Follicular Unit Extraction

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ABSTRACT

Follicular unit extraction (FUE) is a method of producing follicular unit hair grafts that involves removing the grafts individually from the scalp. The advantages of this technique over the conventional strip harvest are that it does not leave a linear scar, and the procedure produces little or no postoperative pain and discomfort. There are some disadvantages such as increased surgical times, graft fragility, and higher cost to the patient. This article describes the instrumentation and surgical methodology of FUE. It also presents some surgical difficulties and how to minimize their impact. Indications and patient candidacy are also discussed.

KEYWORDS: Hair transplantation, follicular unit extraction, FUE, graft production

Follicular unit extraction (FUE) is a technique of graft production that has experienced recent popularity because of the absence of a linear donor scar and significantly less donor-site pain and discomfort. The advantage of removing individual follicular units directly from the donor area without the need for microscopic dissection appeals to the hair restoration surgeon as the need for highly trained staff is decreased. FUE is the "minimally invasive" option for the field of hair restoration.

FUE can also be used to produce grafts from various sites on the body including the chest, back, extremities, neck, and pubic areas. The role of these grafts and their use will be discussed later.

FUE has as its roots the work of Masumi Inaba[1] as well as Raymond Woods and Angela Campbell in Australia (no published references). The first attempt to bring FUE to the attention of the transplant community in a formal way was by Rassman and Bernstein[2] in 2002 with the first English-language paper on the subject describing their methodology of FUE called the FOX Procedure (derived from FOllicular unit eXtraction).

The goal of this article is to present the current methodologies, challenges, and complications of this technique, a discussion of body hair transfer, and the indications for FUE.

RELEVANT ANATOMY AND ETIOLOGY OF FUE DIFFICULTIES

The major challenge when performing FUE is to remove the grafts from the skin without harming the follicles. The primary etiology for follicle damage during the dissection process of FUE is the variability of the subcutaneous arrangement of follicles within the follicular unit and the orientation of follicles that does not necessarily match the apparent direction of the hair shaft above the skin surface. Some of the follicle variability includes curvature, splaying, and abrupt direction changes. Any successful FUE technique has to have some inherent flexibility to account for these factors.

One example of the aforementioned problem is shown in Fig. 1. This depicts the basic structure of the follicular unit and the commonly seen occurrence of a hair shaft that does not correspond with the subcutaneous course of the follicle. A sharp punch inserted too deeply will likely result in a follicle transection.

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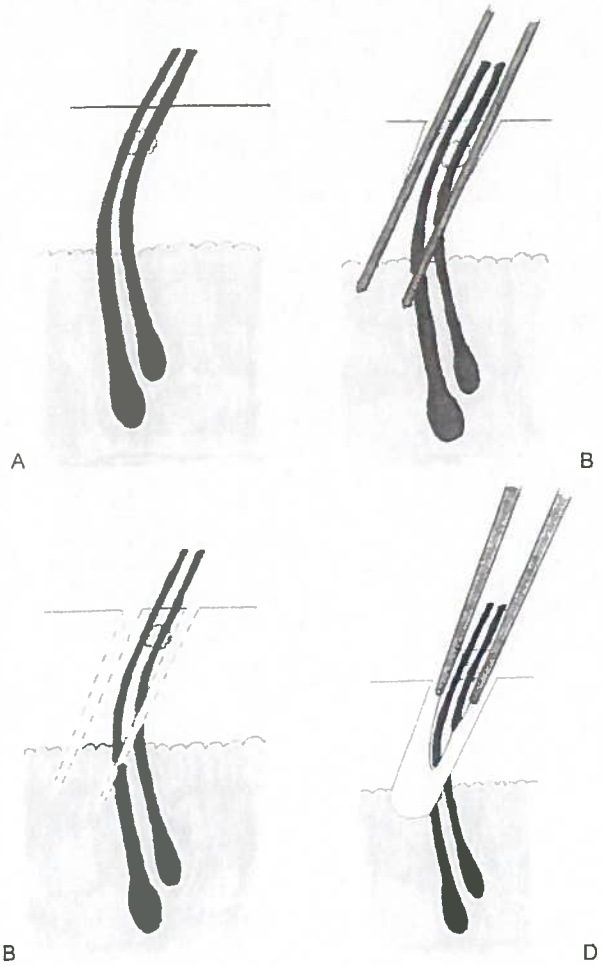

Figure 1 (A) The case where the hair shaft above the skin surface does not match the subcutaneous course of the follicle. (B) Insertion of a sharp punch in the improper orientation will result in (C, D) follicle transection.

DESCRIPTION OF FUE PROCEDURES

Based on published and oral presentations of FUE techniques in journals or at conferences, there are two basic methods for FUE. These techniques rely on the use of either sharp or dull dissecting punches. Once the punch has been used to dissect the follicular unit from the skin, there are various methods to free the graft and harvest it. The details of these methodologies will be discussed in this section.

General FUE Procedure Considerations

Adequate lighting and proper magnification is essential when performing FUE. Surgical headlights are helpful as they eliminate the need for frequent adjustment. Suction may be required to keep the skin free from blood so that the depths of the incision around the target graft can be visualized.

FUE surgery requires that a sharp punch be placed over the hairs of the follicular unit to be extracted. The failure to complete this step with some degree of accuracy increases the chances of an inadvertent follicle transection significantly. Usually, magnification of × 3.5 to × 6.5 is required to accomplish this feat successfully. One of the most significant, and easily correctable, reasons for the failure to obtain quality grafts by novice surgeons is inadequate magnification and the inability to accurately position the punch over the emerging hairs.

The patient position for FUE is based on physician preference. Surgeons who typically harvest the donor strip with the patient in the prone position may be more comfortable performing FUE in the occipital area with the patient prone, and when extracting from the temporoparietal areas, the patient can lie in the lateral decubitus position. The advantage to the surgeon being in a cephalad position is that the motion of the hand and arm of the surgeon is toward himself or herself providing greater control and stability.

Some surgeons prefer a position where the patient is seated and the surgeon is essentially looking upward at the follicular unit. The hand and arm motion in this position is away from the surgeon's body. In my experience, this position, although possibly more comfortable for the patient, increases operator fatigue and does not enhance arm and hand stability.

The donor area for FUE is the same region that has been accepted for strip excision, the difference being that during an FUE procedure, the entire possible donor zone can be used rather than just a small area. An exception to the standard donor area is the low supra-auricular region and the neck regions to obtain hairs of smaller caliber that are useful for the frontal hairline or anterior temples. The physician and patient must be aware that grafts from this area may experience thinning over time. The decision to use grafts from these areas is based on the patient's age and family history of thinning in these areas.

The patient's donor area can be prepped by shaving the donor area hair to a length of 1 to 2 mm. This affords the best visualization and access, allowing maximal harvesting efficiency. This is depicted in Fig. 2A, B.

In patients who will not allow a wide shave as shown above, multiple 3- to 5-mm-wide strips of scalp ("microstrip prep") can be shaved with intervening strips of 3 to 5 mm where the hair is left long (Fig. 2C, D). This method of donor area shaving is more time consuming and concentrates the harvest in relatively small areas. In these cases, care must be taken to avoid graft extraction in these areas during subsequent surgeries so that the overall harvest is randomly distributed over the entire donor region.

The last option for donor area shaving is to cut the hair short on only the follicular units to be extracted. This method allows for a random distribution of extraction sites but requires a significant amount of time.

Figure 2 Photographs represent the range of donor area shaving options: (A) wide shave, (B) total shave, (C) microstrip, (D) microstrip with the hair combed over the extraction sites. Photographs (A) and (B) also show the extraction sites 1 day postoperatively.

FOX Procedure

This technique was described by Rassman and Bernstein, and it involves the placement of a 1-mm sharp punch over a follicular unit and aligned to the approximate angle of the hair shafts and presumably the follicles below the skin surface. The punch is then inserted through the skin to the level of the upper dermis, and the follicular unit is then grasped with forceps and removed. A fine needle can be used to assist in dissecting the graft from the surrounding skin if needed.

The obstacles to the successful implementation of this technique are related to the inability to anticipate the direction of the follicle in the skin with a high degree of accuracy and the tendency of the sharp punch to transect follicles if they are splayed. If the depth of dissection is too shallow, excessive traction must be applied to the follicular unit, which often results in traumatic avulsions or transections.

Rassman and Bernstein's study showed that ~60% of the patients evaluated by a FOX test (an FUE test session evaluating rates of transection) were in fact candidates for FUE using their technique. "Good" candidates were those patients that had a transection rate of 20% or less.

Rose and Cole developed the Follicular Isolation Technique (FIT), which is a variation of the FOX technique. Their technique uses a sharp punch with a mechanism for limiting the depth of insertion. Depth limitation was described as part of the FOX technique whereby the authors suggested advancing the punch to the region of the reticular dermis stopping short of entering the subcutaneous space. There are no published reports on the FIT technique; however in presentations, Cole reports transection rates averaging 5.5% in a group of 200 patients.

Tumescence is generally used in sharp dissection techniques as it prevents the movement of the follicular unit due to manipulation of the skin and may help straighten the follicles as well.

SAFE System

The SAFE System described by Harris[3,4] uses two different methodologies, both of which rely on "blunt" instrumentation to minimize the risk of follicle

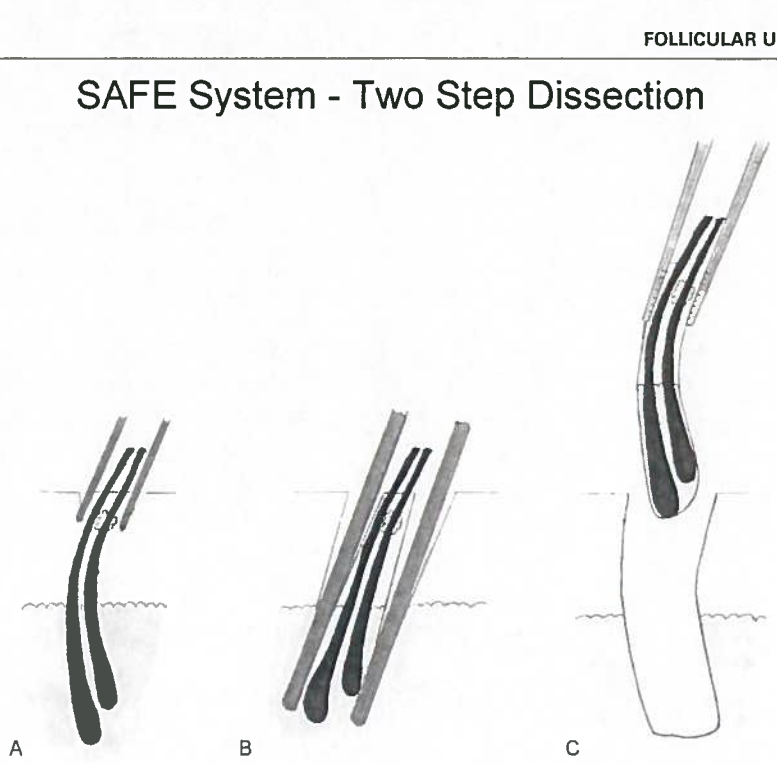

Figure 3 (A) A sharp punch is inserted to a shallow depth, 0.3 to 0.5 mm, followed by (B) blunt punch insertion. (C) The follicular unit is them removed.

transection. Tumescence is not required or recommended for this technique.

The first method consists of two dissection steps. The first step involves using a sharp punch to create an 0.3- to 0.5-mm depth "scoring incision" around the follicular unit. This is followed by the insertion of a blunt, tapered "dissecting" punch to its full depth (~4 mm); the graft is then removed from the donor area (Fig. 3). The blunt tip allows the separation of the follicles from the surrounding tissue and facilitates the "gathering" of splayed follicles into the lumen of the dull punch. Because tumescent fluid is not used, the follicles are not held rigid in the dermis permitting them to move into the punch. In spite of these factors, if there is a significant difference between the insertion angle of the blunt punch and the course of the follicle, there is a risk of blunt traumatic transection.

The initial studies examining this technique revealed a follicle transection rate of 5.6% in ~7000 extracted grafts. Analysis of more recent SAFE System FUE procedures has shown that with experience, transection rates of less than 2% can be obtained. This range is well within the acceptable rates compared with microscopic dissection of follicular units.

A version of the blunt punch that allows a single-step dissection is the serrated dull tip. This dissection tip (Fig. 4) lacks sharp edges and has a serrated leading edge, which permits the punch to be inserted directly into the skin. In patients who have firmer or "tougher" skin, a scoring incision may be required. Figure 5 illustrates the use of the serrated tip. Follicle transection rates vary depending on the patient and the inside diameter of the punch. They range from 1.3% for the 1-mm punch to 4% using the 0.75-mm punch. Some patients have transection rates above 10% with this particular tip, and its use should be discontinued.

The choice of punch size for a particular patient depends on the operator's experience and the average configuration and width of the patient's follicular units. Tighter grouping of follicles may permit an 0.75-mm punch to be used for four to five hair follicular units, whereas in cases where the follicles are more spread out, the 1-mm punch may be used. In

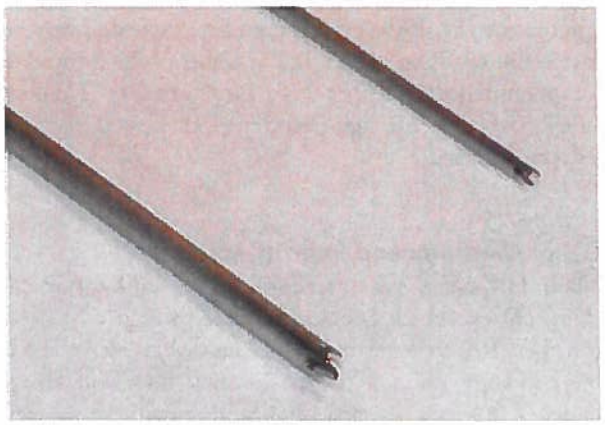

Figure 4 The serrated dull dissecting tips in the 1-mm and 0.75-mm inside diameter sizes.

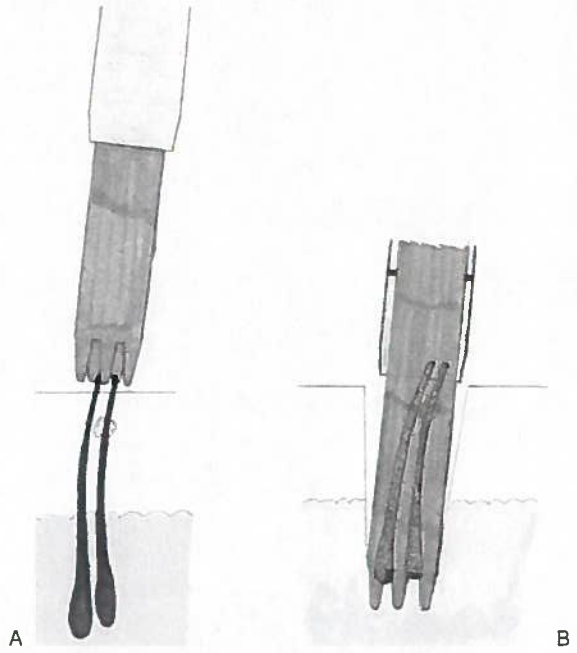

Figure 5 (A) The serrated tip is placed over the follicular unit, and (B) the tip is inserted into the skin.

general, the smallest diameter punch should be used to minimize skin trauma and create the smallest scars possible. Punches larger than 1 mm can cause more visible scarring.

Graft burial is a potential problem with the use of the dull dissecting tips.[5] The leading edge can compress the dermal tissue as the punch is advanced causing the graft to be buried. The graft burial rate varies with the type of punch used (dull vs. serrated) and the inside diameter. The 1-mm dull punch has burial rates from 1 to 7%, and the 1-mm serrated tip has burial rates around 1%.

When a graft is buried, the initial step is to place the tips of the extraction forceps into the site and attempt to grasp the unit. If this fails, pressure around the site may force the graft to the surface. The next step is to dilate the extraction site with a fine hemostat and to search for the graft in the site. If the graft cannot be removed, it may be left in situ resulting in a slight possibility of the formation an inflammatory cyst that will require excision. The rate of this occurrence is significantly less than 0.002% of all extracted grafts.

Other Methods and Instrumentation

Mark DiStefano has introduced the MSD, or multi sharp device, which is essentially a bivalve needle used for FUE. Robert True and Yves Crassas have described a methodology using a powered rotary drill and sharp punches. The success and applicability of these devices or instruments is not well documented, but they appear to work well in the hands of their proponents.

Difficulties in Graft Dissection

Regardless of the technique being used, the dissection process may result in follicle transections. If a "high" level (1 to 2 mm below the skin surface) transection is seen, this is called *topping*. This is due to the insertion of the sharp punch at an angle that is significantly mismatched to the subcutaneous course of the follicles resulting in a very superficial follicle transection. This occurrence will likely not damage the follicles, and the remedy for this situation is to insert the sharp punch into the skin at a less acute angle.

If the transection of the follicles appears to occur at a deeper level, such as the sebaceous gland or deeper, there is a mismatch between the angle of insertion of the punch and the true course of the follicles. In the case of sharp dissection, either the insertion depth must be limited or the angle of insertion must be adjusted. To accomplish this task, the sharp punch may be inserted in small increments while evaluating the course of the follicles and the angle can be adjusted as needed. Adequate light, magnification, and hemostasis are critical.

In the case of SAFE System extractions, there are two causes for deeper level transections. The first possibility is that the "superficial" scoring incision is too deep. The operator must ensure that the incision is no deeper than 0.3 to 0.5 mm (the junction of the bevel and the shaft of a sharp punch). The second possibility is that the dull dissecting punch is inserted at an angle that does not correspond at all with the follicle course. Evaluation of the transected follicles will indicate the required change in orientation.

Graft Harvesting

Regardless of the dissection technique used, the graft must be removed from the donor area. There is usually some tethering of the distal graft to the deeper dermal tissue that must be freed to allow graft removal. The degree of tethering varies with the follicular unit's location on the scalp. The temporal region and often the neck areas exhibit a higher degree of tethering than does the occiput.

Occasionally, when the graft is grasped at or near the epidermis, the skin is inadvertently removed. This phenomenon is called *capping*. The follicular unit may still be removed producing a viable graft. If capping occurs frequently, it may indicate that the dissection of the follicular unit may be too superficial.

If the graft is tethered, serial grasping of the graft with small forceps in a "hand over hand" method with the pulling force parallel to the follicle orientation can be attempted. Great care should be used in avoiding excessive grasping force as graft damage is likely. If the two-step blunt dissection technique was used, reinsertion of the blunt punch to its full depth may free the

graft. Another option is to insert a small-gauge needle (25 to 27 gauge) at intervals around the graft in effect creating perforations ("postage stamp" effect) to free it from the surrounding tissue.

Should the graft remain fixed in position, the options are to repeat the above maneuvers or to leave the follicular unit and move on to the next potential graft. Often, the time spent in freeing a single tethered graft is better spent pursuing other grafts.

Efficiency Issues

To decrease the total operating time and to decrease surgeon fatigue and patient discomfort, every effort should be made to increase the efficiency of the extraction process. The most effective way to accomplish this is for the surgeon to perform the graft dissection while the assistant or assistants perform the graft removal from the skin.

When using a sharp dissection or serrated tip single-step technique, it is common for the surgeon to dissect 50 to 100 grafts in one area, then move to another area to dissect grafts. The second area selected should allow the assistants room to maneuver and harvest grafts unimpeded from the initial area.

When using the two-step blunt dissection method, it is helpful to perform the initial scoring incision for 25 to 100 grafts followed by the blunt dissection step. Once this is completed, the surgeon can then move to a second area as described above.

If at all possible, the patient should be encouraged to allow a total donor area shave as this may enhance efficiency by 20 to 25%. If performed properly, extraction rates of 250 to 400 grafts per hour are possible in some patients.

FUE PROCEDURE WARNINGS

By virtue of the mechanical removal of the grafts from the skin, the follicular units are stripped of most of the perifollicular fat (Fig. 6). This creates challenges in handling these grafts and may be responsible for occurrences of poor growth. There is no published data on the extent of this problem, but it is likely higher than the rate seen in microscopically prepared grafts.

The lack of fat around the graft increases the risk of desiccation, and the technicians must take great care to maintain the moisture status of the grafts. Changes in normal protocols may be required to keep the grafts hydrated. Simple changes could include limiting the number of grafts in the planter's well, and when sorting the extracted grafts, they should be placed immediately into the holding solution.

The grafts are subjected to possible trauma during the extraction and the implantation phases. During extraction, tethering of the graft often necessitates the grasping action with forceps or similar instrument. Because of the delicate nature of the grafts and the fact that the force exerted may be greatly underestimated by the technician or surgeon, it is better to rely on visual cues rather than tactile cues. One such cue is the serrations on the forceps, and ensuring that they never interlock indicating severe compression of the graft.

As opposed to grafts produced by microscopic dissection, FUE grafts lack connective tissue around the follicles, and this allows the follicles to splay. To implant the grafts, the technician must grasp the distal end of the follicles, which may cause crush trauma to the distal end of the follicles.

Another problem that may occur during implantation is the possibility that the graft may become "kinked" or curved at the distal end during the insertion process (Fig. 7). This may either lead to the graft producing a curved or kinky hair or the graft may become nonviable. A solution is to grasp the graft at the distal end and attempt to insert the graft in a single motion into the depths of the recipient site. Attempts at serial insertions increase the likelihood of curling the follicle.

Figure 6 Typical FUE grafts illustrating the lack of fatty tissue around the follicles.

Figure 7 Hairs removed from nonviable grafts in the recipient area 2 months after surgery showing a kinked distal follicle.

DONOR AREA MANAGEMENT AND CONSIDERATIONS

The appropriate donor area for FUE is the same as that described for conventional strip harvest with the possible exception of the neck region and the supraauricular area as previously mentioned. Grafts from these areas tend to have finer hairs, which may be ideal for use in the frontal hairline or anterior temples.

The hair density of the extracted grafts can vary with the density of the patients' natural density as well as the punch size used for the extraction. A 1-mm punch may result in average hairs per follicular unit above 2.5. The reason for this is because follicular units with higher hair density are normally selected for density. When using an 0.75-mm punch, the average hairs per follicular unit decreases to ~2.1 hairs. This is similar to hair density in grafts obtained by strip excision.

The overall objective is to harvest 50% or less of the potential grafts in a given area to avoid the "moth-eaten" appearance of too much thinning. A person with extremely high density may have more than 50% of the hair harvested without an excessive amount of visible thinning.

The range of extractions per square centimeter for a 1-mm punch may be 8 to 20 per cm^2 depending on native follicular unit density. An 0.75-mm punch usually allows for extraction densities of 25 or more sites per cm^2. One should be aware that the area of the extraction hole using an 0.75-mm punch is 56% of the size created by the 1-mm punch; this difference is significant. Figure 2A, B illustrates 1-mm extraction sites 1 day after surgery. Figure 8 illustrates the difference between the 1-mm punch and the 0.75-mm punch extraction sites.

Care must be taken to avoid removing grafts that are adjacent to one another as this may cause the visual appearance of a small linear scar. To avoid this problem, the surgeon may use a pattern that is zig-zag or may use a random pattern avoiding adjacent follicular units in the area.

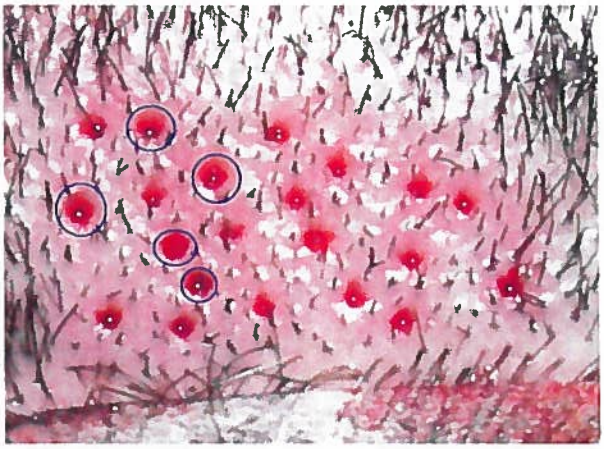

Figure 8 SAFE System extraction sites during surgery. The 1-mm punch sites are identified (circled in blue) to compare against the 0.75-mm sites. The size difference is appreciable.

Patients should be aware that it is unlikely that they could shave their heads and not have the extraction sites be visible as there may be subtle extraction patterns or skin color changes. Patients under the impression that FUE allows for total undetectability of the harvest process should be cautioned.

FUE may permit harvesting of a greater number of grafts than could be obtained by strip surgery alone. It is common to see patients that have had multiple strip surgeries and have minimal or no laxity remaining yet have donor areas that seem to have adequate density to allow additional graft harvest. FUE in these cases may allow the surgeon to obtain an additional 1000 to 2000 grafts. Another use of FUE is the ability to maximize the number of grafts moved in a single session by combining strip excision with FUE.

BODY HAIR TRANSFER

The technique of FUE has made possible the harvest and subsequent implantation of hair from body sites including the extremities, chest, back, beard, pubis, and labia. However, the ability to perform the surgery does not mean that these areas provide a realistic and reliable source of donor hair follicles.

There are several factors that make the use of body hair an option only after all available scalp hair has been exhausted. The primary reason is that body hair has an inherent growth cycle that is usually measured in months rather than years. In spite of Hwang's[6] work, there has been no conclusive evidence that the recipient area exerts a significant degree of influence in changing the growth cycle of a body hair to that matching scalp hair. In fact, the clinical results are suggestive that the majority of hairs transferred from the body retain the donor area characteristics. The body hair that likely has the most favorable characteristics in terms of growth cycle and shaft diameter is beard hair.

Another unfavorable characteristic of body hairs is that the follicular units typically have fewer than two hairs per follicular unit, usually averaging less than 1.3 hairs per graft. Obviously, a transplant will require almost twice as many body hair grafts to provide the same number of hairs as a given number of scalp grafts.

Anecdotally, there is the possibility that the graft survival rate of body hair is not as good as in scalp transfer. Possible reasons for this include trauma during harvest, smaller grafts subject to desiccation and handling effects, and the possibility that grafts planted in a phase other than anagen do not survive as well. Unfortunately, accurate survival statistics are not available.

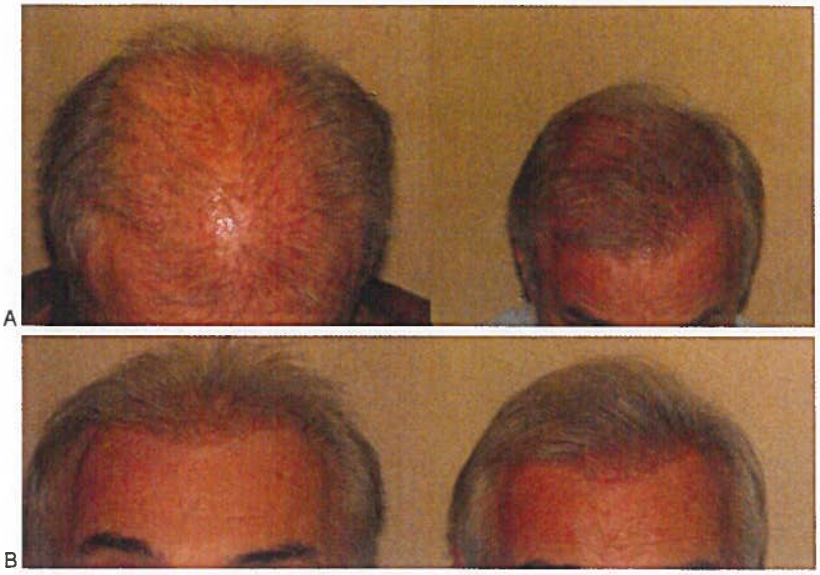

Figure 9 (A, B) A patient who received ~1000 chest hair grafts to the forelock area.

In general body hair grafts do not produce the coverage or density that scalp hair transplants provide. They are better used for light coverage or "fill-in" when there is absolutely no scalp hair available. Figure 9 is an example of a chest-to-scalp body hair transfer (BHT) using ~1000 grafts to the forelock area. The scalp hair is white whereas the chest hairs are black, clearly indicating the source of the hair.

At the time of this writing, there are physicians performing BHT sessions of 9000 to 18,000 grafts to the scalp. The patients having these surgeries may obtain results that are less than acceptable. Patients interested in BHT must be counseled properly regarding the unique characteristics of body hair grafts, the low-density results, the need for multiple surgeries, and the possibility of lower survival rates compared with those of scalp grafts. They should also be warned that BHT is a relatively new procedure with little or no literature to support it generalized use.

FUE CANDIDACY

Although this view is not shared by all practitioners of FUE, it is the author's belief that in general, any patient who is a candidate for hair restoration using strip excision would be a candidate for FUE. Because the grafts produced by FUE are the same anatomic structures that are produced by strip excision, the aesthetic results are the same (Fig. 10).

There have been several articles and book chapters written describing the criteria for FUE candidacy. Often, these criteria are related to a surgeon's limitations such as expertise or available resources. I do not believe that criteria based on these factors are valid. However, I do believe that there are patients who are better or more appropriate candidates for FUE.

The following patient types may be "good" candidates for FUE: Patients who have

1. A desire to wear their hair very short, and therefore a linear scar may be visible.
2. Significant scarring from previous surgery that precludes strip excision.
3. No available scalp laxity.
4. A tendency to heal with thickened or wide linear scars.
5. A need to resume a high level of activity soon after the procedure.
6. A significant aversion to pain.
7. Extremely wide hair shafts who require finer hair from the supraauricular or low neck regions to create a finer, more aesthetic result.
8. A need for BHT.
9. Poor aesthetic results at the frontal hair line due to large grafts; FUE can be used to thin grafts one follicular unit at a time.

In general, there are very few patients who may not be candidates for FUE; however, there are some patients who may have skin characteristics that make FUE more time consuming or difficult, and the physician may elect not to perform the procedure. One condition that may make FUE difficult or impractical is the presence of a type of scar tissue that binds the follicular unit in such a way to cause follicle damage during extraction. Another may be an African-American patient in whom the follicles have such a high degree of curvature that high rates of transection are inevitable.

Figure 10 (A, B, E, F) Before and (C, D, G, H) after photographs of typical FUE patients. The patient in photos A, B, C, D received 1349 follicular units, and the patient in photos E, F, G, H received 1009 grafts.

CONCLUSION

FUE is procedure that offers patients the advantages of minimal postoperative pain, extremely rapid recovery from the surgery, and the ability to wear the hair close cropped. However, the procedure is not widely accepted among physicians because of the learning curve of the procedure, the paucity of instrumentation, and the time required to perform the procedure.

Hopefully, as the techniques and instrumentation improve, physician acceptance will rise. Other advantages of FUE such as more exact graft counts, a decreased reliance on auxiliary staff, and the ability to select the mix of follicular units for a specific case will drive a higher physician acceptance. More efficient means of harvesting will also allow the cost to patients to decrease.

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