The age of surgical robots

Miguel G. Canales, MD *Mountain View, California;* David A. Berman, MD *Palo Alto, California*

Hair transplantation is the most commonly performed cosmetic surgery for men in the United States, and is growing in popularity amongst women. The aging baby boomer population combined with better techniques that deliver natural, undetectable results have been major factors for the growing number of individuals considering this procedure. Despite this, only a small percentage of the population with androgenetic alopecia has ever seriously considered hair transplantation to reverse hair loss. The vast majority of cosmetic physicians still do not offer hair transplantation on their menu of surgical procedures. Robotic technology has the potential to address some of the concerns of both patients and physicians.

Why Robotics?

Over the past decades, anthropomorphic machines have become familiar figures in popular culture through books such as Isaac Asimov's *I, Robot* and movies such as *Star Wars*. The popularity of robots in fiction indicates that people are receptive to the idea that these machines will one day walk among us as helpers. A robot is a reprogrammable, computer-controlled mechanical device equipped with sensors and actuators.[1] Moreover, very few robots in development are designed to be anthropomorphic. Under this definition there lies a range of robots from the simplest, single-axis manipulator, up through the most complicated highly autonomous cyborg. For the moment, the state-of-the-art in artificial intelligence is such that most robots have either a limited level of autonomy, or they are relegated to perform highly structured, low-risk tasks.

Robots have a number of advantages and often times enhance and extend humans capabilities. Robots excel at performing rote manipulation tasks. Their accuracy and repeatability may reach the sub-millimeter level. Robots can be optimized to perform tasks demanding a high amount of precision at fast speeds, automatically and tirelessly, thus increasing productivity and efficiency. Their performance output is consistent and predictable. These technical strengths may make them suitable for a number of hair transplantation tasks, such as follicular unit extraction. Some of the drawbacks to robots include cost, nonversatility, inability to process qualitative information, and lack of judgment.

Robots already play a vital role in industries such as automobile manufacturing (where there is approximately one robot for every 10 workers) and are making prominent advances in the fields of cancer surgery, cardiology, and radiation therapy. Commercially available medical robotic systems such as the da Vinci® System (Intuitive Surgical, Inc.), the Sensei™Robotic Catheter System (Hansen Medical, Inc.), and the Cyberknife® System (Accuray, Inc.) are widely deployed in hospitals and have been used to treat complex diseases on tens of thousands of patients. For example, it is estimated that 45% of all prostate cancer surgeries in the United States are performed using the telerobotic da Vinci® Surgical System.[2] The development of an automated robotic system for hair transplantation is being undertaken by Restoration Robotics™, Inc., a Silicon Valley medical device start-up company.

Restoration Robotics™ Prototype System

The Restoration Robotics™ prototype system is an interactive image-guided robotic system ("System") consisting of the following several key components (Figure 1): a robotic arm, a mechanism that actuates punches, stereo cameras and imaging algorithms, and a control computer. System testing is currently focused on harvesting follicular units. The System is not FDA approved and not commercially available.

Figure 1. Restoration Robotics™ prototype system (Berman Skin Institute, Palo Alto, California).

The robotic harvesting technique resembles that of follicular unit extraction (FUE). The donor area, as in FUE, is cropped to a short length to enable the stereo camera system to visualize hair follicles. The imaging algorithms are capable of identifying follicular units, determining their type (1-hair FU, 2-hair FU, 3-hair FU, etc.), and calculating the angle, orientation and location of each follicular unit on the scalp surface. Using this position and location data, the imaging system semi-autonomously guides the robotic arm and mechanism to core and extract follicular units one at a time. The punch size is 1mm in internal diameter. The coring of the follicular unit is enabled by a proprietary punch design that aims to minimize transection rates. The System, using a feature called visual servoing, continuously tracks and adjusts to patient movement so that harvesting of targeted follicular units is precise. Based on inputs by the User, the degree of automation can be adjusted; for example, the System may be configured to harvest 10–20 follicular units sequentially. The harvested follicular unit may then be automatically transported to a vial where it is kept moist and cool. As the technology is developed and optimized, it may be possible to achieve harvest speeds of up to 1,000 follicular units per hour.

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Potential Benefits of Robotics in Hair Transplantation

Robotically automating donor harvesting may attract more physicians into the field of hair transplantation. Current techniques, such as strip harvesting, are labor intensive and require well-trained technicians. The large staff requirement alone deters many talented physicians from entering the field. Robotic harvesting may lessen the number of staff needed for a hair transplantation procedure allowing the physician to utilize their staff in other revenue generating procedures. Additionally, robotic harvesting at high speeds may shorten the procedure time, which would be a benefit to the patient and the physician's practice.

Follicular unit extraction is perceived by some physicians and patients to be less invasive than the strip harvest technique. The robotic technique uses the FUE paradigm to harvest follicles using a small punch thus obviating the need for a large linear scar. The harvesting technique may attract a different population of patients who wish to avoid large incisions. Furthermore, avoiding large incisions may permit an earlier return to work or regular activities because of less post-operative discomfort. Additionally, it is postulated that follicular unit extraction may increase the amount of follicular units available for harvesting. Clinical studies are needed to lend support to these perceptions. Figure 2 shows robotically harvested follicular units.

Figure 2. Robotically harvested follicular units.

Conclusion

Although still in its infancy, robotic technology applied to hair transplantation has the potential to revolutionize the field just as it has done in other areas of surgery. Although the feasibility of a robotic harvesting technique is currently being demonstrated, prospective clinical trials are being undertaken to evaluate efficacy and safety. As the technology evolves, robotic approaches to other aspects of the hair transplantation procedure will be developed.

References

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2. Internacional Federation of Robotics, 2005 Data.✧

Editor's note: Miguel Canales received his medical degree from Harvard Medical School and received General Surgery training at Stanford University. Dr. Canales is currently the Medical Director of Restoration Robotics, Inc. (Mountain View, CA), a medical device company developing an image-guided robotic system for hair transplantation. The System is currently undergoing clinical testing. Dr. Canales has expertise in developing robotic surgical products and procedures in various surgical subspecialties, including urology, cardiac surgery and gynecology, that have been adopted worldwide.

ABHRS Recertification Exam*
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For further information and to register, contact:
Peter B. Canalia, JD, Executive Director
American Board of Hair Restoration Surgery (ABHRS)
18525 South Torrence Avenue
Lansing, IL 60438 USA
Tel: 708-474-2600 • Fax: 708-474-6260
E-mail: abhrs@sbcglobal.net
Website: www.abhrs.org

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*Note: The exam will be held during the 16th Annual Scientific Meeting of the ISHRS.