Follicular Unit Extraction

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KEYWORDS
- FUE • Follicular unit extraction • Donor harvesting • Donor area management
- FUE instrumentation • Body hair grafting • Plug/minigrafts repair

KEY POINTS
- When performing FUE, always wear high-quality magnification of at least ×4.5 to ×6.5.
- If one commits to providing this procedure for patients, then one has to commit to the practice and refinement of the technique before making it a standard procedure in the practice.
- Be sure to explain the procedure to patients, the advantages and disadvantages, and avoid the hype that surrounds this procedure.

INTRODUCTION

Follicular unit extraction (FUE) is a method of graft harvest whereby punches of various types are used to remove follicular units from the donor region one at a time. The principal advantages of this technique to patients are chiefly the lack of a linear scar and more rapid healing of the donor region. In general, this technique will allow patients to cut their hair to approximately one-fourth inch or less. For physicians, FUE offers a technique for repairing plugy-appearing or inappropriately placed hairlines and also the ability to harvest additional grafts in patients who have little or no scalp laxity. Over the past 5 years FUE has gained a degree of popular acceptance by patients such that it is the fastest growing procedure in hair restoration.

There are 2 basic punch types used to perform FUE, sharp and dull tips, and within each category there are manual and powered versions. The sharp dissection techniques typically involve limited depth punch insertion to decrease the risk of follicle transection. The blunt punch dissection technique allows for a deeper level of dissection, thereby decreasing the force required for graft removal.

This article provides the reader an overview of the uses of the FUE procedure with attention paid to donor area management, procedure considerations, and instrumentation.

UTILITY OF FUE

Hair Restoration

There are several indications for using FUE in restorative and repair procedures (Box 1). In general, any patient who is a candidate for hair restoration by the strip method is a candidate for FUE, as the cosmetic results in the recipient area are the same as in strip surgery (Fig. 1). In addition, there are likely candidates for FUE restoration who are not candidates for strip harvest by virtue of low donor hair density and how short they would like to wear their hair. A patient with very fine donor hair and low donor density may be a poor candidate for a strip harvest, yet may achieve a good result with FUE (Fig. 2).

The obvious candidates, and most patients seeking FUE, are those who desire the option of wearing their hair short. Minimal postoperative pain and discomfort is certainly a desired outcome, but it is not usually the primary motivating factor for having FUE. Fig. 3 is an example
of a patient postoperative FUE opting for a short hair hairstyle and showing minimal visibility of his donor sites. Patients should be aware that although there is no linear scarring, there will be 2 donor area factors that will not allow most to shave their head after surgery. The first may be visible scarring due to hypopigmentation, and the second is the appearance of hypopigmentation, which in reality is the lack of hair in an extraction site that is perceived as hypopigmentation.

Although the amount of postoperative pain after strip surgery is usually not intolerable, many patients who have had a strip procedure and a subsequent FUE note that there is a significant difference in the experience with patients who had FUE often requiring no narcotics and only 2 to 3 days of a nonsteroidal analgesic. The vast majority of patients having FUE also do not experience hypesthesia or sensations of tightness in the donor area.

There are 2 situations in which a combination of a strip harvest and FUE can be used to “expand” donor capacity.

1. Maximize number of grafts obtained from a single surgical session
2. Severe limits to patient’s scalp laxity with normal-density donor area

Combination strip harvest and FUE can be considered in a patient who would like to maximize the number of grafts obtained from a single surgical session (a single day or 2 subsequent days). The typical scenario is that first a strip would be obtained and the grafts planted, and this would be followed by an FUE procedure that may increase a single surgery yield by up to 50%. There have been reports of skin necrosis when the FUE is performed inferior to the strip excision site, so this should be avoided.

Combination strip harvest and FUE can be considered in the case of a patient who has received multiple strip procedures and demonstrates severe limits to his or her scalp laxity, but whose general donor area appears to have “normal” density. In this case, FUE may be used to harvest additional grafts. There are cases in which the use of both procedures has allowed the harvest of more than 12,000 grafts without any adverse consequences to the donor region. Obviously this can be a great benefit in Norwood class 6–7 patients and can change the treatment planning significantly.

**Body Hair Harvest**

FUE has allowed the harvest of body hair without the creation of linear scars on the chest, abdomen, pubis, or submandibular areas. It has also made it possible to harvest areas such as the arms, legs, and back where strip surgeries were never really an option. Although the harvest of body hairs is technically feasible and there is anecdotal information to support its use, there are no studies that address body hair graft survival rates. In my experience, it seems that the use of beard hair may have a higher survival rate than other body donor sites, which may have something to do with either the size of the follicles (generally larger than other body sites) or the length of the anagen cycle. My preference is to harvest hairs in the anagen phase. Anagen hairs may be discerned by

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**Box 1**

Indications for FUE

- Preference for short hair style
- Low-density donor hair
- Tight donor region
- Maximize donor capacity (FUE/strip combo procedures)
- Debulking plugs and minigrafts
- Removal of undesirable hairline grafts
- Body hair harvests

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Fig. 1. Showing 2200 FUE grafts. (A) Preoperative, (B) Postoperative.
either the thickness of the hair shaft or presence of hair pigmentation (in cases of nongray hair), as the telogen hairs will be lighter in color and finer in caliber. One may also shave the donor area approximately 4 to 7 days before the surgery to facilitate identification of the actively growing anagen hair, as the telogen hairs will not have elongated since shaving.

Although many body donor areas, such as the arms, legs, beard, and chest, are potentially visible at times, the scarring from FUE has not been problematic in most patients. The scarring on the chest can be visible as small hypopigmented dotlike scars with the chest shaved (Fig. 4). The situation is similar for beard extractions, although the natural irregularity of pigmentation and the natural visibility of the hair ostia make the beard donor sites virtually invisible in most patients. It is prudent to extract only from the submandibular region; however, in some patients who desire more beard grafts, a test session may be performed to see if the scarring above the jaw line or in buccal regions will be visible or problematic for the patient.

The anesthetic administration for beard extractions can usually be accomplished with a wide field block with spot infiltrations for breakthrough sensation. The chest will require a tumescent anesthetic technique similar to that used for liposuction.

In counseling patients, I usually suggest that all scalp donor hair available be harvested before considering body hair FUE. The primary reasons for this are the uncertain survival rate and that the average approximate body region density of 1.2 hairs per graft makes it more difficult to create a dense result. The other possible reason for using scalp hair preferentially is that the quality and characteristics of the hair more closely match the hair in the recipient region as opposed the case of beard hair on the scalp where a texture mismatch is probable. Fig. 5 shows a body hair (beard donor) transplant result.

Fig. 2. Showing 1800 FUE grafts. (A) Preoperative, (B) Postoperative.

Fig. 3. The donor area of a patient who elects to wear his hair short after 2800 extractions. He would be a questionable candidate for strip surgery because of diffuse thinning of the donor area as well as his desire to wear his hair short.

Fig. 4. The small white dotlike scars from FUE performed on the chest.
Hair Restoration Repairs

FUE can be very valuable in the cases of patients requiring repairs such as inappropriately placed or linear hairlines, multihair grafts in the hairline, or visibly pluggy grafts. In the situation of a hairline placed inappropriately low, the patient’s options are to undergo laser hair removal and “waste” the donor hair, or to have the grafts removed and replaced in a more appropriate position. Another indication is the patient who initially had grafts placed in a proper position, but later has additional hair loss and decides to remove the previous grafts and restore a natural pattern rather than have more procedures. The extracted grafts can then be replaced into donor scar if need be.

In the case of a pluggy-appearing hairline due to either minigrafts or multihair follicular units, the offending hairs or grafts may be thinned by FUE. There are 2 advantages of this technique over simply placing follicular units in front of the offending grafts. The first is that if the hairline is already at the limits of a conservative location, there is no need to lower the hairline any farther. The second is that with the removal of offending units, a single-pass correction with follicular units is often possible.

The technique used in my practice is to first identify the cosmetic issue and then formulate a surgical plan. The plan may be a combination of graft removal and the addition of follicular units. The offending hair or grafts are first identified and trimmed to approximately 1 mm. Now the surgeon may have an approximate “real-time” view of what the FUE can accomplish. This is fine-tuned to the surgeon’s satisfaction to either reduce plugginess or to decrease the hairline linearity, and then the hairs or follicular units that were trimmed are removed by FUE. Fig. 6 shows a reduction in plugginess and linearity in 1 session and Fig. 7 shows

**Fig. 5.** (A) Preoperative and (B) postoperative appearance after approximately 2000 beard grafts were used over the top of the scalp to increase the density.

**Fig. 6.** FUE and additional follicular unit grafting were used to reduce the pluggy appearance and linearity. (A) Preoperative and (B) postoperative appearance.
almost complete FUE removal of unattractive hairline grafts to restore the patient as close as possible to his pretransplant state.

**DONOR AREA CONSIDERATIONS**

The “safe” donor area for FUE is, in general, the same region used for strip harvest. There are, however, some areas that require special attention or may be used under special circumstances. The lower neck regions and the supra-auricular regions can be used to obtain grafts that contain hair of finer caliber for use in the frontal hairline. A risk of graft loss exists for those hairs obtained from the neck in patients at risk for retrograde alopecia.

In some patients, the hair at the superior aspect of the fringe can appear very thick or “puffy” when compared with the thin or bald area just superior to it or to the thinning hair in the supra-auricular and low neck regions. A unique situation exists here because thinning of the extraction zone following an FUE procedure can further enhance the appearance of a very thick upper fringe region. A possible solution to the situation is to extract follicular units high into the thick fringe region to intentionally thin this disproportionately high-density hair. This method helps to provide a more “blended” appearance throughout the entire donor area rather than creating a more visually distinct transition between a nonharvested upper fringe and the more commonly used inferior extraction zone. There are 2 strategies or techniques that may be followed and both have advantages and disadvantages. The first option is to extract units from the upper fringe, selecting the units that appear to be “permanent” (no miniaturization). This increases the likelihood that they will remain stable in the transplanted area. This strategy may be less predictable in younger patients in whom the miniaturization process may not have yet started. The potential downside here is that the extraction of permanent hair for stability in the transplanted area risks exposure of the extraction sites at some future time should miniaturization progress over time in the superior fringe. It may be argued that the sites will be virtually undetectable; however, they may be more visible and problematic in some patients. The second option is to remove follicular units from the high fringe that appear to be miniaturizing in the hopes that medical therapy will stabilize them in the transplanted area and the nonminiaturized hairs that are left in the fringe will camouflage the donor sites. With either strategy, the situation may be mitigated by the use of stabilizing medical therapies.

In general, the total number of grafts available using FUE is probably similar to the number available from strip harvesting, but the actual number is dependent on the density of the hair in the donor region. The endpoint for FUE is thinning of the donor hair to a level that is visibly discernible. In a single harvest session it is important to avoid “overharvesting” in a particular area, as the localized trauma may increase the risk of donor area postoperative shock loss. Harvesting approximately 20% to 30% of the available units in a particular area has never resulted in a case of shock loss in my practice and yet allows for the extraction of 2400 to 4000 grafts in a single session if need be.

Care should be taken to avoid overharvesting in a small donor area, as this area may appear significantly less dense than the surrounding donor region, especially if the hair is worn short.

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**Fig. 7.** FUE used to remove grafts to restore a pretransplant appearance. (A) Preoperative and (B) postoperative appearance.
increase the probability of creating a low-density area when the hair is worn short. The ideal surgical plan would distribute the FUE sites over the entire donor area at a uniform density relative to the native follicular unit density. Subsequent harvest sessions should be performed in regions not previously harvested to spread the effect of multiple procedures diffusely throughout the entire region.

PERFORMING THE FUE PROCEDURE

Donor Area Preparation

There are several ways to shave the donor area in preparation for the FUE procedure. Normally in patients who elect to undergo FUE because of their desire to eventually wear their hair short (less than one-half inch), the optimal strategy is to shave the entire donor area in preparation for the procedure.

This allows the surgeon to extract diffusely over the entire donor region to avoid focal thinning.

An option for patients who do not want to shave their entire donor area and are unlikely to wear their hair short after the procedure is to perform a “microstrip shave” where 2-mm to 4-mm wide strips are shaved along the donor site. The shaved microstrips are separated by 2-mm to 4-mm strips of unshaven hair so as to leave the donor harvest sites hidden. The limit of this type of preparation is approximately 1200 to 1500 grafts in a single surgical session, as only half of the potential donor area is exposed. Subsequent surgeries should focus the harvest between the previous microstrip harvest regions. Patients must be counseled that should they cut their hair short, distinct “striplike” regions of low density will be visible.

The final shave preparation, as advocated by Cole in personal communications, is to cut only the hair of the follicular units to be extracted over the entire donor area. This will provide a diffuse extraction pattern and diffuse scars, but the technique will require a longer procedure time.

Anesthetic Considerations

The usual method of administration is a ring block in the periphery of the donor region followed by a “bead” of anesthetic along the occipital protuberance to block the greater occipital nerves. The typical anesthetic is a combination of lidocaine followed by a longer-acting agent, such as bupivacaine, or alternatively a single agent, such as articaine. The recipient area is anesthetized in the physician’s preferred fashion.

Patient and Surgeon Position

There are 2 basic patient-positioning strategies for FUE.

1. The surgeon is in a position that is primarily opposite the direction of hair growth. For the occipital region, the patient is prone and the surgeon is positioned at the head. This allows the surgeon to direct his or her arm motion toward the surgeon’s body rather than away. This allows for less fatigue and a higher degree of control. The same strategy is used for the temporal regions, where the patient is positioned in the lateral decubitus position.

2. The patient is sitting upright and the surgeon positioned to align with the emerging hairs. This provides the surgeon with the ability to obtain a “line-of-site” directionality to the FUE device. This may cause fatigue for some surgeons and will preclude the patient from being sedated to any great degree. The advantage to this technique is that the surgeon may perform dissections or recipient site openings while grafts are simultaneously being harvested or planted. This method will increase the efficiency of the case.

FUE Methodology

The chief challenge in performing FUE is the uncertainty of the subcutaneous course and configuration of the follicles that may not be represented in the visible hair shafts above the skin surface. These differences may be in the angulation, curvature, or splay of the follicles.

To deal with this discrepancy, 2 strategies have emerged that are related to the 2 major classes of dissection tips available.

1. Sharp punch dissection
2. “Dull” dissecting punches

Sharp punch dissection was first described in the literature by Rassman and colleagues, who noted that follicle transection rates increased as dissection depths increased. To decrease follicle transection, they advocated a limited-depth dissection. However, they observed that that this resulted in some degree of tethering between the follicle and the underlying tissue. This tethering had to be overcome by grasping and pulling forces that varied by individual. Cole developed a manual punch device (US Patent number 2005/0203545 A1, issued September 15, 2005) that featured an adjustable mechanical depth limiter to assist the user in maintaining a more consistent depth of dissection. Various methods for removing the grafts dissected by the sharp punch technique
have been developed to address the problem of subcutaneous follicular tethering associated with limited depth dissection. These methods including dissecting the tethering tissue around the unit with needles in a “postage stamp” perforation pattern or grasping the distal follicles with a hemostat like instrument (Fig. 8) or forceps.

The use of “dull” dissecting punches was developed for dealing with the uncertain subcutaneous course and configuration of the follicles. The proposed mechanism is that the dull tip is less likely to cut the follicles and the tip acts as a “guide” directing the follicles into the lumen of the punch. In addition to providing a low transection rate, the methodology allows a deeper dissection that separates the follicles from the subcutaneous tissue. This method promotes less manipulation and force on the grafts during the extraction.

Both dissection instrumentation modalities, sharp and dull, are available in manual and motorized (powered) systems. The main benefits of the motorized systems are the speed at which dissections can be performed and a decrease in operator fatigue. Surgeon preference, however, will dictate the type of system to be used.

**Sharp Punch Technique**

As mentioned, the key to the use of a sharp punch (powered or manual system) is that the punch insertion is subjected to depth limitation. This is most often accomplished with a depth limiter, such as a bead or silicone tube on the punch, providing a physical barrier to skin entry. The limiter can be set at various depths, but typically it must be at least as deep as the attachment of the arrector pili muscle, usually 2.0 to 2.5 mm, to allow graft removal. Some practitioners advocate a deeper dissection at least to a level where the follicles remain in a bundled configuration.

Transection rates increase dramatically if one goes beyond the region where follicle splay begins.

Stabilization of the skin is very important. The sharp punch has to be accurately “aimed” along the course of the follicles and the follicles must remain immobilized to minimize follicular damage. The skin is usually stabilized by the use of tumescent fluid in the target areas. The problem encountered by some practitioners is that excessive tumescent fluid injections into a region can cause the harvest area to become “mushy” and make subsequent dissection attempts in the region difficult.

Once the skin has been injected with a tumescent solution, the surgeon, wearing adequate magnification loupes, assumes his or her preferred position to perform the dissections. The punch is aimed such that the emerging hair is centered and the angle of entry is matched to the emergence angle of the hair. The punch is inserted, usually with a twisting motion in the case of a manual punch and directly into the skin using a powered punch. Another extraction variation is first inserting the punch tip at an angle close to 90° to the skin and entering just enough to score the skin. Following the scoring incision, the punch angle is adjusted to the hair angle. This method creates a wound that more closely approximates a circle than an oval. The punch is then inserted to the depth limiter and the grafts are removed and inspected. The depth controller can be adjusted depending on the length of the follicles, the position of the sebaceous gland, the ease of extraction, or the degree and position of splay in the follicles. These variables can change in different scalp regions so a continuous evaluation is conducted so that adjustments can be made.

Manual sharp dermal punches are available from a variety of suppliers. The most common sizes for FUE are 0.8 mm to 1.0 mm. The powered versions are also available from several hair restoration suppliers. There are specialized versions, such as the Neograft (Neograft Solutions, Dallas, TX) device, which has a suction apparatus that assists in harvesting and planting grafts, and a device called the PCID (Cole Instruments, Alpharetta, GA) (Fig. 9), which is a programmable device that oscillates or rotates the punch depending on the surgeon’s requirements.

**Dull Punch Technique**

The general process for using a dull punch technique involves a few distinct steps that differ from the sharp punch technique. There is also...
a technique difference between the manual and the powered dull punch versions. The manual dull punch technique, called the SAFE System (HSC Development, Greenwood Village, CO), is essentially a 2-step dissection process that was first described in 2003 at the International Society of Hair Restoration Surgery meeting in Vancouver and published in 2006. The first step is “scoring” the epidermis and dermis to a limited depth of approximately 0.3 to 0.5 mm to allow entry of the blunt dissection punch. The blunt punch is then oriented to the approximate angle of the emerging hairs and inserted into the scoring incision. It is then rotated or oscillated by hand to a depth of approximately 4.2 mm, the depth of a “hard stop” on the punch, after which the follicular unit is removed. The chief criticism of this technique is a graft burial risk of approximately 7%. Although most buried grafts are recoverable, there remains an unrecoverable rate of 1.4%. In 9 years of performing FUE, there have been 3 instances of hair-bearing inflammatory cysts that required an excision procedure.

The powered version of the dull punch device, the Powered SAFE System (Fig. 10), is a single-step dissection process that requires a defined technique to ensure success. After the donor area hair is shaved to the desired length, a 3-cm² to 4-cm² area is infiltrated with 1 to 2 mL of a dilute epinephrine solution in the subcutaneous fat for the purpose of hemostasis. Traction is placed opposite the direction of hair growth and the rotating dull punch is then positioned over the emerging hair at the approximate angle and direction of hair growth. Slight pressure perpendicular to the skin surface is placed on the punch handpiece to allow the punch edge closest to the skin to “engage” or enter the skin. Using continued pressure in the same perpendicular direction, the punch will dissect the unit free. The punch can be inserted to the shoulder (depth approximately 4 mm) or the punch can be inserted to a submaximal depth if it is determined that a limited depth dissection will work. When the punch is inserted, there should be an audible and visual slowing of the punch rotation, as this will minimize transection rates. The absence of slowing following insertion should indicate to the operator that a decrease in the rotation speed is required. The amount of slowing may be decreased as the surgeon gains experience.

**Robotic FUE**

This technique is accomplished with the ARTAS System (Restoration Robotics, San Jose, CA), a robotic device (Fig. 11) used under physician control. The technique involves the placement of a skin tension device which stabilizes the skin. This skin tension device houses fiducial markings on the periphery to define the active donor region and provide data for the assessment of the angles and directions of the hairs emerging from the scalp. The physician directs the robot to either dissect random grafts a given distance apart, to select follicular units with a given number of hairs, or to dissect those grafts that the physician designates.

The robot uses a 2-step dissection process similar to the 2-step manual dull punch system described previously. Once the robot has selected a target graft, an inner sharp punch will score the skin to a depth of approximately 1 to 2 mm. This is followed by a 1.2-mm rotating dull punch that is inserted to a depth of...
approximately 4 mm to dissect the follicular unit free from the skin. Adjustments to the insertion depths of the 2 punches, the speed of rotation, and the angle of insertion are essentially automated. The operator, however, can make fine adjustments as needed based on observations of the dissection process. Once the system has completed the dissection with the skin tension device, it is moved to the next donor area and the process is repeated until the desired number of dissections has been complete. The follicular units are then removed from the donor area.

Graft Handling and Planting Considerations

Once the grafts have been dissected and removed from the donor area with care to avoid crush injury, they are immediately placed into the holding solution of choice. Because most of the grafts are devoid of investing fat, an effort must be made to ensure that their time outside of the holding solution during the counting or sorting process is minimized. Additionally, the planting process must also be conducted with care to prevent graft desiccation and overmanipulation. The planters should limit graft exposure during their insertion to less than 2 minutes.

A team without extensive graft-placing experience places a high risk of overmanipulation and graft damage, which could easily result in suboptimal clinical results. In cases of an inexperienced team, consideration should be given to using one of the implanter devices available on the market.

Postoperative Considerations

The recipient areas can be treated the same way that one would treat the area after a strip harvest. Although the nature of an FUE procedure usually results in significantly less pain and discomfort than a strip harvest, the patient should have a narcotic and possibly a sleeping aid prescribed. The donor area can be dressed the first evening with an occlusive dressing and antibiotic ointment; however, this is optional. The continued application of an antibiotic ointment can be used if the patient would like to

Pearls: Performing FUE

After having observed many doctors attempting to perform FUE, there are several suggestions that will make the adoption of FUE easier.

- **One of the most important factors is that the doctor learning the technique should invest in high-quality surgical loupes with magnification in the range of ×4.5 to ×6.5.** I have observed physicians, claiming that ×2.5 or ×3.0 magnification is perfectly adequate, attempt to center a punch over the emerging hair and miss the target more than 50% of the time. If the punch cannot be centered, there is little likelihood that a successful graft extraction will be possible.

- **Performing FUE requires excellent eye-hand coordination, patience, stamina, and commitment.** The physician interested in performing this procedure needs to critically assess his or her qualifications in these 4 areas. If there is an issue, then a realistic decision needs to be made whether or not to pursue FUE. If the surgeon is lacking in the first 3 areas but has a high level of commitment, then consideration of the ARTAS System may be reasonable.

- **A surgeon interested in FUE must practice with his or her instrument of choice.** A suggestion for this is to perform FUE on every patient undergoing a strip procedure and attempt to remove 25 to 50 grafts. Once this can be accomplished in 3 to 5 minutes with a transection rate of 10% or less, the surgeon is ready for FUE cases in the range of 250 to 500 grafts. Of course if the surgeon would prefer not to become proficient at a manual technique, automated or not, there is the option of obtaining an ARTAS System. With this system, the surgeon may, after a day or two of training, extract at a reasonable rate with low transections.
have the scabs separate as rapidly as possible. Strenuous activity may be started after 3 to 4 days, as there is minimal or no risk of hematoma formation.

SUMMARY

FUE can be a valuable addition to a surgeon’s repertoire, as the demand for this procedure is growing. Granted, there are details that have yet to be worked out, such as optimal extraction densities, scarring issues, dealing with donor area depletion, and strategies for combining strip and FUE for maximal graft availability. However, the technique has provided excellent results for thousands of patients.

What is certain is that some patients want a procedure that will not only provide excellent results but also minimal scarring, rapid recovery, and the ability to wear their hair short if they desire. Surgeons willing to take the time and effort to learn the procedure will be able to offer this segment of patients a procedure that will meet their needs. FUE has proven valuable in patients that require repairs and for former strip patients that require additional surgery. Those physicians not offering FUE to patients will surely be perceived as lagging behind the technology curve.

REFERENCES