Characteristics of robotically harvested hair follicles in Koreans

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Background: Recently, an automated robotic hair restoration device was developed and is increasingly being used for hair restoration.

Objective: We sought to analyze the hair follicles of Korean patients that were harvested by a hair restoration robotic device.

Methods: Data were reviewed from a total of 22 patients who underwent robotic follicular unit (FU) extraction hair restoration surgery at Seoul National University Bundang Hospital. Hair follicles collected from 3 grids in the central parts of the safe donor zone of each patient were analyzed.

Results: The total number of harvested FUs was 5213, and the total number of collected FUs was 4955. The average yield was 95.1% ± 3.5%. Among the 12,017 harvested hairs, 590 hairs were transected and the average transection rate was 4.91% ± 2.9%. FUs of double hairs made up the majority of harvested FUs (44.1%), followed by triple hairs (31.9%). The transection rate increases in FUs that contain multiple hairs.

Limitations: A relatively small sample size and lack of comparative study with conventional FU extraction modalities are limitations.

Conclusions: The robotic system qualifies for use in hair restoration surgery. It efficiently harvests not only single hairs but multiple hairs as well. (J Am Acad Dermatol 2015;72:146-50.)

Key words: androgenetic alopecia; follicular unit extraction; hair restoration surgery; robot; transection rate.

Hair is considered a major aspect of appearance, and consequently, hair restoration surgery for androgenetic alopecia has become an increasingly common procedure. The 2 main harvesting techniques for hair restoration surgery are follicular unit (FU) strip surgery and FU extraction (FUE). FU strip surgery produces grafts by excision of a linear strip of donor scalp with subsequent dissection to obtain individual FUs.[1,2] FUE is a harvesting method that extracts individual FUs using small and precise punches.[3] FUE has recently gained popularity because it offers many advantages over the strip method, such as the absence of linear scarring on the donor tissue, less pain, and shorter recovery time for the patient.[4] Furthermore, by using the FUE method, the exact number of hairs needed for hair transplantation can be harvested. However, FUE is still a time-consuming, technically difficult, and labor-intensive procedure for surgeons. An

Abbreviations used:

FDA: Food and Drug Administration
FU: follicular unit
FUE: follicular unit extraction

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automated robotic hair restoration device was developed recently and received US Food and Drug Administration (FDA) 510(k) clearance on April 11, 2011. To date, there have been no published clinical data in peer-reviewed scientific journals using this robotic system to our knowledge. In the current study, the authors analyzed hair follicles harvested by the robot for hair restoration surgery in Korean patients.

CAPSULE SUMMARY

- Strip surgery and follicular unit extraction are 2 main harvesting techniques in hair restoration.
- The newly developed robotic device harvests multiple hairs with high yields and low transection rates.
- The robot harvests hairs efficiently, without the strip surgery's linear scar or time-consuming process of follicular unit extraction.

METHODS

Robot system

The ARTAS robotic system (Restoration Robotics Inc, San Jose, CA) is an interactive, computer-assisted, and physician-controlled robotic system used for the FUE harvest. The robot system extracts individual FUs, one at a time, directly from a patient's safe donor area. The system is composed of a cart with a 6-axis articulated robotic arm (Fig 1, *A*). A needle mechanism is affixed to the end of the robotic arm to separate FUs from the scalp. The needle mechanism also houses stereo cameras and force sensors that guide the dissection and provide safety measures in real time. A specialized chair is used to position and stabilize the patient's head and body during the procedure.

The dissection system uses a needle-in-needle configuration in which a sharp bi-beveled needle (inner needle) is concentrically arranged within a blunt outer punch (Fig 1, *B*). A skin tensioner is integral to the dissection process (Fig 1, *C*). During a dissection, the inner needle makes a shallow scoring incision of 1 mm in diameter around the selected FU. The outer punch, which spins at between 400 and 800 rotations per minute, dilates the scoring incision and dissects deeper into the skin to separate the FU from the surrounding tissue. A suction system elevates the FU above the skin and thereby eases the extraction process. Stereo cameras and an image processing system are able to identify FUs on the scalp and precisely measure and calculate the angles and direction of each FU within its field of view. Imaging feedback allows the robot to dynamically track and harvest each hair even in the presence of motion caused by the patient's breathing and incidental head movements.

The details of the robotic procedure are as follows. The patient's hair in the donor area is shaved down to about 1 mm in length to reveal the FUs to be harvested. The surgeon injects a local anesthetic to numb the donor area. A tensioning device is placed over the area to be harvested to provide consistent skin tension. Optical targets are then established by the imaging system to guide the robot back and forth over the donor area as it dissects the follicles. Once the system is ready, the physician and assistant can initiate the dissection process. Generally, the robot determines directions and rotations per minute of the needle, and targets follicles to be extracted in a random pattern. However, the surgeons can optimize the dissection parameters, such as depths of the inner needle and outer punch and distance between harvest attempts, using a handheld remote control and a computer monitor. The surgeons also can choose follicles to be extracted or skipped in manual mode. After extracting FUs, the surgeon makes slits in the recipient area and the extracted follicles are inserted in the slits after proper processing. The patients are instructed to take oral antibiotics 2 hours before the surgery and for 3 days after the surgery for prophylaxis. The patients are also instructed to take oral acetaminophen and methylprednisolone to reduce pain and swelling until 3 days after procedure.

For this study, the ARTAS software, Version 4.8.2 (Restoration Robotics Inc) was used for harvesting hair follicles. We used the classic skin tensioner for this study: each dissection area (grid) defined by the classic skin tensioner is approximately $3.5 \times 3.5\ cm^2$. The surgeon followed the distribution, direction, angle, and rotations-per-minute parameters, which were set automatically by the robot. The surgeon adjusted the depth of the inner needle and outer punch, and exercised the option of overriding the FU selection of the robotic system. To eliminate interoperator variability, the corresponding author conducted all of the surgeries and collected all of the analyzed hair follicles. The distance between harvested FUs was set to 1.9 mm.

Patients

A total of 22 patients who underwent robotic-assisted hair restoration surgery from September 2012 to March 2013 at Seoul National University Bundang Hospital with the robotic system were included in the current study. Medical records of the patients were reviewed after surgery.