Title
Follicular unit extraction hair transplant harvest: a review of current recommendations and future considerations

Journal
Dermatology Online Journal, 20(3)

Authors
Bicknell, Lindsay M
Kash, Natalie
Kavouspour, Chitra
et al.

Publication Date
2014

DOI
10.5070/D3203021754

Volume 20 Number 3
March 2014

Review

Follicular unit extraction hair transplant harvest: a review of current recommendations and future considerations

Lindsay M. Bicknell MD[1,3], Natalie Kash BS MSIII[2], Chitra Kavouspour MS MSIII[3], Rashid M. Rashid MD PhD[4]

Dermatology Online Journal 20 (3): 2

[1]Scott & White Memorial Hospital, Temple, TX

[2]University of Texas Medical School at Houston, Houston, TX

[3]Texas A&M Health Science Center, Temple, TX

[4]Mosaic Clinic Hair Transplant Center, Houston, TX

Correspondence:

Rashid M. Rashid, MD PhD
Mosaic Clinic Hair Transplant Center
2401 Yale Street
Houston, TX 77008
RashidMDPhD@gmail.com
713.234.6789

Abstract

Alopecia affects many individuals worldwide. Owing to the large role that hair loss plays in self-image and self-confidence, an increasing number of these men and women seek options for hair restoration.

Major considerations and sources of hesitation for strip surgical restoration are the visible linear scar, prolonged downtime, and other expected side effects of invasive procedures. These problems can be circumvented by smaller harvest approaches. However, the traditional punch harvest, which produces no linear scar, does leave patients with an often-unsatisfactory “doll hair” appearance. Follicular Unit Extraction (FUE) is a minimally invasive surgical procedure that utilizes a punch device to harvest occipital follicular units that are later transplanted in areas of loss to restore hair growth. FUE captures the benefit of multiple available restoration techniques and avoids the disadvantages of traditional strip surgery. A number of variations on the procedure are currently in practice and many more exciting advances are underway.

Keywords: Follicular Unit Extraction; hair restoration; androgenic alopecia; NeoGraft; strip surgery; line scar; robotic surgery

Introduction

Hair loss patients have an increased risk of psychosocial and psychiatric conditions, as well as prostate cancer, cardiovascular disease, and squamous cell cancer of the scalp [1]. For androgenic alopecia, the only permanent available solution is surgical hair restoration. Techniques have evolved dramatically, with FUE as the most recent advancement in minimally invasive surgical hair restoration.

Androgenic alopecia is poorly understood, but its etiology rests in environmental factors and numerous genes, including those for 5-a-reductase, aromatase, and sex-hormone binding globulin. These gene mutations cause an increased concentration of 5-alpha-dihydrotestosterone (DHT), which has a greater affinity for androgen receptors than testosterone or dehydroepiandosterone (DHEA). DHT binding to androgen receptors is thought to induce production of cytokines TGFB1 and TGFB2, which

consequently causes dermal papillae senescence and telogen transformation. This manifests as frontal and temporal hair loss in male patients [2]. Female patients also experience androgenic alopecia, although hair loss tends to be more diffuse over the scalp with maintenance of the frontal hairline. Women with increased circulating androgens may present with a more masculine hair loss pattern [2]. General considerations for all patients with hair loss include thorough evaluation for medical causes, including infectious disease, iron deficiency, hypothyroidism, and other hormone imbalances. Treatment of causal conditions often improves patient response to hair restoration therapy [2].

Surgical Hair Restoration Options

Dermatologist, Dr. Orentreich, first described surgical hair restoration in the 1950's. His original procedure, which involved using 4mm punches to extract follicles from excised scalp, was not unlike the strip surgery harvest technique used today [3, 4]. Modern strip surgery uses single or double bladed knives to extract individual follicular units from an elliptical, 8-14 cm by 1 cm strip of occipital scalp that extends to the lower epidermis. Follicular units contain 1 to 4 hairs each and are harvested from the excised strip under magnification using a manual blade. After harvest, follicular units are stored in a holding solution such as saline in preparation for transplant [5, 6]. Unlike Dr. Orentreich's original procedure in which more than one follicular unit was implanted simultaneously, current methods avoid creation of an unnatural, tufted hairline by implanting one follicular unit at a time, a method referred to as Follicular Unit Hair Transplantation (FUT) [7].

Strip Surgery Considerations

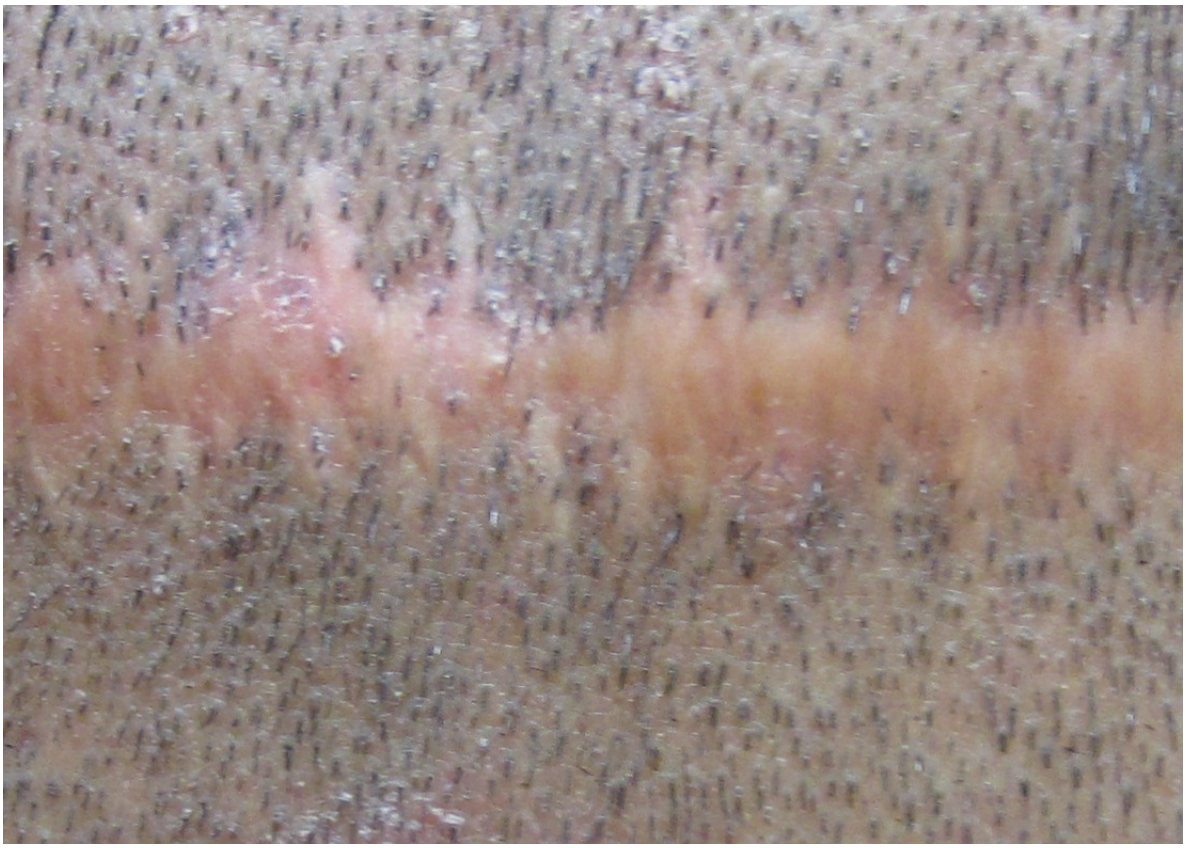

Figure 1. Line scar. Occipital scar secondary to strip surgery harvest

Strip surgery is a good option for patients who cannot tolerate a long procedure and/or who have an appropriate amount of occipital scalp skin. Low scalp laxity limits the quantity of harvested follicles and excess occipital scalp skin can lead to widened scars with this method. Because harvest is performed under direct visualization of the follicular hair bulb, few hairs are transected and a high graft survival rate results [6]. Conversely, strip surgery harvest leaves patients with a noticeable linear scar on the occiput, as in Figure 1, and is not preferred in patients who wish to wear short hairstyles that might reveal the scar. Additionally, in rare cases patients experience neurological sequelae including postoperative hyperesthesia and hypoesthesia [8]. The procedure also requires a surgeon or a skilled technician to spend hours at the workbench performing manual harvest of individual follicular units from the excised scalp specimen. In the skilled, this process may be significantly less time consuming with reports of completion in 10 to 15 minutes, but often at the risk of increased graft transection and fewer viable follicles [6, 9, 10]. After the procedure, patients are instructed to avoid alcohol and tobacco for one and two weeks respectively, limit strenuous activity for several weeks, and use photoprotection on the scalp. The length of time requiring avoidance of activity further depends on the tensile strength of the sutures and the length of the incision [7].

Follicular Unit Extraction

Much advancement has been made in surgical hair restoration in the last 10 years, leading to development of the Follicular Unit Extraction technique. FUE has its roots in the FUT technique utilized in strip surgery, in which individual follicular units are removed from a large section of scalp tissue. FUE was first described in 2002 based on findings by Inabas, who noted that only the upper third of follicular units, where the arrector pili muscle attachment is located, needed be freed by a punch for effective, viable follicle extraction [3, 10, 11]. Previous techniques freed the full depth of the follicular unit. Instead of removing a large area of scalp skin for follicular unit harvest, in FUE, individual units are removed from the scalp and prepared for direct transplantation into recipient scalp. This process leaves little scar, and thus creates a natural, aesthetically pleasing result. Additionally, no cases have been reported of neurological sequelae and patients experience minimal downtime before returning to normal activity.

Follicular Unit Extraction Procedure

The process of FUE is as follows:

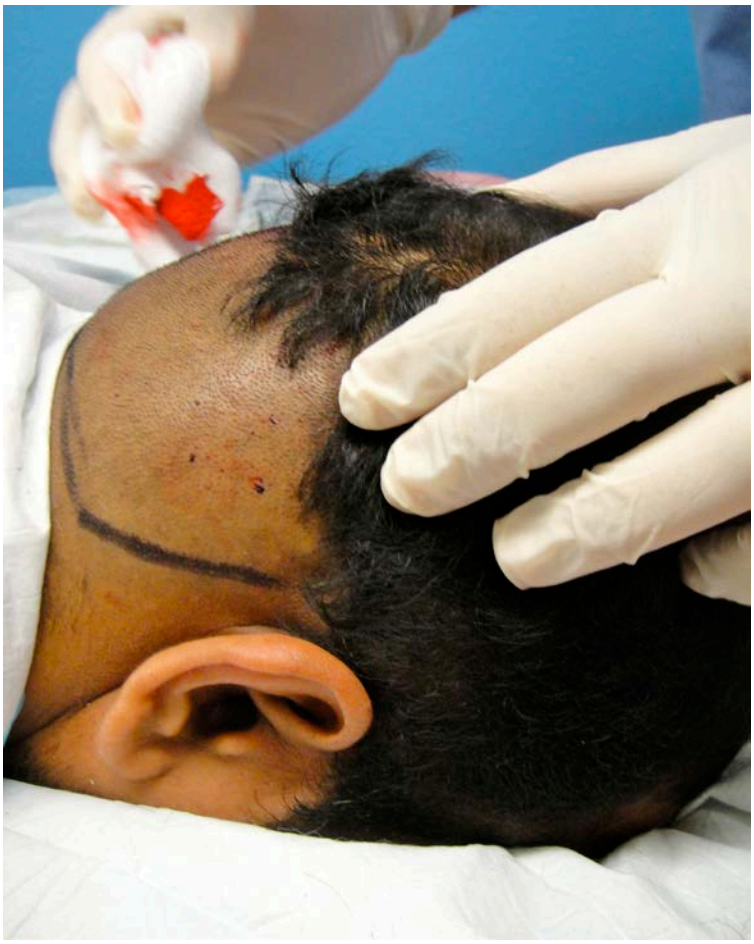

Figure 2. Donor area shave. Full occipital donor area shave, as opposed to microshave (not pictured).

The hair in the donor area is shaved to 1-2mm in length to allow adequate visualization of the direction of hair entry into the scalp and direction of the hair bulb. The donor area can be fully shaved, as in Figure 2, or “micro shaved” into 3-5mm strips for patients who wish for a less noticeable donor area. Grafts are largely taken from the occipital scalp because these hair follicles have fewer androgen receptors and thus experience less androgenic loss. Occipital hairs are also thought to remain in anagen for a lifetime [4, 5, 10]. Supraauricular and temporal hair is thinner and can be used to create a more natural look in areas with normally thinner hair growth, but these implants experience a greater degree of thinning over time [5, 10].

The patient is placed in a prone position for occipital harvest, or lateral decubitus position for temporal and parietal harvest. He or she may also sit erect. Though more comfortable for the patient, this method results in decreased control and increased graft transection rates because the physician has to operate away from himself while sitting behind and slightly below the patient [10].

The donor area is anesthetized with a lidocaine or bupivicaine solution diluted with saline, with or without epinephrine. The patient’s previous response to epinephrine must be elucidated in order to avoid ischemia or necrosis of the scalp. [6]

Follicular unit extraction is performed under 2.5X to 6X magnification. Good lighting is very important. Use of a headlamp may be helpful in addition to overhead lighting [4].

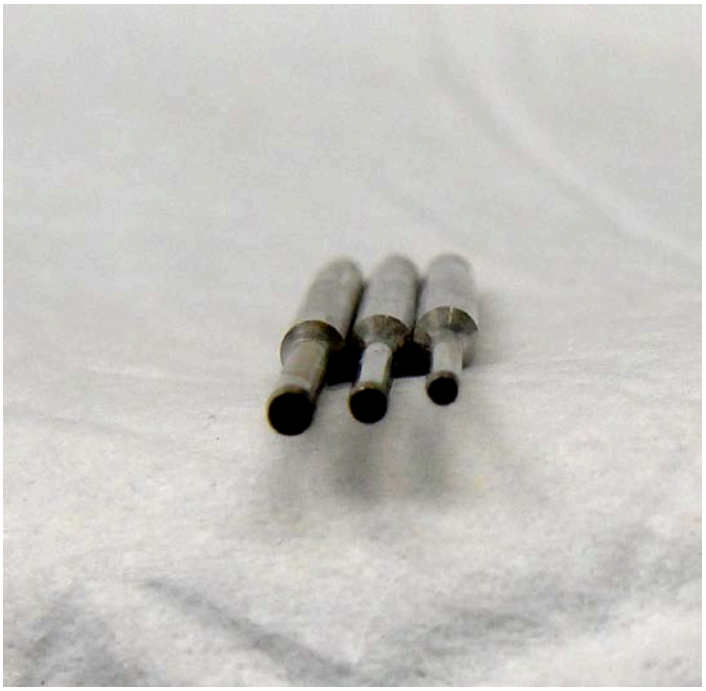

Figure 3. Punch devices. From left to right, 1.2mm, 1.0, and 0.8mm size punches are pictured.

Punch size is chosen based on follicular unit density. The more closely aligned, the smaller the punch required. The smallest punch possible, usually a 1mm or 0.75mm, is chosen in order to minimize trauma to the scalp. Figure 3 demonstrates the larger 1.2mm, 1.0mm, and preferred 0.8mm punch sizes. The punch device is aligned over the scalp in the direction of the hair bulb and advanced to the level of the lower dermis [4, 10, 11].

Figure 4. Follicular unit extraction: Donor site during harvest session

Figure 5. Grafts: Harvested grafts are stored in cooled saline while awaiting transplant.

After removal of the punch, the follicular unit is manually extracted with forceps or a needle. Forcep placement too near the epidermis can result in “capping,” in which the epidermis is removed leaving the rest of the follicular unit in the scalp. This not only leaves the graft behind, but also subjects it to increased dessication. To prevent capping, walk the forceps down the follicular unit to ensure adequate depth, or use a small needle for removal. Figure 4 demonstrates the donor area during the extraction phase of FUE. Extracted grafts are then stored in saline or lactated ringers until ready for transplant, as seen in Figure 5. After the surgeon has punched an area of donor scalp, an assistant may remove the follicles while the surgeon moves to another area to expedite the harvest process [10].

Figure 6a. Spear: Spear device used to create transplant sites in recipient tissue: **Figure 6b.** Spear. Closer view of spear blade.

The recipient site is prepared with knives, as seen in Figures 6a and 6a, needles, or punches and grafts are transplanted in the desired pattern by one of three methods: creation of single transplant site with immediate graft insertion, creation of all transplant sites followed by insertion of all grafts, or use of an implanter. Grafts are placed 35/square centimeter to 55/square centimeter dense, but may also be arranged up to 70/square centimeter if appropriate in patients with more dense hair growth. In some, as few as 20 grafts/square centimeter is adequate to mimic the patient’s natural hair pattern [5].

This process is repeated over multiple small 700 to 1500-graft sessions, but 6 to 12 hour, 2000 graft megasessions are growing in popularity [4, 5, 11].

FUE VARIATIONS

2-Step Versus 3-Step Methods

Variations and advances on this basic procedure include 2- versus 3-step punch technique and new automated punch systems. The traditional 2-step technique of FUE is as described above, with a sharp punch device inserted to the level of the lower dermis, followed by forceps removal of the graft. Saline tumescence is often used to create tension and promote accuracy with the sharp device. Constant re-evaluation of follicular unit growth direction during the punch as well as advancement of the punch to the lower dermis helps further reduce graft transection [4, 10].

The 3-step technique utilizes a sharp punch to score the area around the follicular unit to approximately 0.5mm deep, followed by a blunt punch pushed in a uni-directional twisting motion to the level of the lower dermis. As in the 2-step method, the graft is removed manually with forceps. The 3-step FUE technique has a lower transection rate because the blunt deep punch device tends to push hair bulbs into the punch rather than cutting through them during advancement [10]. A uni-directional twisting motion avoids follicle shearing and may further avoid transection [10]. 3-step FUE is more time consuming than the 2-step method, but the leading disadvantage is an increased risk of buried grafts. Buried grafts occur when the hair descends into the dermis with the blunt punch and becomes trapped in the hole. The buried graft may be removed by applying pressure around the incision to extrude the hair or by expanding the incision with a hemostat and manually removing the hair with forceps. Inflammatory cysts occur in 0.002% of buried grafts that are not removed and may require future excision. Serrated, 2-step punch devices and multi-blade harvest knives are also available for use in FUE, but are not recommended owing to very high transection rates [5, 10].

Automated Versus Powered FUE

Figure 7a. Neograft device. View of control panel.

Figure 7b. Neograft device: Neograft handheld harvesting device is controlled via footpedal (not shown).

In the past 15 years, a number of powered FUE devices have been developed. One such device, the Neograft (Figure 7a), consists of three parts: a hairtome, handheld pneumatic press device for harvesting grafts, a micrometer with a sharp punch blade for making recipient holes, and a handheld pneumatic graft implanter. The pneumatic punch device pictured in Figure 7b contains a rotating blade, controlled via footpedal, and is attached to a vacuum tube that deposits grafts into a collection chamber where they remain until implantation. The device rotates at 700 to 1500 rpm and is advanced until the surgeon notes a decrease in tension,

indicating that it has reached the subcutaneous tissue [11]. Another similar powered device is the SAFE system, which uses the 3-step blunt dissection method in contrast to the 2-step sharp method of Neograft [10].

Powered FUE systems show a significant decrease in both harvest time and transection rate. Onda et al. reported that the powered FUE device achieves the same number of grafts in six minutes that manual FUE achieves in 14.2 minutes on average. Additionally, they reported that the powered FUE has a 5.4% transection rate as compared to the 17.3% transection rate of manual methods [11]. Megasessions may also be performed with the automated device to fully capitalize on the aforementioned advantages. Although these automated devices pose some advantages to manual methods, they are significantly more expensive. Additionally, grafts stored in the vacuum-attached collection device are at increased risk of drying out [11, 12]. This problem is overcome by removing collection device filters, which prevent grafts from falling directly into a saline bath, and by cooling the collection reservoir [12].

Pre- and Post-Operative Considerations

Pre-operatively, patients should discontinue minoxidil to reduce the risk of bleeding and abstain from alcohol, smoking, and non-steroidal anti-inflammatory drugs (NSAIDs) for two to seven days. Additionally, pre-operative photographs are taken and maintained for post-operative comparison. Physicians may also prescribe a sedative, such as a benzodiazepine or doxepin, to calm patient nerves before the procedure [5].

Post-operative care includes placement of compression or a simple sterile bandage on the donor area. Antibiotics and ice compression on the recipient site may be used as needed for swelling expected about three days after the procedure. Healing occurs by secondary intention and re-epithelialization of the donor area is complete two to three days after FUE. New hair growth occurs in recipient tissue in about the second month post-operatively and can cause formation of sterile pustules [3, 4, 5, 11].

FUE complications are mild and include pain at the donor site, crusting at the recipient site, subdermal cysts, and drug gastritis secondary to NSAID analgesics. One report describes a case of necrosis at the donor site owing to exaggerated response to epinephrine in the lidocaine anesthetic [13, 14].

Challenges to FUE

Blind Extraction

Figure 8a. Viable graft. Note presence of the hairbulb at the lower left, indicating potential for regrowth.

Figure 8b. Transected graft. Note absence of the hairbulb at the proximal part of the graft (upper left).

A unique set of challenges exists with all FUE methods. First and foremost is that FUE is a blind procedure. In strip surgery, the full hair follicle is visualized during harvest; as a result the transection rate is low. In FUE, the hair bulb cannot be visualized during the punch and transection occurs at a higher rate owing to unanticipated follicular unit splay, curvature, and abrupt turns. Surgeons must carefully observe visual cues, such as follicular direction change or poor forcep placement, to assure the lowest transection rate possible [10]. However, unlike transection with strip harvest that leaves an incomplete extracted unit, FUE transection leaves the bulb in the scalp preserving its regenerative potential. Figures 8a and 8b demonstrate both a successfully extracted follicular unit with bulb intact (a) and a transected unit that is devoid of its bulb (b).

Limited Donor Supply

One of the leading concerns of FUE is adequate donor hair supply. If too few follicular units are available in the donor scalp the recipient area may not appear adequately filled after transplant. To remedy this, recent studies have investigated the ability of transected follicular units to regenerate proper hairs. Transected follicles may regenerate as long as the hair bulb, where stem cells are located, is intact. Additionally, those transected more distally (away from the scalp) may regrow more than those with more proximal (closer to the scalp) transection. Transplant of transected follicles is widely practiced in the hope that these hairs will indeed grow, but the resulting hairs tend to be thin and may not blend as desired [3, 15, 16].

Graft Viability

FUE creates much smaller grafts with less hydrating fat than those in strip surgery, putting them at increased risk of dessication. After harvest, grafts should be placed immediately in a holding solution to maintain moisture. In FUE systems with a filter, such as the Neograft, the filter in the collection device can be removed to expedite the transfer of grafts to saline and prevent unnecessary drying [17]. Additionally, cooling of the saline solution with external ice packs may also increase graft viability [10, 17].

Implantation

Careful transplant technique has a lasting impact on FUE results. If the distal end of the graft becomes folded in the transplant site, the hair may grow in a curly or kinked pattern, or not grow at all. The best way to avoid this is to hold the graft at the distal end and implant it in one motion, rather than feed it down in several steps. The harvest and implantation steps are more difficult in African American patients because they have more tortuous hair follicles [10]. For cases in which the curvature of the follicle limits the effectiveness of FUE, punch grafting may be indicated. Harvesting larger grafts via punch decreases the risk of transecting tortuous hair follicles [9, 12].

Donor Site

Although FUE leaves a minimal scar at the donor site, harvesting grafts in a regular or blocked manner may leave a recognizable pattern of hair removal or hyperpigmentation under short hairstyles. A zig-zag or random pattern hides extraction sites and patterned hyperpigmentation post-operatively [10].

Body Hair Transplantation

Another benefit of FUE is the ability to utilize body hair for transplantation to the scalp, beard, eyebrows, and even eyelashes. FUE can be utilized to harvest hair from the chest, back, beard, pubis, and labia; beard grafts yield the most natural results. In one study, 1,500 chest hairs were successfully transplanted to the fronto-temporal and crown areas of a patient with diffuse scalp scarring. In this procedure, 80-90% of the grafts survived and took on the recipient site characteristics [9]. Although these results are uncommon, body hair is an option for patients in whom all scalp donor areas are exhausted. Body hair is best for light coverage implantation because body follicular units contain fewer hairs, with even fewer in anagen phase. Body hair also grows in a different cycle than scalp hair (months versus years) and tends to follow the “donor dominance” theory, maintaining the characteristics of its original site and creating an unnatural result [4, 9, 10, 18].

Candidacy: The FOX System

The first pre-requisites for FUE candidacy are a skilled surgeon and realistic patient expectations. A number of subtypes of alopecia have been treated with FUE, including androgenic alopecia, scarring alopecia, and traumatic alopecia [4, 19]. In their first publication on FUE, Bernstein and Rassman described the first FUE candidacy system, the FOX test. The FOX test consists of extraction of a number of test grafts from the patient’s scalp. The transection rate is calculated from the yield and the degree of

dermal hair attachment is determined. Patients are graded on a scale of FOX1 to FOX5. FOX1 indicates that hairs pop out of the scalp easily with minimal transection, whereas FOX5 indicates very tight dermal attachment with a high transection rate. Patients with scores of FOX1 to FOX3 are considered good FUE candidates [3, 4, 10]. The FOX score also indicates the necessary donor area size. Of the available data, FUE is most successful in patients with androgenic alopecia, but is also beneficial for many other individuals [5].

FUE is preferred in patients who wear short hairstyles, or who have no occipital skin laxity owing to previous strip surgery. Patients with a tendency to scar also benefit, as do those who need a quick return to physical activity, such as athletes [4, 10]. Other good candidates include those with aversion to pain, small areas of hair loss, scarring and other skin diseases, and those with need for body hair transplant. FUE can also thin or correct previous hair restoration surgeries that created an unnatural aesthetic [10].

Patients who should consider other hair restoration options are those unwilling to shave hair short in the donor area or who cannot sit still for prolonged periods. Young patients in whom hair loss is still progressing should look to medical treatment first and often require continued pharmacologic therapy after FUE [4, 5, 10].

Follicular Unit Extraction Advantages and Disadvantages

Compared to other options, FUE is less invasive, more efficient as it combines the excision and harvest steps, and avoids creation of a linear scar like strip surgery. Additionally, FUE may achieve more desirable outcomes because the small transplants can be packed densely for a natural look. Eyebrow, beard, mustache, and eyelash hair loss has also been remedied via FUE [4, 5, 10, 11]. On the other hand, FUE requires more of the patient's time as compared to strip surgery in which the majority of the harvest is performed in the lab without the necessity of the patient's presence. FUE is also quite taxing on the surgeon, requiring not only more experience, but also increased operating time leading to neck, muscle, and eye fatigue [5, 4, 11].

Current price estimates for FUE range from $3.00 to $7.00 per follicular unit extracted. A typical hair reconstruction requires an average of 700 to 1,500 grafts, so the overall cost may be as much as or more than $10,000. As discussed previously, although strip surgery creates an undesirable scar on the scalp, it often has a much higher yield of viable grafts and does not require the patient to return to clinic for serial harvest sessions. Further, since FUE does require the patient to be in the operating chair for more time, local anesthesia must constantly be re-administered to ensure optimal patient comfort. Although current data is lacking regarding the current frequency that patients are undergoing strip surgery versus FUE, a recent survey from the International Society of Hair Restoration Surgery indicated that FUE comprises approximately 30% of hair restoration cases. This is increased from 1-5% in years past. (ISHRS, www.ishrs.org, 2013 Practice Census Results)

Future of FUE

The future of FUE rests in the development of robotic systems, as well as the ability to clone patient hairs and bypass the harvest step altogether. One such robotic device, the ARTAS system, incorporates a digital, visually guided microscope and follicular unit identification system with a two-step punch harvest device with a precision of 0.014 mm [20]. Robotic FUE offers increased accuracy, precision, speed, consistency, and predictability. Surgeons also no longer experience the fatigue or need the experience required for manual or automated methods. FUE via the ARTAS system has limited availability worldwide and is quite expensive. Other limitations include the requirement of straight, dark hair, and light colored skin because the targeting system is based on color matching. Additionally, no data is currently available on its use or transection rates [4, 20].

Although hair induction pathways are poorly understood, the ability to manipulate these pathways to induce hair growth or clone patient hairs offers a promise for the future of FUE. Hair growth is thought to involve the wnt and BMP pathways. Manipulation of these cell cycle signals may allow physicians to increase FUE donor yield. Such investigations stem from findings that hair grafts transected at certain levels can generate new hair if transplanted [14]. Other research shows that if just the dermal sheath of donor hairs is abstracted and implanted into recipient tissue, it regenerates a dermal papillae and leads to hair growth. Transplanted dermal papillae combined with epidermal cells can also promote new hair growth [14, 21, 22, 23]. Manipulation of dermal sheath cells and mesenchymal stem cells located in the bulge and bulb areas has achieved some success in cloning hairs. Such research is difficult because dermal papillae cells tend to lose their induction ability during culture and cloning [21, 22, 23]. Before these advances are implemented as standard of care further research needs be completed regarding current FUE systems. Of current interest is the practice of FUE in young people in whom hair loss may still be occurring. In addition, the maximum density and number of grafts that can and should be used in a single session to yield the best results has not been fully determined [24].

Conclusion

Follicular Unit Extraction is the preferred option in many patients seeking surgical hair restoration. FUE is usually practiced in patients with androgenic alopecia, but has successfully restored a natural hair appearance in patients with a number of other alopecia types. Currently available methods include manual and automated systems, offering the benefit of increased efficiency without the noticeable occipital line scar implicated in traditional surgical techniques. FUE advancements include hands-free robotic systems and substitution of patient grafts with cloned follicular units to optimize donor supply.

References

1. Ogunmakin KO, Rashid RM. Alopecia: the case for medical necessity. Skinmed. 2011 Mar-Apr;9(2):79-94 [PMID: 21548511]
2. McElwee K, Shapiro J. Promising Therapies for Treating and/or Preventing Androgenic Alopecia. SkinTherapyLetter. 2012 June;17(6):1-4 [PMID: 22735503]
3. Rassman W, Bernstein R, McClellan R, Jones R, Worton E, Uyttendaele H. Follicular Unit Extraction: Minimally Invasive Surgery for Hair Transplantation. Dermatol Surg. 2002;28:720-728 [PMID: 12174065]
4. Dua A, Dua K. Follicular unit extraction hair transplant. J Cutan Aesthet Surg. 2010;3(2):76-81. [PMID: 21031064]
5. Patwardhan N, Mysore V. Hair transplantation: Standard guidelines of care. Indian J Dermatol, Venereol, Lepr. 2008;74(7):46-53. [PMID: 18688103]
6. Pathomvanich D. Donor Harvesting: A New Approach to Minimize Transection of Hair Follicles. Dermatol Surg 2000;26:345-348. [PMID: 10759823]
7. Bernstein RM, Rassman WR. Follicular unit transplantation: 2005. Dermatol Clin. 2005 Jul;23(3):393-414. [PMID: 16039422]
8. Wesley CK, Unger RH, Rosenberg M, Unger MA, Unger WP. Factors influencing postoperative hyperesthesia in hair restoration surgery. Am J Cosmet Dermatol. 2011 Dec;10(4):301-6. [PMID: 22151939]
9. Woods R, Campbell A. Chest hair micrografts display extended growth in scalp tissue: a case report. Br Assoc Plast Surg. 2004;57:789-791. [PMID: 15544779]
10. Harris J. Follicular Unit Extraction. Facial Plastic Surgery. 2008;24(4):404-413. [PMID: 19034817]
11. Onda M, Igawa H, Inoue K, Tanino R. Novel Technique of Follicular Unit Extraction Hair Transplantation with a Powered Punching Device. Dermatol Surg. 2008;34:1683-1688 [PMID: 19018825]
12. Callender VD, McMichael AJ, Cohen GF. Medical and surgical therapies for alopecias in black women. 2004:17:164-176. [PMID: 15113284]
13. Karacal N, Uraloglu M, Dindar T, LIvaoglu M. Necrosis of the donor site after hair restoration with follicular unit extraction (FUE): A case report. J Plast, Reconstr, Aesthet Surg. 2012;65:e87-e89. [PMID: 21768010]
14. 13. Poswal A, Bhutia S, Mehta R. WHEN FUE GOES WRONG!. Indian J Dermatol. 2011 Sep-Oct;56(5):517-519. [PMID: 22121268]
15. Horne K, Jahoda C. Restoration of hair growth by surgical implantation of follicular dermal sheath. Development. 1992; 116:563-571. [PMID: 1289054]
16. Gho C, Neumann HA. Donor hair follicle preservation by partial follicular unit extraction. A method to optimize hair transplantation. J Dermatol Treat. 2010 Nov;21(6):337-34. [PMID: 20388024]
17. Rashid RM, Bicknell LM. Follicular unit extraction hair transplant automation: options in overcoming challenges of the latest technology in hair restoration with the goal of avoiding the line scar. Dermatol Online J. 2012 Sep 15;18(9):12. [PMID: 23031379]
18.
19. Umar S. Hair transplantation in patients with inadequate head donor supply using nonhead hair: report of 3 cases. Ann Plast Surg. 2011 Oct;67(4):332-5. [PMID: 21540728]
20. Wang JP, Fan JC, Chai JK. The treatment of cicatricial alopecia after burn with the technique of synchronously perforating and transplanting follicular-units. Qhongua Shao Shang Za Zhi. 2009 Dec;25(6):411-4. [PMID: 20193160]
21. Lin X, Makazawa T, Yasuda R, Kobayashi E, Sakuma I, Liao H. Robotic hair harvesting system: a new proposal. Med Image Comput Assist Interv. 2011; 14(Pt1):113-20. [PMID: 22003607]
22. Er E, Kulach M, Hamiloglu E. In Vivo Follicular Unit Multiplication: Is It Possible to Harvest an Unlimited Donor Supply? Dermatol Surg. 2006;32:1322-1326. [PMID: 17083583]
23. Bajpai V, Mistriotis P, Andreadis S. Clonal multipotency and effect of ong-term in vitro expansion on differentiation potential of human hair follicle derived mesenchymal stem cells. Stem Cell Research. 2012;8:74-84. [PMID: 22099022]
24. Osada A, Kobayashi K, Masui S, Hamazaki TS, Yasuda K, Okochi H. Cloned cells from the murine dermal papilla have hair-inducing ability. J Dermatol Science. 2009;54:129-131. [PMID: 19150224]
25. Sellheyer K, Krahl D. Skin mesenchymal stem cells: Prospects for clinical dermatology. J Am Acad Dermatol. 2010 Nov;63(5): 859-865. [PMID: 20471137]

ABBREVIATION LEGEND

- DHEA Dehydroepiandosterone
- DHT 5-a-dhihydrotestosterone
- FOX Original name for follicular unit extraction procedure coined by Drs. Bernstein and Rassman in their original publication
- FUE Follicular Unit Extraction
- FUT Follicular Unit hair Transplantation
- NSAIDS Non-Steroidal Anti-Inflammatory Drugs
- TGFB1 Transforming Growth Factor Beta 1
- TGFB2 Transforming Growth Factor Beta 2