor area. Post-operatively, the hair surgeon is capable of monitoring the procedure outcome by using graphs presenting the increase in density in a time line way(Fig. 4).

Conclusion

The quantification of parameters, which up until now were calculated manually or empirically, are now established automatically. By utilizing image processing of micro-photos of the recipient area, in conjunction with the aforementioned methodology, an invaluable tool can be offered which provides immediate patient data, quantifies the patient outcome and allows the physician to precisely design a hair transplant treatment planning for an optimal aesthetic result.