Chapter 4

FOLLICULAR UNIT EXTRACTION (FUE)

by

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INTRODUCTION

A recent trend in surgery is to devise techniques that result in less trauma, less scarring, and a more rapid recovery. In hair restoration surgery, the donor area is most affected by these three postoperative sequelae. To address these concerns, a technique of graft production called follicular unit extraction (FUE) has been developed. Hair follicles naturally grow in units of one to four hairs (Figure 4.1). Instead of harvesting a "strip" or ellipse of skin from the scalp, which is then divided into follicular units, the follicular units are removed individually from the donor area. This technique has provided a less invasive method for graft production, and it results in the absence of a linear scar and much less pain and discomfort at the donor site.

Although it is primarily used for scalp graft production, FUE has also been used to produce grafts from various sites on the body including the chest, back, extremities, neck, and pubic areas. This technique, called body hair transfer (BHT), will also be covered in the context of FUE.

The reader should note that many of the statements are based on anecdotal evidence from the author's experience and from other physicians' reports as there is a paucity of published reports on FUE. This may be due to reluctance of physicians to share their knowledge in order to retain a marketing advantage or simply due to the relative infancy of this technique.

Recent internet publicity has elevated expectations about what FUE has to offer the field of hair restoration. The goal of this chapter is to present a realistic view of FUE, including a historical review of FUE, the technological hurdles, the current methodologies, the complications encountered, a review of body hair transfer, and the indications for FUE.

HISTORICAL PERSPECTIVE

In 2002, Rassman and Bernstein were the first to publish their version of FUE, calling it the "Fox Procedure," which is derived from "*F*Ollicular unit e*X*traction." Some of their preliminary work was inspired by the work of Inaba as well as Woods and Campbell in Australia, who were performing FUE. The difficulties of the technique soon became apparent. They included limited patient candidacy (approximately 60% of patients are candidates) because of the high risk of follicle transection or damage due to shearing during the extraction phase. The technique is also difficult to learn. These quickly

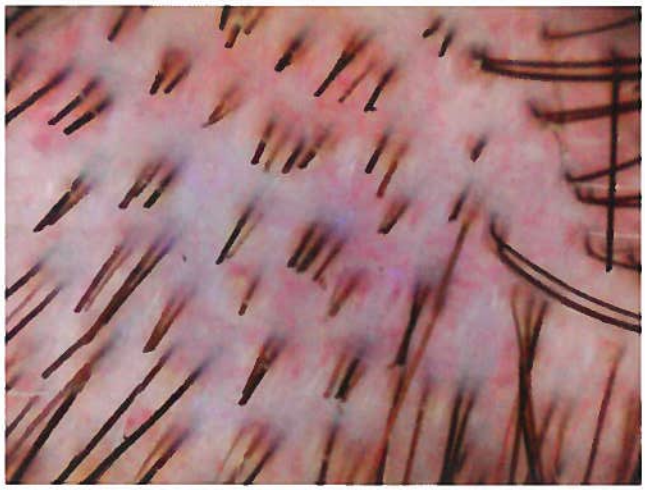

FIG. 4.1. Hair follicles naturally grow in groupings of one to four hairs.

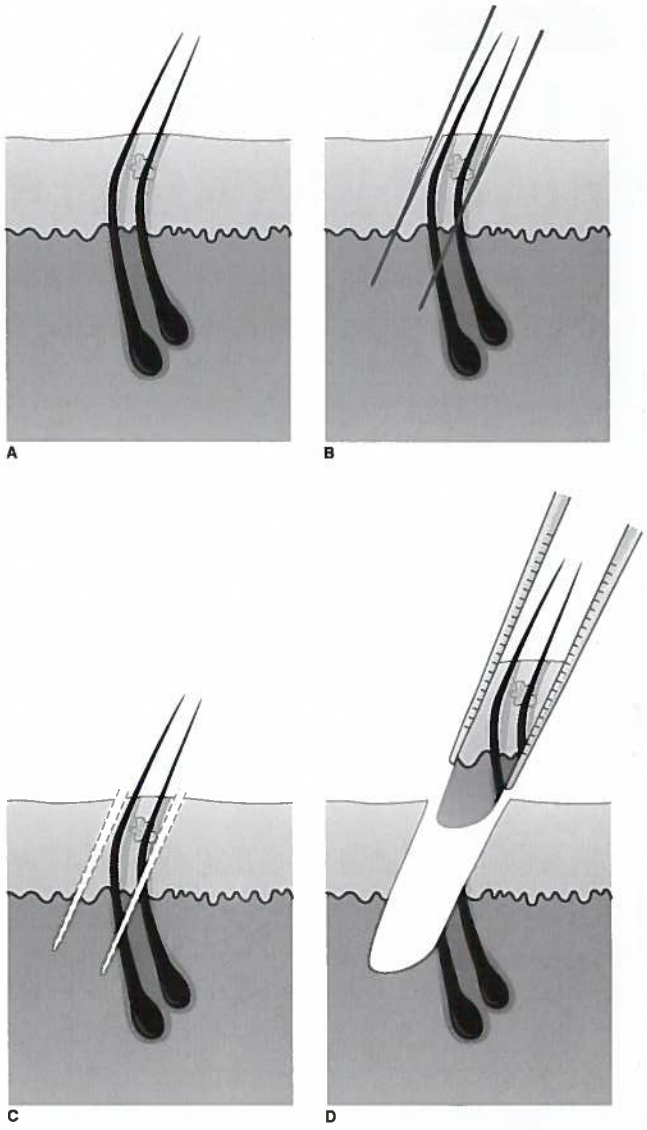

FIG. 4.2. Transection of the follicular unit can occur when the underlying follicle is not in line with the hair shaft.

proved to be effective barriers to the utilization of this FUE technique for the average patient and his or her physician.

One observation made by Rassman and Bernstein was the need to limit the depth of insertion of the sharp punch so that it would not result in transection. Practically, this is difficult to achieve when using a mass-produced sharp dermal punch.

In order to reduce the risk of follicle transection, the author has developed a technique called the SAFE (*S*urgically *A*dvanced *F*ollicular *E*xtraction) System™. This technique allows many patients who are not eligible for the FOX procedure to undergo hair transplantation with the FUE procedure. The primary advantage of the SAFE System over the FOX procedure is that the primary follicular unit dissecting instrument is a dull (no cutting surfaces) punch that significantly reduces the risk of transection and expands candidacy to almost 100% of patients.

RELEVANT ANATOMY AND ETIOLOGY OF FUE DIFFICULTIES

Frequently, the direction of the follicle below the skin is different from that above. Histologically, one can observe curvature, splaying, or abrupt direction changes of hair follicles. These changes make dissection difficult and must be accounted for in any successful FUE technique. Any technique that does not account for these factors is not a viable FUE technique.

Figure 4.2 depicts a hair shaft that is not in line with the subcutaneous course of the follicle. If a sharp instrument is introduced to a sufficient depth, there is a risk of follicle transection.

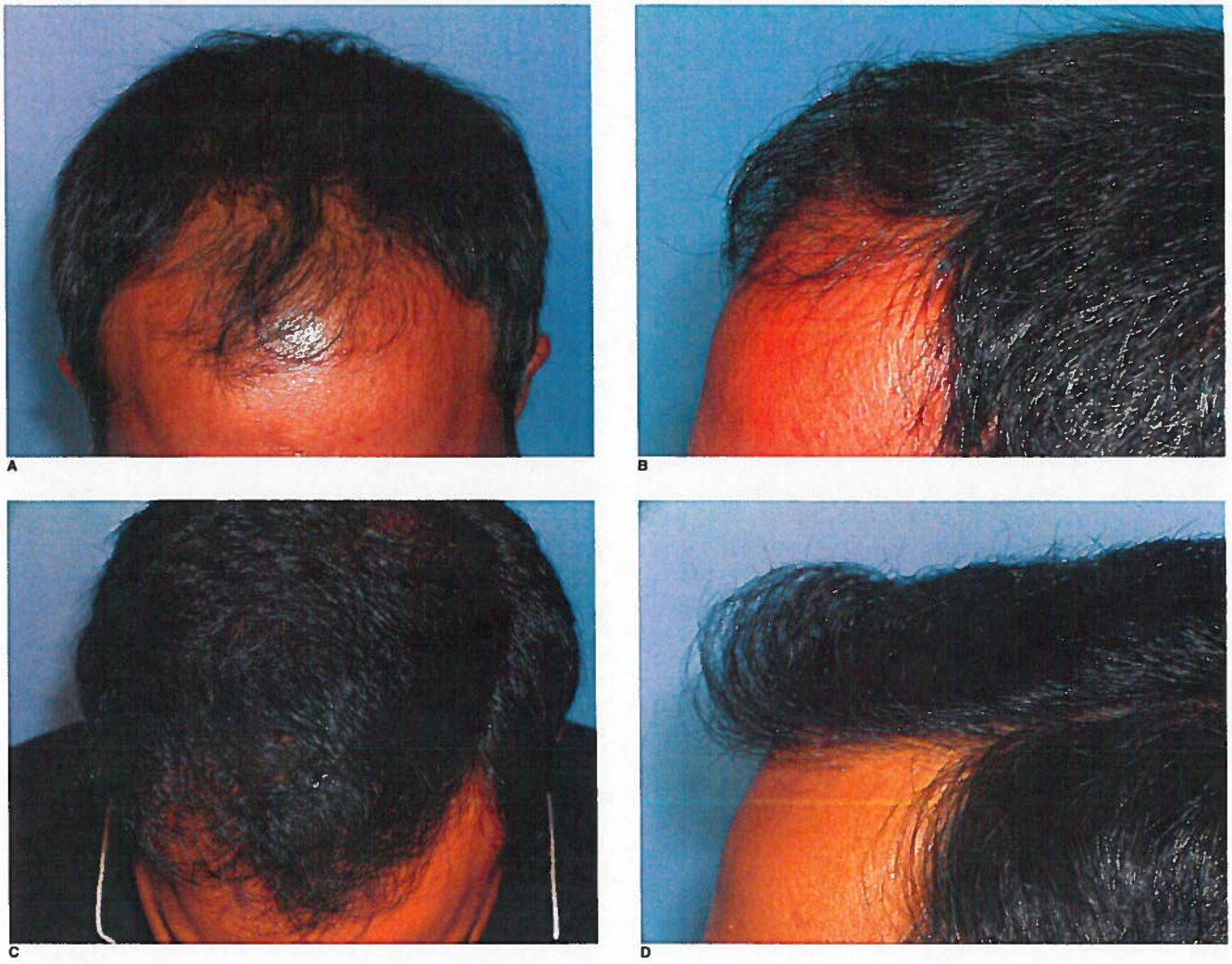

FIG. 4.3. ***(A) Frontal view of the patient before FUE. (B) Side view of the patient before FUE. (C) Frontal view of the patient after FUE. (D) Side view of the patient after FUE.***

FUE CANDIDACY

In general, any patient who is a candidate for hair restoration utilizing strip excision would be a candidate for FUE. They should undergo the same medical evaluation and discussion of expectations. The results from FUE are not unlike those from strip excision, given that the same follicular units comprise the grafts (Figures 4.3A–D).

Several articles and book chapters have listed out criteria for FUE candidacy. However, many of the criteria are based on the surgeon's limitations, expertise, or available resources. Rather, they should be based on patient characteristics. The following list contains patient profiles of "good" candidates for FUE:

1. Patients who might wear their hair very short and in whom a linear scar may be visible
2. Patients with a high degree of scarring from previous surgery that precludes strip excision
3. Patients with no available scalp laxity for strip harvest
4. Patients who heal with thickened or wide linear scars
5. Patients who need to resume a high level of activity soon after the procedure, such as athletes

6. Patients with a significant aversion to pain
7. Patients with extremely wide hair shafts who require finer hair from the supra-auricular or low neck regions to create a finer, more aesthetic result
8. Patients requiring BHT
9. Patients with poor aesthetic results at the frontal hairline due to large grafts; FUE can be utilized to thin grafts one follicular unit at a time.

In general, the only patients who may not be candidates for FUE, other than for the usual reasons such as young age, poor donor capacity, or unrealistic expectations, are those who have conditions that make FUE technically impossible. Some patients have skin characteristics that make FUE more time consuming or difficult and the physician may elect not to perform the procedure based on a preoperative evaluation or test surgery. The primary condition that may make FUE nearly impossible is the presence of scar tissue. It can bind the follicular unit in such a way as to cause excessive transection or follicle damage during extraction.

DESCRIPTION OF PROCEDURES

General Considerations for FUE

Whichever method is chosen to perform FUE, adequate lighting and proper magnification are essential. When performing FUE, the field of view is often restricted due to the high magnification required; therefore, surgical headlights are usually preferable to overhead lighting as the need for frequent adjustment is eliminated. Suction may be required to keep the skin free from blood so that the depth of the incision around the target graft can be visualized.

The FUE process begins with the accurate placement of a sharp punch over the hairs of the follicular unit where they emerge from the scalp. To accomplish this, a magnification of 3.5× to 6.5× is generally required. One of the primary reasons why novice physicians have trouble harvesting high-quality grafts with FUE is inadequate magnification and poor placement of the punch over the emerging hairs. Proper magnification, lighting, and ergonomic seating can help overcome these obstacles.

Surgeons who are used to removing a donor strip with the patient in the prone position may perform FUE in the occipital region with the patient in the same position. When extracting from the temporoparietal areas, the patient can lie in the lateral decubitus position. The advantage of these patient positions is that the motion of the arm of the surgeon is toward him or herself. Many feel this provides more accurate control.

Other surgeons prefer that the patient be seated and that the line of sight from the surgeon's eyes to the follicular unit is from inferior to superior. The general direction of the hand and arm motion is away from the surgeon during the dissection process.

As with strip excision, the traditional donor area for FUE is the appropriate areas of the occipital and temporoparietal scalp. One may also use the low supra-auricular region and the neck to obtain hairs of smaller caliber that are useful for the frontal hairline or anterior temples. The danger is that the patient may experience thinning in these areas with age, which will translate to the loss of grafts. The decision to utilize grafts from these areas is based on the patient's age or family history of thinning in these areas.

The patient's donor area is routinely shaved to a length of 1–2 mm. Better visualization and access are afforded by a wide shave (Figure 4.4A) or total shave (Figure 4.4B).

Some patients will not allow a wide shave, so multiple 3- to 5-mm-wide strips of scalp ("micro-strip prep") are shaved with an intervening strip of 3–5 mm where the hair is left long enough to cover the shaved areas (Figure 4.4C). This method of shaving

FIG. 4.4. (A) A wide shave of the donor area allows for good visualization. (B) A complete shave, if permitted by the patient, provides even better visualization. (C) Patients may prefer a partial shave of only those areas needed for graft extraction.

the donor area is more time consuming and concentrates the harvest in relatively small areas. Subsequent micro-strip prep surgeries must utilize areas not previously harvested so that the overall harvest is randomly distributed over the entire donor region.

One final option for shaving the donor area is cutting the hair short on only the follicular units to be harvested. This method allows for a random distribution of extraction locations but represents the most time-consuming option for donor shaving and preparation.

FOX Procedure

First described by Rassman and Bernstein, the FOX procedure involves the placement of a 1-mm sharp punch over the targeted follicular unit and aligning it to the approximate angle of the hair shafts below the skin surface. The punch is then inserted through the skin to the level of the upper dermis. The isolated follicular unit is then grasped with fine, rat-toothed forceps and gently pulled out from the skin. If necessary, a fine needle is used to separate the follicular unit from the surrounding skin. Figures 4.5 and 4.6 demonstrate the donor area after harvesting follicular units with a 1-mm punch.

FIG. 4.5. Donor area after harvesting with a 1-mm punch.

FIG. 4.6. Enlarged view of donor area after harvesting with a 1-mm punch.

As mentioned earlier, it is difficult to anticipate the correct angle of the follicle in the skin to avoid transaction. Another problem is that if dissection is too shallow, excessive traction must be applied to the follicular unit, which can result in a traumatic avulsion.

Rassman and Bernstein felt that approximately 60% of the patients, evaluated by a FOX test (an abbreviated FUE test session evaluating rates of transection), were in fact candidates for this method of FUE. "Good" candidates could have follicle transection rates up to 20%.

Rose and Cole developed a technique called the Follicular Isolation Technique (FIT), which is a variation of the FOX technique. This approach utilizes a punch designed so that the hub is long enough to reach the reticular dermis but stops short of entering the subcutis; this is accomplished by a patented adjusting mechanism. There are no published reports on the FIT technique; however, reports suggest that transection rates of follicles using this technique averaged 5.5% in 200 patients studied.

Tumescence is generally used in sharp dissection techniques. Theoretically, 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 utilizes two different strategies, both of which rely on "blunt" instrumentation to minimize the risk of follicle transection. Tumescence is neither required nor recommended for this technique.

The first SAFE System method to be described consists of two dissection steps. The first step is the creation of a 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 (approximately 4 mm); the graft is then extracted (Figure 4.7). 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. Follicles that are curved can move into the lumen without having to come in contact with a sharp cutting edge. The lack of tumescence means that the follicles are not held rigidly in the dermis and can move freely into the punch. If there is a significant difference between the angle of the punch and that of the follicle, there is a risk of blunt traumatic transection.

The first studies to examine this technique revealed a follicle transection rate of 5.6% in approximately 7,000 extracted grafts. Subsequent analyses have shown that with experience, the transection rates can be less than 2%. This compares favorably with microscopic graft dissection from a strip.

An enhanced version of the blunt punch allows a single-step dissection with a serrated, dull tip. This dissection tip (Figure 4.8) lacks sharp edges, minimizing transaction, but the serrated leading edge allows for direct insertion into the skin. This combination eliminates the need for a scoring incision. Figure 4.9 illustrates the use of a serrated tip. Follicle transection rates depend on the patient and the inside diameter of the punch. They range from 1.3% for the 1-mm punch to 4% for the 0.75-mm punch. Some patients have higher transection rates with serrated

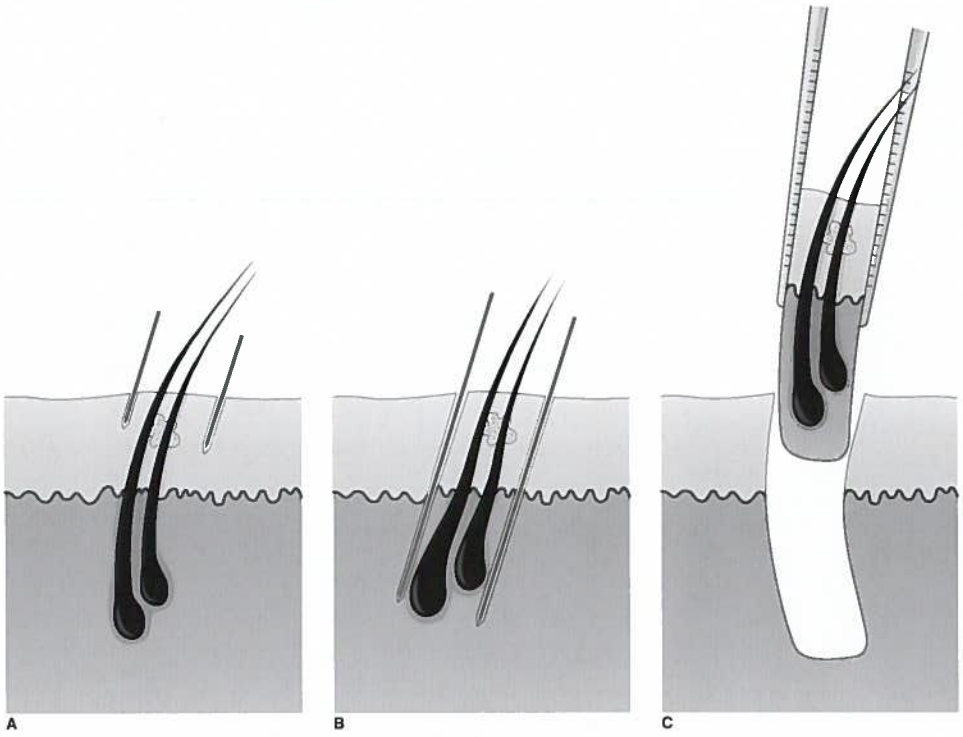

FIG. 4.7. Graft extraction using the SAFE method.

dissecting tips. When this becomes apparent, the remaining extractions are performed using the two-step dissection technique described earlier.

Blunt, sharp, and serrated punches are available in 0.75 and 1 mm inside diameter sizes. The decision to use a particular size depends on the operator's experience and the average configuration and width of the patient's follicular units. The tighter configurations of the follicular units will permit the 0.75-mm punch to be utilized for four to five hair follicular units. If the general configuration of the four and five hair units is more spread out, the 1-mm punch should be used to harvest the graft. In 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 scarring that may be visible and unacceptable.

A variety of instruments should be available for any particular case. Blunt punches measuring 1 and 0.75 mm as well as eight to ten sharp punches of the corresponding sizes should be available for a 1,000 graft extraction case. I would also suggest that the 0.75- and 1-mm serrated tips be available as this methodology can decrease the procedure time substantially.

A potential problem with the use of the dull dissecting tips is the possibility that the leading edge

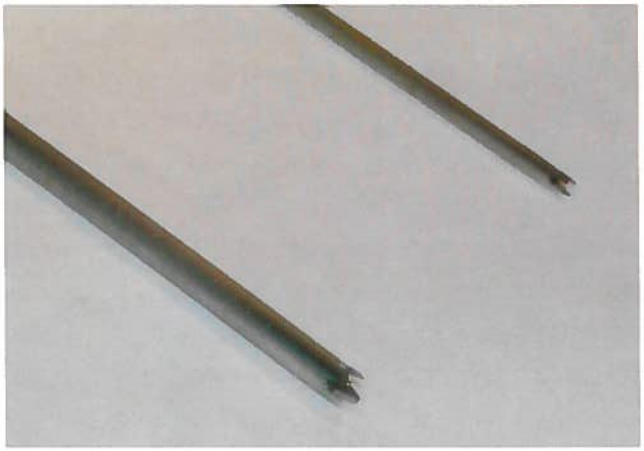

FIG. 4.8. The dull dissecting tip scores the skin but minimizes transection of follicles.

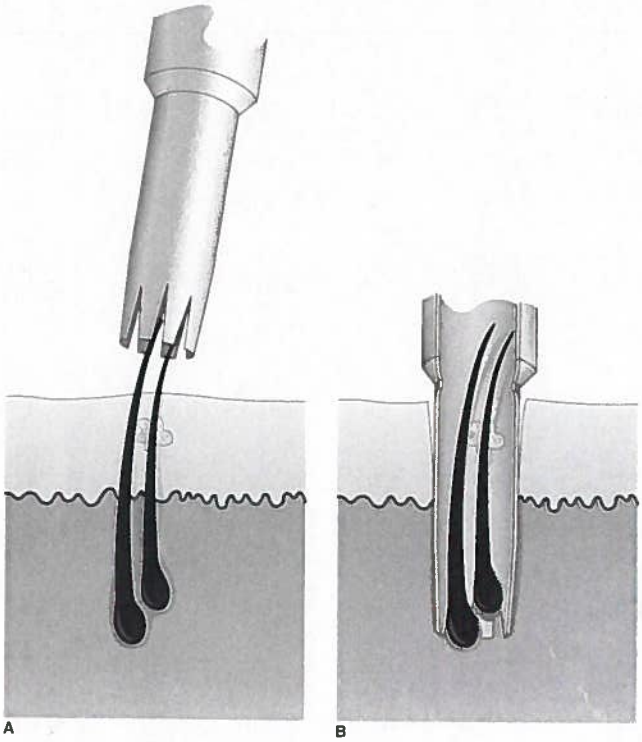

FIG. 4.9. Illustration of a serrated tip as it is used to punch around the follicular unit.

will 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 utilized (dull versus serrated) and the inside diameter. A 1-mm dull punch may have burial rates from 1–7%, and the 1-mm serrated tip has burial rates of 1% or less.

When a graft becomes buried, the next step is to place the extraction forceps in to the site and grasp for the unit. If this fails, pressure around the site may force graft expulsion allowing removal. The next step is to dilate the extraction site with a fine hemostat; the graft is typically seen at the base of the site. Should all attempts at locating the graft fail, it may be left in place. There is a slight possibility that the graft may cause the formation of 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

There are several other instruments used by individual physicians to aid in either graft dissection or harvest; however, none are commercially available as of yet. Most involve different configurations of the dissecting tip with different areas having either sharp or blunt configurations.

Of some interest is the use of powered rotating punches for dissecting the graft. The reports of this technique often describe the use of punches 1 mm or greater and relate transection rates greater than those seen with manual techniques. The primary advantage of the powered instrumentation is the speed at which grafts may be harvested. This has to be weighed against the larger donor scars and damage to follicles.

Difficulties in Graft Dissection

Regardless of the technique, the graft dissection process may result in follicle transection. If transection is noted very high in the dermis, affecting all the follicles at a level 1–2 mm below the skin surface, this is called "topping." This finding is related to insertion of a sharp punch at an angle that is significantly mismatched to subcutaneous course of the follicles. This results in a very superficial follicular unit transaction that leaves the underlying follicles intact. The remedy for topping is to insert the sharp punch into the skin at a less acute angle.

If the transection of the follicles occurs at a deeper level, 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 depth of insertion must be more shallow 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 changed as needed.

In the case of SAFE extractions, deeper transections suggest that the "superficial" scoring incision is

too deep. An adjustment of the insertion to ensure that the incision is no deeper than 0.3–0.5 mm (the junction of the bevel and the shaft of a sharp punch) should be made. The second possibility is that the dull dissecting punch is inserted in such a way that there is a gross mismatch between the follicle direction and direction of insertion. Evaluation of the transected follicular unit will indicate the required change in orientation.

GRAFT HARVESTING

The next step involves removing the graft from the donor area. Tethering of the distal graft to the deeper dermal tissue must be freed to allow graft removal from the skin. The degree of tethering may vary from one scalp location to another. The neck and temporal region tend to exhibit a higher degree of tethering than the mid-occipital region.

Usually, one can grasp the follicular unit with small forceps near the region of the sebaceous gland and, with minimal pressure and pulling, remove the graft easily from the skin. Different extraction forces may be required in different patients or in different regions of the scalp on the same patient.

Occasionally, when the graft is grasped at or near the epidermis, the skin superficial to the sebaceous glad is inadvertently removed and this is called "capping." If the follicular unit is removed, it still produces a viable graft. If capping occurs frequently, it may mean that the dissection of the follicular unit is too superficial.

Should the graft be tethered, serial grasping of the graft with small forceps in a "hand-over-hand" method with the pulling force exerted parallel to the follicle orientation can be attempted. Great care should be taken not to damage the graft by squeezing too tightly. If the two-step blunt dissection technique was employed, reinsertion of the blunt punch to its full depth may free the graft.

A small (25–27) gauge needle may also be inserted at small intervals into the incision around the tethered graft creating perforations ("postage stamp" effect) to free it from the surrounding tissue. The graft may then be grasped and attempts at removal repeated.

Should the graft remain fixed in position, one may repeat the above maneuvers or leave the graft in place and move on to the next follicular unit. Often, the time spent in freeing a single tethered graft is better spent in pursuing another graft.

CAVEATS

The grafts produced by FUE are essentially stripped of any investing tissue (Figure 4.10). This single fact makes graft handling more difficult and may explain the occasional reports of poor growth from FUE. The extent of this problem has not been published, but it may be higher than the rate seen with strip excision.

The lack of fat around the graft can easily lead to graft desiccation, and the technicians must be aware of the moisture status of the grafts. Usually, fewer grafts can be located outside the storage media at any one time. The lack of connective tissue around the follicles can allow the follicles to splay. This requires that the planter grasp the distal end of the

FIG. 4.10. Microscopic view of grafts after FUE. Note that there is some loss of investing tissue around the follicles themselves.

follicles in order to implant them, which will subject the follicles to the risk of crush trauma.

Another problem that may occur during implantation is the possibility that the graft may become kinked at the distal end during the insertion process. This may lead either to the graft producing a curved or kinky hair or the graft becoming nonviable.

DONOR AREA MANAGEMENT AND CONSIDERATIONS

The number of hairs in the extracted grafts will be determined mostly by the size of the punch used. When utilizing a 1-mm punch, the average hairs per follicular unit can exceed 2.5 as follicular units with higher hair density are preferentially selected. When the punch size is decreased to 0.75 mm, the average hairs per follicular unit decreases to approximately 2.1 hairs, which is similar to hair density of grafts obtained by strip excision.

The overall objective is to harvest fewer than half of the potential grafts in a given area in order to avoid creating a moth-eaten look. If a person has extremely high density with excellent hair characteristics, more than 50% of the hair may be harvested. The density of extractions per square centimeter in a nonharvested area can vary; however, the range for a 1-mm punch may be 8–20 per cm^2 depending on native follicular unit density. The use of a 0.75-mm punch usually allows for extraction densities of twenty five or more sites per cm^2. One should be aware that the area of the extraction hole utilizing a 0.75-mm punch is 56% of the size created by the 1-mm punch; this difference is significant. Figure 4.11 illustrates the difference between the 1-mm-punch (circled in blue) and the 0.75-mm-punch extraction sites.

Care must be taken to avoid harvesting grafts too closely to one another. This may cause the appearance of a small linear scar. To avoid this problem, the surgeon should stagger the punches in a zigzag or random pattern. Although this technique leaves no linear scar, donor sites may be visible in patients who shave their heads. It should be mentioned that subtle extraction patterns or skin color changes may still be visible. Patients under the impression that FUE allows for total camouflage of the harvest process should be cautioned accordingly.

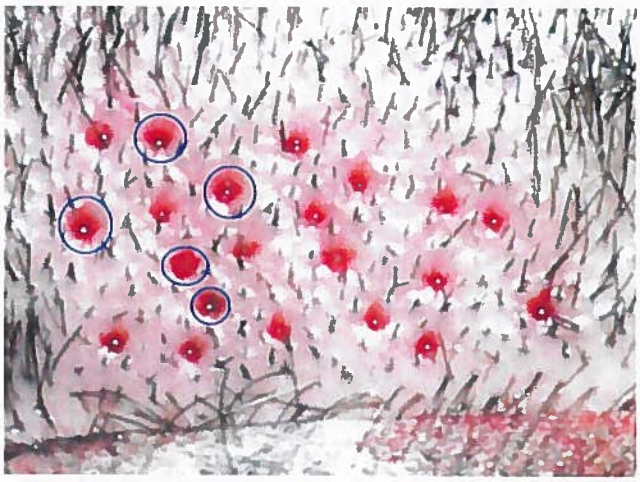

FIG. 4.11. Difference in size between 1-mm (circled in blue) and 0.75-mm punch extraction sites.

Although controversial, scalp FUE after strip harvesting may allow for the removal of a greater number of grafts than conventional strip harvesting alone. It is not uncommon for patients to have had multiple strip surgeries with minimal or no laxity remaining. However, they may still have donor areas with adequate density to allow additional graft harvest. FUE can allow the surgeon to obtain an additional 2,000–4,000 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 advent of single follicular unit harvest has made possible the extraction and implantation of hair from other body sites including the extremities, chest, back, beard, pubis, and labia. However, the capability of performing the surgery does not mean that these

areas provide a realistic and reliable source of donor follicles.

There are several reasons why body hair is not as good an option as scalp hair for transplantation. First, body hair has an inherent growth cycle that is measured in months rather than years. In spite of the excellent work done by Huang, transplanting hair into different body sites, it has not been demonstrated that the recipient area exerts a significant degree of "dominance" in changing the growth cycle of a body hair to that matching scalp hair. In fact, clinical results suggest that the majority of hairs transferred from the body retain the donor area characteristics. The body hair with the most favorable characteristics in terms of growth cycle and shaft diameter is beard hair. It is somewhat coarse, but seems to grow to a reasonable length.

Follicular units from nonscalp locations typically contain fewer than two hairs per follicular unit and average less than 1.3 hairs per graft. Obviously, this will require almost twice as many grafts to provide the same number of hairs as a similar number of scalp grafts. Anecdotally, there is evidence that body hair has poorer graft survival than scalp hair, and this may depend on whether the graft was transplanted during the anagen phase or not. Accurate survival statistics are not available.

In general, body hair grafts do not produce the coverage or density that scalp hair grafts do. They may also not appear as natural depending on the area of the body from which they were extracted. They may be reasonable for providing light coverage in areas where great density is not required, such as the anterior temples or filling in spaces between thinly distributed scalp grafts. At the time of this writing, there are physicians providing BHT sessions as large as 9,000–18,000 grafts to the scalp. This situation is a setup for unhappy patients who may be gravely disappointed with the cosmetic results and extensive donor-site scarring.

CONCLUSION

FUE is a relatively new procedure that is gaining acceptance by physicians and patients alike. Patients are aware of the significant advantages, such as decreased postoperative pain, rapid recovery time, and the ability to wear the hair closely cropped. Patients are usually the first to embrace techniques that offer a less invasive alternative compared to traditional procedures. The production of 1,000 grafts from a strip with 100 follicular units/cm^2 will remove approximately 5,000 mm^3 of tissue. FUE offers less tissue ablation; harvesting 1,000 grafts with a 1-mm punch will remove 3,925 mm^3 of skin and a 0.75-mm punch will remove 2,208 mm^3. This procedure is truly "minimally" invasive. The net effect of this is more rapid healing and minimal pain.

As the techniques and instrumentation improve, the disadvantages of longer operating times and the high cost to the patient will decrease. The advantages, such as more exact planning for the number of grafts required, a decreased reliance on auxiliary staff, and the ability to select the mix of follicular units for the specific case will drive a higher acceptance of this procedure by physicians.

With the future of mechanized manual extraction devices and the possibility of robotic technology, this technique may be the future of graft production. It offers the patient the possibility of the natural, undetectable results that we have with the standard follicular unit transplantation with the added advantages of significantly less pain, more rapid recovery, and less visible scarring.

SUGGESTED READING

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