## A Mathematical Proof of How the Outgrowth Angle of Hair Follicles Influences the Injury to the Donor Area in FUE Harvesting

Follicular unit extraction (FUE) is considered to be a minimally invasive hair transplant method.[1,2] However, the trauma on the skin is sometimes very noticeable especially if the patient wears very short hair. This injury depends on many factors, with the outgrowth angle of hair follicles being an important one. The objectives of this study were to evaluate the mathematical relationship between the outgrowth angle of the hair follicles and the injury to the donor area, to measure the amount of trauma, and to provide information on how this can be reduced.

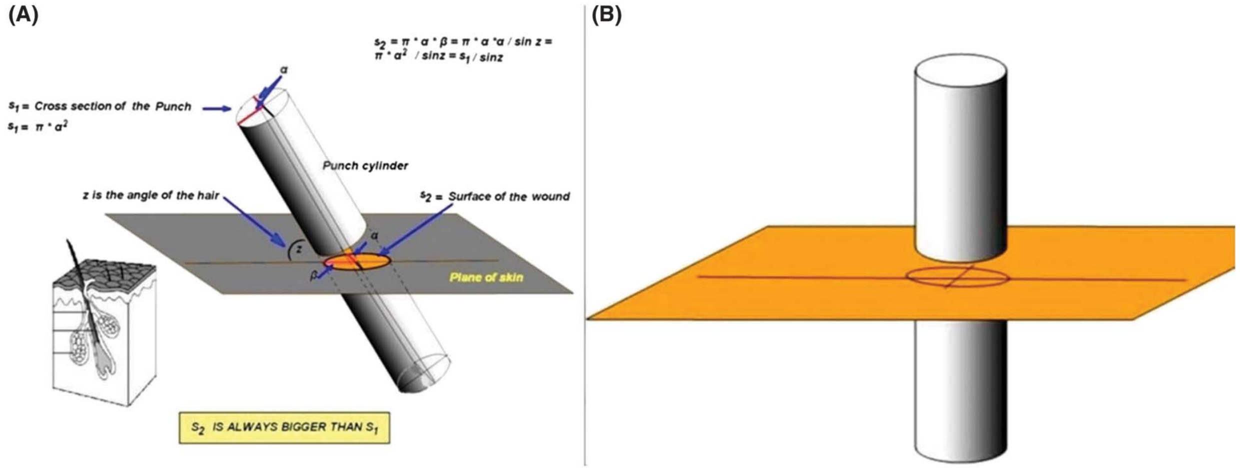


**Figure 1.** (A) The cylinder of the punch cuts the surface of the skin at a certain angle *z* causing wound surface larger than its cross section. (B) When the punch is placed at 90°, the wound surface is equal to the punch cross section.

## Methods

In order for a follicular unit to be extracted safely from the donor area, the axis of the punch should be aligned with the apparent direction of the hair on the skin surface.

The diagram in Figure 1A represents the cylinder of the punch cutting the surface of the skin at a certain angle $z$, where $z$ is the outgrowth angle of the hair follicles.

It can be seen that although the punch cross section $s_1$ is circular, the shape of the wound $s_2$ is elliptic. Based on this important observation, we can find from trigonometric theory that $s_2 = \frac{s_1}{\sin z}$.

Presuming that $\alpha$ is the radius of the cylinder of the punch, we can safely make the assumption that one of the two semi axes of the elliptic shape wound is equal to $\alpha$. The second one $\beta$ is given by the formula:

$$\beta = \frac{\alpha}{\sin z}. \quad (1)$$

$$\text{So } s_1 = \pi \times \alpha^2, \text{ where } \pi = 3.14, \quad (2)$$

$$\text{while } s_2 = \pi \times \alpha \times \beta = \frac{\pi \times \alpha \times \alpha}{\sin z} = \frac{\pi \times \alpha^2}{\sin z} = \frac{s_1}{\sin z}, \quad (3)$$

since $\sin z \,\varepsilon\, [0, 1)$ when $z \,\varepsilon\, [0, 90°)$, $s_2$ is always bigger than the $s_1$, which means that the punch causes a wound surface bigger that its cross section.[3]

The higher the angle $z$ the smaller the surface of the wound and vice versa.

The only case where $s_1 = s_2$ occurs when the outgrowth $z$ is at 90°, in other words, when the axis of the punch is placed perpendicularly to the skin surface (Figure 1B).

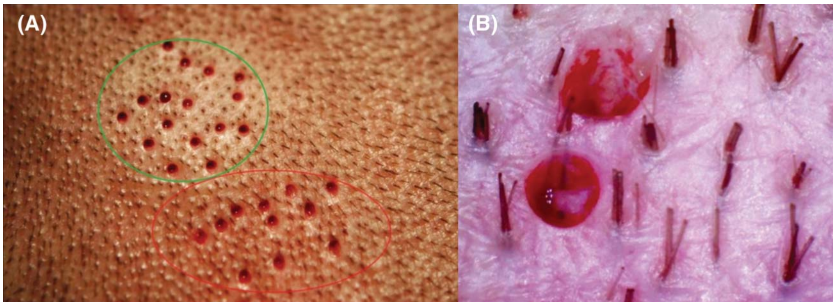


**Figure 2.** (A) A 1.0-mm punch causes different size holes at different angles. The holes within the green circle were produced by placing the punch perpendicularly to the surface of the donor area, whereas the holes within the red circle were produced by placing the same punch at an acute angle. (B) The micropicture (ProScope HR2 digital micropicture; magnification, ×400) illustrates the difference of each wound produced by the same size punch at 90° and 30°, respectively.

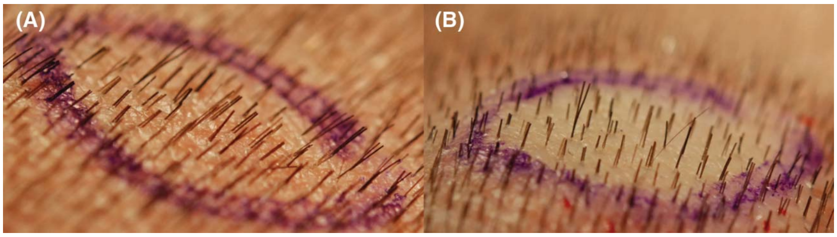


**Figure 3.** (A) Before injecting normal saline. (B) After injecting normal saline intradermally. The hair follicles become more vertical so the punch can be placed perpendicularly to the surface of the skin producing smaller size holes.

## Results

Given that the angle $z$ is at 30°, then $\sin z = \sin 30° = \frac{1}{2}$. It is apparent that Equation 3 implies $s_2 = 2s_1$. This means there is a 100% increase in the trauma that is caused by the punch.

In Figure 2A, it can be seen that the same size punch causes different size holes at different angles, whereas in the micropicture (Figure 2B), the difference between the surface of the wounds, produced by the same size punch at 90 and 30°, respectively, is very noticeable. In other words, a punch perpendicular to the skin produces a circle, but a punch directed at a more acute angle creates an ellipse significantly larger in surface than the circle.

To manage this problem, we propose that normal saline be injected intradermally into the donor area. In this way, the hair follicles become more vertical (Figure 3) and the value of $\sin z$ increases making the value of $s_2$ much smaller.

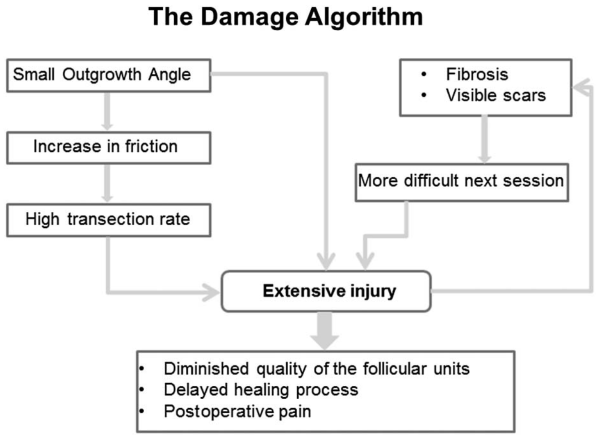


**Figure 4.** The damage algorithm shows how a small outgrowth angle dramatically affects the trauma to the donor area.

Based on the principles that the surface of the circle $s_1$ is given by Equation 2, where $\alpha$ is the radius of the punch, and the surface of the wound is given by Equation 3, we find that a punch size of 0.8 mm in diameter corresponds to a cross section surface equal to 0.5024 $mm^2$ and causes a surface wound of 1.0048 $mm^2$, when the angle $z$ is at 30°. However, after injecting normal saline, a punch size 1.00 mm in diameter corresponds to a cross section surface equal to 0.785 $mm^2$ and causes the same size of wound when the angle $z$ is at 90°. Even when using 56.25% larger cross section surface punch, the skin injury is decreased by 21.98%.

## Discussion

Although FUE is considered to be a minimally invasive method, the trauma on the skin still remains noticeable, and this is influenced by many factors like the punch size, the number of the follicular units extracted per square centimeter, the transection rate,[4] previous operations, the outgrowth angle of the hair follicles, and the thickness of the walls of the cylinder of the punch. At this point, we should mention that for mathematical reasons we took the walls as zero. In practice, this is not accurate. Based on our mathematical calculations, it seems that the value of the outgrowth angle triggers a series of events that affect the damage algorithm as it is shown in Figure 4.

A small outgrowth angle causes damage to the donor area, but at the same time increases friction during the punch rotation on the skin and the transection rate, which inevitably causes further injury. The latter implies fibrosis and visible scarring on the donor area making the next session more difficult, which results in further injury to the donor area. The possible consequences of the extensive injury could be the diminished quality of the follicular units, the delayed healing process, and the increased probability of postoperative pain.

However, the injection of normal saline makes both the direction of the hair follicles more predictable and the skin firmer while decreasing the transection rate and assuring that more intact follicular units can be extracted. Therefore, we suggest that 0.2 to 0.3 mL of normal saline per square centimeter should be injected intradermally into a small section (approximately 8 $cm^2$) of the donor area for harvesting to begin. Depending on how quickly the normal saline drains away, this process is repeated either in the same region of the donor or in a new area until the desired number of follicular units is obtained.

Furthermore, it should be emphasized that by injecting normal saline, the skin is stretched. So once normal saline has drained away, the skin returns to normal. Thus, the dimensions of the surface of the wound are further reduced. This important fact results in accelerating the healing process, decreasing the degree of scarring, and minimizing any possible blood loss. Of course, it depends on our medical team to evaluate this reasonable hypothesis further by investigating persuasive evidence and validating all the experimental results.

## References


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## Google Glass: Dermatologic and Cosmetic Surgery Applications

Technologic advancements have the ability to affect our lives in countless ways and each time a new digital device is introduced, it is human nature to figure out possible applications for our professional lives as well. When Apple first introduced their iPad, people were admiring this technology but questioned what it would be used for. A few short years showed that the iPad had countless applications in the personal and professional lives of tens of thousands of individual people. For dermatologists and cosmetic surgeons, the iPad and related "apps" can be used for practice management, digital imaging, clinical photography, patient education, and numerous other uses. This was a case of technology looking for purpose.

Another device that is (or will shortly be) available and has huge possibilities to enhance the practice of dermatologic and cosmetic surgery is Google Glass. Google Glass is a futuristic device that is basically a combination of your computer and cell phone and sits on an eyeglass frame just above the wearer's field of vision. It looks much like the device Arnold wore in the "Terminator" (Figure 1).

So, what does it do and what can it do for dermatology and cosmetic surgery? Out of the box, the glasses are like eyeglasses without lenses although you can order them with lens for normal glasses and/or sunglasses. On wearing them, a sensor over the temple activates