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IN THIS ISSUE

Redefining the "E" in FUE: Excision = Incision + Extraction

Ricardo Mejia, MD | *Jupiter, Florida, USA* | www.skinandhairdoc@aol.com

Extraction in the purest form can be defined as "the action of taking out something, especially using effort or force." In 2013, Dr. Parsa Mohebi and the FUE Research Committee published a report in the *Forum* (Vol. 23, No. 5, pp. 165-168) entitled, "Standardization of the terminology used in FUE: part I." In it, they noted that the concept of FUE was first published in the tabloid newspaper "The Sun Herald" in Australia on October 15, 1995, in an advertisement for Dr. Woods & Dr. Campbell's top-up microsurgical technique where the donor extraction was done one follicular unit at a time. The advertisement described the concept of FUE as "Hair Follicle Single Unit Extraction." In 2002, Drs. Bill Rassman and Bob Bernstein published "Follicular Unit Extraction: Minimally Invasive Surgery for Hair Transplantation" (*Dermatol Surg.* 2002; 28(8): 720-727). They described the term FUE as "the removal of individual clusters of follicles from the donor area using a sharp dissecting punch or trephine." Drs. Rassman and Bernstein described the way 1mm-diameter punch incisions were made to separate the hair follicles and remove them.

In those early years, the key question for surgeons was: How do we remove the follicles? Hence, the word "extraction" was appropriately used. This term also provided a significant marketing advantage as

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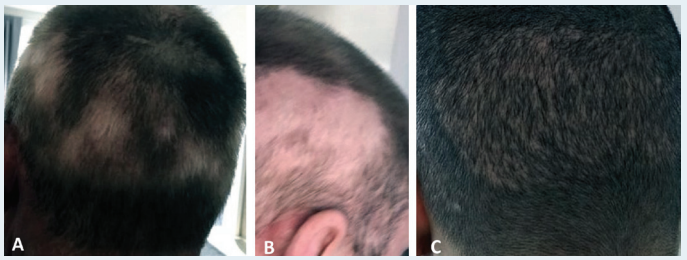
Determining Safe Excision Limits in FUE: Factors That Affect, and a Simple Way to Maintain, Aesthetic Donor Density

Sharon A. Keene, MD, FISHRS | *Tucson, Arizona, USA* | drkeene@hairrestore.com;
William R. Rassman, MD | *Los Angeles, California, USA*; James A. Harris, MD, FISHRS | *Denver, Colorado, USA*

Overharvesting and difficulties measuring variables affecting donor coverage

The explosive worldwide popularity of the Follicular Unit Extraction (FUE) method for donor harvesting (recently re-defined to reflect the more appropriate surgical description, Follicular Unit Excision) has contributed to an increase in patients affected by donor area overharvesting. This has resulted in serious cosmetic defects ranging from minor degrees of visibly moth-eaten donor areas to almost complete donor alopecia. A separate, but related, problem occurs when areas of focal donor necrosis are created by overly aggressive FUE. Figure 1 illustrates examples of various donor defects that have been seen post-FUE. Safe excision guidelines to educate doctors to avoid these complications do not currently exist. In an effort to guide medical practitioners toward safe limits of FUE, the Hair Diameter Index[1,2] and the Hair Coverage Value[3] have been proposed to aid in predicting FUE harvest limits based on hair shaft diameters and hair count/square centimeter.

FIGURE 1. Donor areas in A and B illustrate focal scarring and alopecia following FUE; C illustrates a "mottled" donor area appearance.



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While the above indices are cumbersome to measure manually, they do include the important factors of hair follicle density and hair shaft diameter. Consider, however, that hair shaft diameter is not uniform among hairs on the same head with neighboring hairs sometimes varying by a factor of 2, and variability occurs even within the same hair. Because of this variability, a sample size of at least 25 hairs must be measured for a reasonably meaningful average.[4-6] To further complicate these calculations, variable hair density between occipital and parietal areas necessitates several index measurements be obtained for a given patient during their first procedure.[7] This becomes even more complex for subsequent FUE surgeries as donor density becomes increasingly variable. More importantly, these parameters (Hair Diameter Index and the Hair Coverage Value) exclude a variety of other contributing factors and circumstances that at times may be more important to the cosmetic appearance of the donor area. A simpler approach described in this paper focuses on easily measured baseline follicular unit (FU) density, safe excision density, and residual donor FU density after FUE. Surgical judgment based on experience as well as knowledge and understanding of contributing cosmetic factors can be used to fine-tune maximum FU excision and residual FU donor density.

Respecting the safe donor area

Experienced hair restoration surgeons know that the same factors that allow us to successfully restore density to the recipient area are relevant to the appearance of cosmetic coverage and fullness in the donor area. Furthermore, various circumstances can increase the importance of one factor over another. To maintain safe donor area (SDA) excision densities (FU/cm²) after FUE, we must first consider basic tenets imposed by donor area limitations. Permanent donor follicles are finite for all patients. Those patients destined for advanced patterns of hair loss are caught in a hair restoration conundrum: the larger the area of projected need, the smaller the donor area is to provide for it. To determine the safe excision density, we must first consider donor area limitations and avoid excising from areas likely to be affected by androgenetic alopecia (AGA). This usually means excluding the nape of the neck, superior lateral fringes, and the superior aspects of the occiput near the regions of the balding crown.

IMPORTANT VALUES

1. **Preoperative density (65-85)—measured prior to surgery**

Values below depend on the hair characteristics described in this article:

2. **Safe single pass excision density—FU/cm² that can be safely excised in one surgery (10-25)**
3. **Maximum excision density—FU/cm² that can be safely excised in multiple surgeries**
4. **Residual donor density—FU/cm² projected for minimum density necessary for satisfactory donor area coverage after one or more surgeries (40-50)**

Predicting the SDA is influenced by the following: a patient's age at the time of assessment, the projected pattern of hair loss based on family history, whether the patient has or is likely to maintain a stable pattern, and whether a patient will progress to more advanced patterns of hair loss. Successful hair transplantation should be considered using a "master plan" that considers hair loss from natural causes as well as the potential loss of hair caused by the surgery. Patients presenting with advanced patterns of hair loss must be educated as to the limitations of donor supply prior to surgery or risk falling prey to those who promise to deliver more hair to the recipient area than the donor area can safely provide. These promises can be made by inexperienced or unscrupulous doctors, and in some cases by unlicensed technicians. When this occurs, what was previously a recipient site focus for the patient can become a donor area nightmare. Experienced surgeons respect the donor area and its follicles in the way they are harvested and managed. If not, both the recipient and donor areas can be adversely affected.

How follicular distribution affects cosmetic donor density

In addition to density and hair shaft diameter, other factors influence cosmetic coverage in the donor area. While each patient's donor density in their occipital or temporal areas is generally consistent, the follicular unit *distribution* within each square centimeter can be irregular. After excising FUs, it is important to attempt to leave the remaining density consistent in each square centimeter excised. Other factors impacting cosmetic density include hair/scalp color contrast and the three-dimensional properties impacting the appearance of volume, which include straight versus wavy or curly hair, the exit angle of the hair, and the patient's planned hair length. This article focuses on the importance of these additional factors in greater detail, and on the clinical situations in which one factor becomes more important than the others. We will introduce simple predictive methods including **safe single pass excision** density based on the preoperative FU density and **maximum excision density** based on the projected **minimum residual donor FU density** necessary for satisfactory donor area coverage. Minimum residual donor FU density depends on the hair characteristics described in this article.

The inability to predict cosmetic improvement on the basis of hair counts and hair shaft diameter alone is shown by the cosmetic limits of 4mm-diameter punch grafts in common use until the mid-1990s. Each graft contained 15-20 FUs placed in punch holes in the recipient area surrounded by bare scalp. This technique created 4mm-diameter punch scars in the donor area. Although a canopy of hair was created to cover the recipient area, short hair styles exposed a pluggy distribution of hair. The same unnatural pattern of hair distribution was seen in the donor area.[8] The pattern of distribution for hair numbers and hair shaft diameter must be considered when follicles are redistributed to the recipient area as well as in the donor area after the excision process.

Visible FUE donor area defects can occur if too many FUs are removed too close to each other. While small punches (<1mm) leave tiny donor scars, increases in excision density create larger spaces between follicular groupings. Jimenez et al. established that normal follicular spacing varies between

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1-1.4mm[9] and excising follicular units doubles that distance. Large spaces between residual FUs can create a mottled appearance. Excision distribution must be irregularly uniform across the donor area—with all square centimeters roughly equal in excision density. If both hair and FU density in one area of scalp is not balanced with other harvested areas, a visible low-density cosmetic defect can be created that may be detectable upon casual observation. Figure 2 illustrates this problem in a young Asian man, whose preferred hairstyle and hair characteristics contribute to a visible and disturbing defect in density.

FIGURE 2. Young Asian male disturbed by pattern of donor scarring following a single session of FUE.

Other factors affecting donor coverage

In addition to the natural distribution of FUs, hair and scalp color contrast is an important cosmetic factor when considering donor coverage. Minimizing contrast between hair and scalp to effectively mask thinning underlies the premise and focus of scalp camouflage agents and techniques that color the scalp and reduce or eliminate the contrast.[10] A similar goal is achieved with scalp micropigmentation.[11] Patients with lighter hair color and fair scalp, or dark hair and dark scalp, have minimal contrast and can achieve acceptable aesthetic results with less density in the recipient area and can support a lower residual donor area density. However, the reverse is also true, referring again to Figure 2 where high contrast is a significant contributing factor to the visibility of donor area scarring. Had the patient's hair been blonde, gray, or salt and pepper, the area of visibly thinner hair would have been much less apparent or not detectable at all.

It is also known that wavy or curly hair covers the scalp better than straight hair. This advantage applies to the donor area appearance when hair is sufficiently long for the curl to manifest itself. In the case of tight curls, hairs can complete a circle, cover more scalp, and double or triple the visual impact of a single hair follicle. When this occurs, the effect of curl is more important than hair shaft diameter, making a coverage value or hair diameter index inapplicable.

Consider, for example, straight, black hair 80 microns in diameter compared to tightly curled, black hair of 60 microns, both grown to 1 inch. This length allows the curly hair to complete 360 degrees or even triple the strand on itself. The lower diameter, curly hair for the same numbers will appear more dense. Add to this scenario dark scalp with minimal contrast, and the resulting visual effect is more than a multiplier of the original hair diameter. For wavy hair, the greater the frequency of undulations, the greater the appearance of volume (fullness). Wave and curl improve the ability of the hair canopy to block light. Visual qualification of these hair characteristics is complex, with classification of curl and curvature described by De La Mettrie and others.[12] Complex mathematical equations are required to duplicate curl in computer software imaging, with no simple way to quantify the visual impact on density or donor area coverage.[13] This is particularly true given the greater or lesser impact that occurs as a function of hair length and layering. Regardless of the positive visual impact of a wave or curl, it should not be viewed as a reason to overharvest and reduce residual FU density. If a patient gets out of a swimming pool or is in a wind storm, or merely wishes to wear a short hair style, these valuable hair characteristics lose "coverage" value.

When the exit angle of the hair is more acute, it provides more effective "shingling," which improves the appearance of scalp coverage and cosmetic fullness. This acute angulation is a natural orientation of hair in the donor area for most patients, which generally layers over itself, maximizing light blocking. Harris observed that Asian patients, who have more obtuse exit angles, are at greater risk for visible donor thinning from FUE.

Postoperative hair length is a critical factor for determining cosmetic coverage in the donor area. For patients who plan to wear their hair short (3-6mm), also known as a #1-2 guard on clippers used by barbers, there will be no hair "canopy" and little or no layering benefit. The residual donor densities in these patients must be higher than for those who keep their donor area hair longer. Figure 3 illustrates donor defects that could be potentially less noticeable with longer hair styles. Very short hair in the donor area (also known as stubble) eliminates any contribution from wave or curl and strongly reduces the contribution of even coarse hair. Short or stubble hair will accentuate the "empty spaces" created by FUE, making FU distribution and their numbers per cm^2 more important than hair counts per cm^2. For example, if hair in the donor area is 3mm long at a residual donor density of 50 FUs averaging 1.5 hairs/FU vs 30 FUs averaging 2.5 hairs/FU, despite equal hair numbers, the higher FU density will reveal fewer and smaller bare spaces. In this situation, high contrast color differentials can also exacerbate any lower residual FU donor density present (e.g., black hair on light scalp).

FIGURE 3. Longer hair length could assist in donor scar coverage.

Knowledgeable surgeons can integrate these hair characteristics to successfully excise large numbers of grafts with high excision densities while maintaining cosmetically adequate donor coverage. Figure 4 illustrates a successful excision of >6,000 FUs in a patient with favorable hair characteristics including hair/scalp color contrast, medium hair shaft diameter, and wavy hair. Comparison of before and after photos of his donor area reflects a visible decrease in overall donor volume; however, the donor area coverage remains aesthetically pleasing for the patient's hair style and hair characteristics.

Patients must be counseled and cautioned about donor limitations if they have less than favorable hair characteristics in the donor area, such as lower hair shaft diameter, straight hair, high color contrast between hair and scalp, an obtuse

FIGURE 4. Serial photos document cosmetic changes after 6,000 FUE grafts *(compliments J. Harris).*

exit angle of donor hair, average or lower baseline FU or hair follicle densities, or length and style that exposes the scalp.

Donor area capacity

The donor area capacity for FUE can be calculated based on 1) the size of the donor area (in cm^2), 2) baseline FU density per cm^2, 3) the maximum excision density per cm^2, and 4) residual donor FU density. For example, a safe donor area of $189cm^2$ (27cm × 7cm) with baseline average density 65 could easily support an excision density of 10-15, yielding 1,890-2,835 grafts. This would leave a residual donor density of 50-55 in the donor area. This yield may be sufficient for patients with Class II-IV patterns of hair loss depending on the recipient area size and hair characteristics. However, the requirement for greater yields to achieve cosmetic goals in Class V-VII patients may risk overharvesting. Many of these patients will need 3,000-5,000 grafts (or possibly more), requiring excision densities of 16-26 in the above example, leaving residual densities less than 50 (39-49). Depending on other hair characteristics, the residual donor density in this range could begin to appear thin, see-through, and mottled. It is always important to be aware that meeting a patient's goal for recipient area density or coverage may not be achievable without creating visible donor area thinning including alopecia.

Maximum excision density without overharvesting

How can a surgeon determine a safe maximum excision density and avoid the complications of overharvesting? What factors contribute to focal necrosis? Currently no single algorithm integrates all the various factors to predict the minimum adequate donor area density after FUE. However, in every circumstance, FU donor density is a critical factor and this seems a reasonable variable to examine first when identifying safe levels of excision and residual donor density.

Baseline FU density, as a parameter, can be used by a surgeon to educate patients on how excising a particular number of grafts per square centimeter (excision density) will yield a particular number of grafts for transplantation. Furthermore, excision density can be used to explain the visual impact on donor area density (residual FU donor density) incorporating a surgeon's knowledge of the patient's hair characteristics and planned donor length.

Each patient's donor area should be examined and baseline FU density (FU/cm^2) measured at the outset of every preliminary evaluation. FU density in both the occipital and temporal donor regions of the safe zone can be determined using a simple tool, the densitometer, as described by Boden (Figure 5).[14] Average density in the donor area reveals ethnic variation ranging from 65-85 in the central occipital donor area in Caucasians to 61-63 in Asians.[9,15] African hair density has the lowest FU density.[11] While absolute hair counts create the fullness of the canopy, residual FU density and its distribution within that area will determine the cosmetic appearance of the donor area after FUE, therefore, FU density provides a useful barometer until lower residual densities require the incorporation of other factors.

FIGURE 5. Densitometer is an easy tool to determine baseline FU density.

Normal hairline and temporal densities have been noted to average 40-50.[16] A residual donor area density of 40-50 can be expected to maintain adequate coverage for a patient with medium diameter hair that is straight or mildly wavy and has moderate contrast between hair and skin color. A lower residual density could be risky, especially in patients with less favorable hair characteristics such as fine, straight black hair and light scalp. Man-made density charts have been used to compare density of 20-40 when hair groupings are all 1's and 2's versus all 3's and 4's.[17] These charts, shown in Figures 6 and 7 (on page 10), were created by author Dr. Sharon Keene to illustrate the cosmetic importance of hair counts for a certain graft density, but they can also be used to illustrate density issues for the donor area. For example, surgeons must be aware how selectively excising larger FUs during FUE procedures can impact residual donor density, especially after aggressive excision has occurred. As the figures illustrate, residual densities of 20-30, especially when groupings are all 1-2 hairs, are "see-through," thin, and must be avoided. Alternatively, the density chart also illustrates that patients with above average numbers of 3- to 4-hair FUs, if left *in situ*, can tolerate lower residual density and still provide aesthetically pleasing coverage at longer hair lengths.

Most FUE experts recommend 10-15 excisions/cm^2 as a safe single pass density in a person with baseline average density of 65-75. Article co-author Dr. James Harris reports a routine use of higher excision density in the range of 20-25 without problems. In the case of a patient with an average baseline density of 70, an excision density of 10-15 leaves a residual FU donor density of 55-60. A second pass FUE surgery with the same excision density would further reduce

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FIGURE 6. Man-made density charts, black hair, from 20-50 FU/cm^2. Top row illustrates "see-through" appearance at 20-30; bottom row cosmetic coverage at 40-50.

FIGURE 7. Top row illustrates "see-through" for both black and blonde hair at 20 FU, all 1- to 2-hair groupings. The bottom row compares blonde hair at 30 FU/cm^2 with all 1- to 2-hair groupings vs all 3- to 4-hair groupings.

residual density to 40-45, and a third pass to 25-30. Visible thinning may be expected in the latter case, but it could also appear at a residual density between 40-50, particularly when hair shaft diameter is low, contrast is high, hairs are straight, and the hairstyle is short.

The importance of higher-than-average baseline density becomes apparent if we measure residual density in a patient with a baseline density of 100. If this patient undergoes excision at a density of 10-15, the residual donor density will go down to 85-90, resulting in a higher residual density than the baseline density of the previous patient. It is unlikely that a reduction of FU donor density as high as 50% for a patient with 100 will leave visible thinning as this will still provide a residual donor density of 50 regardless of other hair characteristics. In comparison, a maximum excision density of 30-35% for patients with an average density of 70 will leave a residual density of 46-49; the latter is <50, and cosmetic coverage will depend on other hair characteristics previously discussed. Higher maximum excision density can be safe when baseline donor FU densities are higher than average, leaving a higher residual donor FU density. These are relatively simple parameters to obtain in a first-time patient and require simple subtraction to make the calculations.

A more complex situation arises in repeat FUE cases, where excision density from the first surgery may not be uniform and baseline density is low. In such cases, any areas of visible thinning should be documented, measured, and avoided. The "new" baseline density may require measurements in several areas, with the goal to avoid creating more areas of "visible thinning" and to determine a safe excision density that will maintain a cosmetic residual density (40-50), modified based on hair characteristics and planned hair style. Density in the thinning areas can allow the surgeon to know cosmetic density limits for that patient's hair characteristics. ***The centimeter-by-centimeter examination that occurs during surgical FU excision to avoid overharvesting underscores the need for experienced and ethical professionals to make the medical decisions necessary for safe maximum excision density.***

While an average of 10-15 excisions/cm^2 is reportedly safe for a single pass in patients with at least average baseline densities, it also appears safe in avoiding focal necrosis. Contiguous FU excisions, where the punch holes merge with each other, must be avoided, not only to prevent areas of empty skin, which produces mottling, but also to reduce the risk of local devascularization, which could lead to scalp necrosis. Higher excision densities would seem to increase the risk of necrosis, but an exact maximum to avoid this complication has not been identified.

CONCLUSION

There are many factors that contribute to visual hair "fullness" in both the recipient and the donor areas. Avoiding the complications of visual overharvesting or focal necrosis from FUE requires that the surgeon pay attention to irregularly distributed, uniform levels of safe excision densities to maintain a residual density of 40-50. This should leave a donor area that does not appear thin for the patient's hair characteristics and hairstyle the patient prefers to wear. Conservative single pass excision density of 10-15 in virtually all patients who have normal baseline densities is safe. A higher single pass donor FUE density of 20-25 may be possible when the baseline donor densities are significantly higher than average. Hair characteristics, such as the thickness of the hair shafts, the degree of curl or wave, the color contrast between hair and scalp, the exit angle of hairs on the donor scalp, and whether hair will be worn short or long, allow the surgeon to then alter the residual donor FU density using his or her best judgment. While there is no single mathematical algorithm to incorporate all of the factors that contribute to donor area density, a weighted system may be possible to further enhance our ability to predict safe excision and residual donor densities.

References

1. Harris, J.A. Application of the Hair Diameter Index (HDI) in Obtaining a Target Hair Density. Poster presented at the 11th Annual Scientific Meeting of the International Society of Hair Restoration, New York, New York, October 2003.

2. Harris, J.A. Introduction of the Hair Volume Index (HVI) and Its Correlation to Subjective Visual Hair Density. Scientific Session presentation and poster presented at the 11th Annual Scientific Meeting of the International Society of Hair Restoration Surgery. New York, New York, October 2003.
3. Erdogan, K. Coverage Value and Graft Calculation. Presented at the World FUE Institute Meeting, 2015. https://youtu.be/O-gu9rJZhiY
4. Harris, J.A. Biodiversity of Hair Shaft Diameters: A Statistical Analysis. Poster presented at the 11th Annual Scientific Meeting of the International Society of Hair Restoration Surgery. New York, New York, October 2003.
5. Robbins, C.R. The Physical Properties of Hair Fibers. In: *Chemical and Physical Behavior of Human Hair*. Springer-Verlag Berlin Heidelberg, 2012; pp. 586, 597.
6. Ho, Y., et al. Variation and heritability in hair diameter and curvature in an Australian twin sample. *Twin Research and Human Genetics*. 2016(Aug); 19(4):351-358.
7. Vecchio, F., et al. Perception of baldness and hair density. *Dermatol*. 2002; 204(1):33-36.
8. Bernstein, R.M., and W.R. Rassman. The logic of follicular unit transplantation. *Dermatol Clin*. 1999(Apr); 17(2):277-295.
9. Jimeniz, F., and Ruifernández, J.M. Distribution of human hair in follicular units: a mathematical model for estimating the donor size in follicular unit transplantation. *Derm Surg*. 1999(Apr); 25(4):294-298.
10. Donovan, J.C., et al. A review of scalp camouflaging agents and prostheses for individuals with hair loss. D*ermatol Online J*. 2012(Aug); 18(8):1.
11. Rassman, W., et al. Combining follicular unit extraction and scalp micropigmentation for the cosmetic treatment of alopecia. *Plast Reconstr Surg Glob Open*. 7 Nov 2017; 1-6.
12. De la Mettrie, R., et al. Shape, variability & classification of human hair: a worldwide approach. *Human Biol*. 2007(Jun); 7(3):265-281.
13. Hadap, S., et al. Strands and Hair—Modeling, Simulation and Rendering. Presented at the 34th International Conference and Exhibition on Computer Graphics and Interactive Techniques, August 2007, San Diego, United States. Submitted 22 Sep 2010.
14. Boden, S. FUE Donor Evaluation and Surgical Planning. In: *Hair Transplant 360*, Volume 4: Follicular Unit Extraction. JP Medical Ltd., 2015(Nov), p. 114.
15. Ortega-Castillejos, D.K.A., and D. Pathomvanich. Retrospective assessment of follicular unit density in Asian men with androgenetic alopecia. *Dermatol Surg*. 2017(May); 43(5):672-683.
16. Keene, S. Natural hairline density in men: findings of a pilot survey. *Hair Transplant Forum Int'l*. 2009; 19(2):47-48.
17. Keene, S. Man-made density charts answer the question: Which is more important for density, graft counts or hair counts? Poster presented at the 2010 Annual Scientific Meeting of the ISHRS, Boston, Massachusetts, USA. ■