

Examination of the Exit Angle of Hair at the Skin Surface versus the Internal Angle of Hair as It Relates to the FUE/FIT Harvesting Method

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*Conflict of Interest: Dr. Paul Rose owns stock in Restoration Robotics. He uses the ARTAS® System and is a consultant to Restoration Robotics. Dr. Miguel Canales owns stock shares in Restoration Robotics.

ABSTRACT

The FUE/FIT (follicular unit extraction/follicular isolation technique) procedure continues to gain acceptance as a method for harvesting donor grafts. The procedure is based on removing follicular units (FUs) or portions of FUs to use as grafts. A manual punch, mechanized punch, or robotic device is used to remove the FUs.

No matter which method of harvesting is selected, there is concern regarding recovering intact FUs and avoiding transection of hair follicles. A common approach is to align the opening of the punch used with the path of the trimmed hair follicles of an FU and dissect along this path. While some hair follicles under the skin may follow the angle above the skin, others may not, which can lead to greater transection rates.

Hair follicles within dissected slivers were examined from 13 patients. The internal and external hair growth angles of over 300 follicles were examined. Below, we examine the approach to harvesting and the means to decrease transection rates by understanding the path of hair follicles within the skin and as they emerge from the skin.

INTRODUCTION

FUE is a method for harvesting donor hair for hair replacement.^{1,2,3} The technique is based on using a punch, whether by hand or mechanized device, to remove FUs or intact hairs from portions of FUs.^{4,5}

Problems that can occur with the FUE/FIT technique include capping, topping, buried grafts, and adhesion of grafts that can make removal difficult.⁶ The most important problem, however, is transection, which may result in hairs that do not grow.^{7,8} Although some physicians feel that large numbers of transected hairs that remain in the donor area may re-grow, extensive studies on this are lacking. Devroye demonstrated that approximately 60% of transected hairs regrew after FUE removal from the donor area.⁹

To perform FUE, the punch opening is usually aligned with the visible hair direction at the skin surface. Pursuing the incision along this apparent course of the hair may be misleading and result in transection. The reason for this is that, in many instances, the hairs within the FU exit the skin surface at a different angle than the internal course of the hairs within the dermis and subcutaneous tissue.^{10,11}

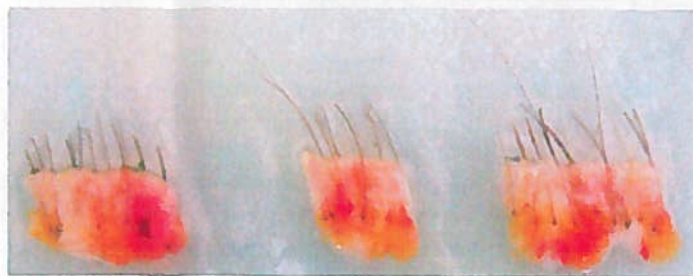
In this study, we looked at the variability of hair exit angle from the skin surface as opposed to the internal angle within the skin. We also reviewed the trigonometry of hair angulation and a means on deciding punch diameter to try to ensure complete removal of FUs and minimize transection.

METHOD

The donor area of each patient was marked and anesthetized with 1% xylocaine with epinephrine. After anesthesia, a No. 10 scalpel blade was used to incise the skin to the dermal/subcutaneous interface. No tumescence was used. A second parallel incision was made to create a full-thickness "strip" of tissue. The tissue was elevated and removed (Figure 1).

Sections of tissue were removed from the center occipital and the lateral aspects of the strip. Slivers were created from this tissue and photographed. The photographs were reproduced and enlarged. The angle of the hair resulting from the path inside the tissue as opposed to the exit angle above the skin was measured with a protractor (Figures 2 and 3). The data was collected to determine the average angle and range of angles evident in the specimens examined.

FIGURE 3. Photograph depicting slivers from a single patient. Notice that the hair angles can vary from hair to hair even within the same FU. Hairs may diverge and cross one another.



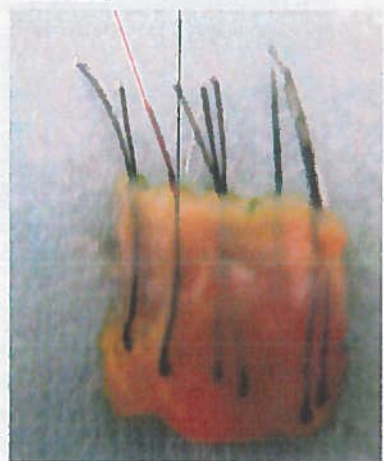
RESULTS

In this study, 310 hairs, from 13 patients, were examined within the slivers obtained. It was noted that the hairs within an FU often crossed or splayed away from each other. In addition, a greater change in angles was noted with curly or wavy hair.

FIGURE 1. Photograph demonstrating the strip recovered and the angle of hairs at the edge of an incision through the strip.



FIGURE 2. Photograph demonstrating a sliver and the angle lines marked for a hair to allow for measurement.



The average angle change (external vs. internal) was 6.43°, which included straight and curly hair. Curly hairs were considered to be hairs that exhibited a prominent curvature creating almost a "C" or a reverse "C" shape. The average angle change with only curly hair was 14.65°, however, sometimes a "curly" hair could be found amongst straighter hairs (Figure 4). In our

FIGURE 4. Photograph of a sliver in which there are straighter hairs mixed with curly hair.



FIGURE 5. Diagram indicating the trigonometric measurements to consider in trying to decide on a punch of appropriate diameter to decrease possible transection. The calculation applies to a punch entering perpendicular to the skin.

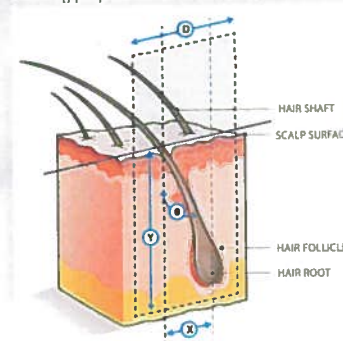


Figure 5 demonstrates the relationships and parameters to consider when deciding on the punch size and angle that allows for complete FU harvesting. Where "D" is the diameter of the punch, "Θ" (theta) is the change in angle of the follicle below the surface of the skin, "Y" is the depth of the punch insertion, and "X" is the lateral offset of the follicle bulb.

Using the relationship $\tan(\Theta) = X/Y$, it is apparent that $d/2$ is $> X$. For example, if theta is equal to 6°, and Y equals 4mm, then $X = 4 \tan(6^\circ) = 0.42$.

Therefore, if the punch size D is 1mm, then there should be little or no damage to the follicles in that FU. On the other hand, if the punch is 0.75mm, there is a significantly greater likelihood of damage to hair follicles. This assumes a depth of insertion beyond the epidermis and into the papillary dermis. An important question is: What is the maximal curvature of the follicle that can be accommodated by a given punch? What is the maximum theta? For example, if $y = 4$, then $x = d/2$ (maximum allowed) and the punch size (D) is 1mm, what is theta? To determine theta, $\theta = \tan x/y = \tan(0.5)/4 = 7.1^\circ$.

DISCUSSION

FUE/FIT is a technique for harvesting grafts that requires understanding of the relationship of the path of hair within the skin with the exit angle of the hair(s) from the skin. As this study demonstrated, the course of hair in the skin can differ dramatically from the exit pathway. Often, the hair exit angle from the skin is actually more acute than the path inside the skin. Failure to recognize this and make appropriate adjustments with the punch can result in high transection rates.

A modification of the surgical technique to consider is to raise or lift the punch slightly a few degrees more perpendicular after the initial entry into the skin. This motion may allow the

surgeon to compensate for the typical change in angle that occurs when going from skin surface, through the epidermis, and into the fat. The angle change is usually less acute than it appear on the skin surface. The use of a blunt punch may provide an added measure of safety in terms of avoiding transection.¹²

This study demonstrated that hairs within the same FU can travel in very different routes and at times even curve backwards. This can create problems, especially with patients with very wavy or curly hair.

While this study provided important information for an approach to harvesting using FUE/FIT, there are several deficiencies.

The study was not done *in vivo* and the skin was anesthetized prior to removal. The anesthesia may have altered the hair angle in the sliver examined. Anecdotally, we noted that when saline was injected into the tissue prior to sliver creation, the hair angles could be altered. Saline injection in the dermis caused the hair to rise in a less acute angle. Similarly, saline injected into the fat also caused elevation of hair exit angle in the fat but to a lesser extent.

Some physicians feel that tumescing the dermis prior to harvesting can allow for an easier alignment of hair in the FUE punch. Other physicians advocate not using tumescence. Exerting external traction upward on the donor area to diminish the change in angle between the skin exit angle and the internal hair angle may also help.

Additionally, the use of a shallow incision with a sharp punch has been used by some surgeons. The use of a shallow incision followed by subsequent use of a blunt punch as described by Harris can be an alternative approach to harvesting.¹¹ A robotic system (ARTAS®, Restoration Robotics, San Jose, California, USA) employs an initial sharp superficial dissection accompanied by the almost simultaneous use of a blunt punch to core out FUs to lower transection rates.¹¹ Many other drills and punches have come onto the market developed by surgeons such as Cole, Rassman, Devroye, Park, and Boaventura that are purported to lower transection rates.

CONCLUSION

The use of the FUE/FIT donor harvesting method is becoming more popular. When using FUE/FIT, it is necessary to properly assess the hair angle in the skin and the angle upon exiting the skin to ensure limited follicle transection.

This study shows that hair exit angle can vary significantly from the internal angle and the deviation is greater for curly or wavy hair.

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