

Orientation of Multi-Hair Follicles in Nonbald Men: Perpendicular Versus Parallel

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BACKGROUND There has been much debate about the orientation of multi-hair grafts in order to obtain an appearance of fullness after the hair transplantation.

OBJECTIVES To analyze natural orientation of multi-hair follicles and the influence of hair flow from the crown swirl.

METHODS Natural orientation of follicles was analyzed microscopically in 100 nonbald men: a clockwise whorl flow group (50 men) and a counterclockwise group (50 men).

RESULTS The majority of multi-hair follicles were oriented perpendicular to the radial line from the whorl in both the groups. The percentage of perpendicular orientation was large in the peripheral and middle scalp areas (49–79%), and it decreased in the vertex (38–49%, $p < .05$ or $.01$). The percentages of parallel, right oblique, and left oblique orientation were small in the peripheral area with a slight increase in the vertex (3–12% vs. 14–24%, $p < .05$ or $.01$).

CONCLUSION Original orientation of multi-hair follicles was mainly perpendicular to the radial line from the whorl irrelevant to the crown swirl hair flow. Multi-hair grafts transplanted perpendicularly would look similar to the natural hair follicles in the front half of the scalp.

Kuniyoshi Yagyu, MD, Koki Hayashi, MD, and Steven C. Chang, MD, have indicated no significant interest with commercial supporters.

Natural appearance and increased density are the main goals of hair restoration surgery. For this purpose, the importance of graft orientation in the recipient area and the superiority of the coronal incision to the sagittal one have recently been debated.^{1–3} Several arguments, however, are based on subjective data. We planned this study to analyze the natural orientation of multi-hair follicles in the scalp of nonbald men. We also analyzed the influence of curvilinear and outward hair flow from the crown swirl on the natural hair orientation in the scalp.

If all the natural multi-hair follicles grow in a simply coronal or sagittal orientation in the scalp, they would appear horizontal or vertical when we view them from the front using a microscope. In clinical patients, however, the majority of multi-hair follicles appeared oblique when we viewed hair follicles from the front toward the back in the anteroposterior direction (Figure 1). If we made a small change in the observational direction, the majority of the multi-hair follicles appeared horizontal. What was the direction? The answer was radial direction from the whorl (Figure

2). Therefore, we analyzed the natural orientation of multi-hair follicles microscopically using the radial observational direction from the outside toward the crown swirl.

Patients and Methods

One hundred nonbald Japanese men, mean age 31.1 ± 5.7 years, were the subjects of this study. They were divided into two groups according to the radial and curvilinear outward direction of the hair flow from the crown swirl: a clockwise group (50 men) and a counterclockwise group (50

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Multi-hair follicles viewed from the antero-posterior direction.

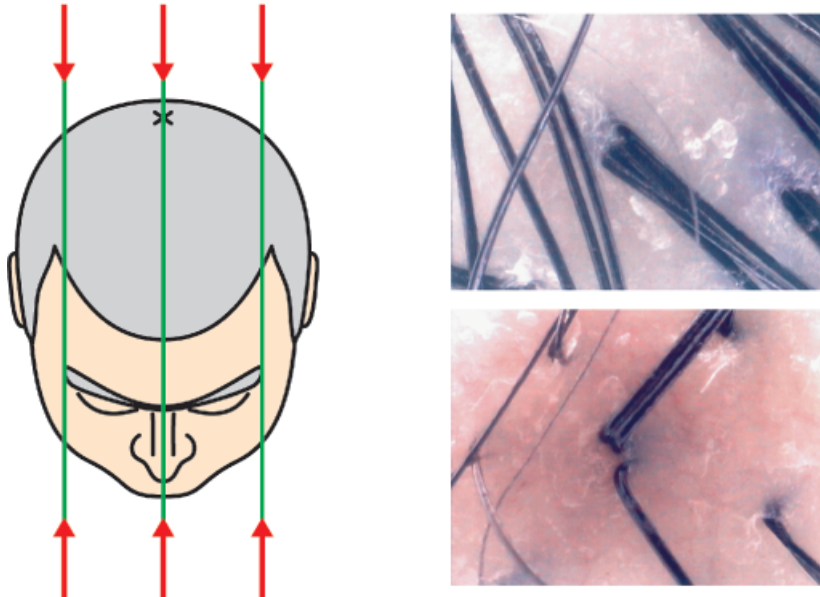


Figure 1. Multi-hair follicles viewed from the anteroposterior direction. The majority of multi-hair follicles looked oblique when patients were viewed from the front toward the back in the antero-posterior direction (original magnification $\times 100$).

the occipital area, our observational point was behind the patient looking forward toward the whorl.

Natural orientation of multi-hair follicles was analyzed at 22 points in the eight areas of the whole scalp using a microscope of $\times 100$ magnification (Scalar video loupe VL-7EX system, Scalar Co., Ltd., Tokyo, Japan) keeping the probe handle of the microscope in the upright position (Figure 3). They were the mid-occipital area, the right and left mastoid areas, the right and left supra-auricular areas, the right and left front-temporal areas, and the mid-front area. In each area, we analyzed follicular orientation at the peripheral points, the middle points, and the points in the vertex.

men). The mean age was 31.0 ± 6.0 years in the clockwise group and 31.2 ± 5.5 years in the counterclockwise group. There was no difference in the characteristics of patients regarding the age and health conditions without androgenetic alopecia between these two groups. People with double swirls were excluded from this study.

Multi-hair follicles in the scalp were viewed in the radial observational direction from the outside toward the whorl. As for the hair follicles in the front area, for example, our observational point was directly in front of the patient looking backwards toward the whorl. As for the hair follicles in

Multi-hair follicles viewed from the radial direction.

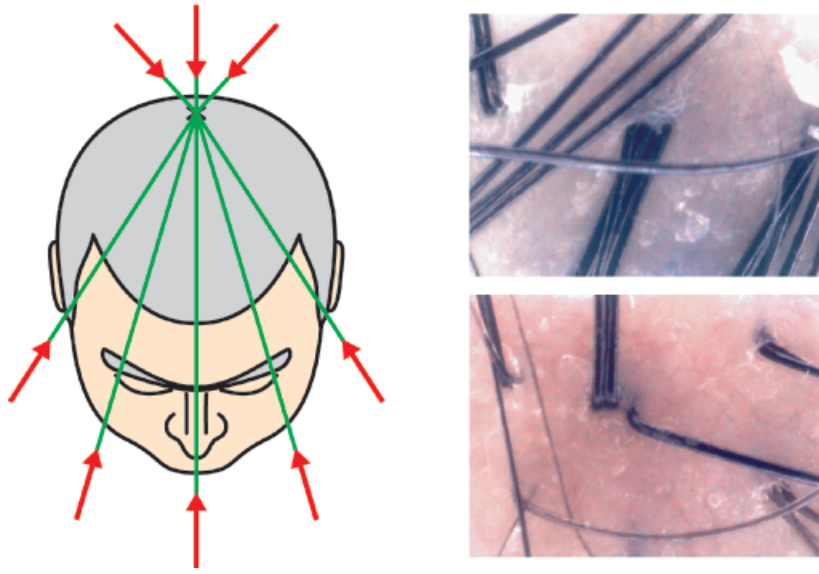


Figure 2. Multi-hair follicles viewed from the radial direction. The majority of multi-hair follicles looked horizontal when the hair follicles of the patients were viewed from the outside toward the whorl in the radial direction (original magnification $\times 100$).

Examined 22 points in the whole scalp.

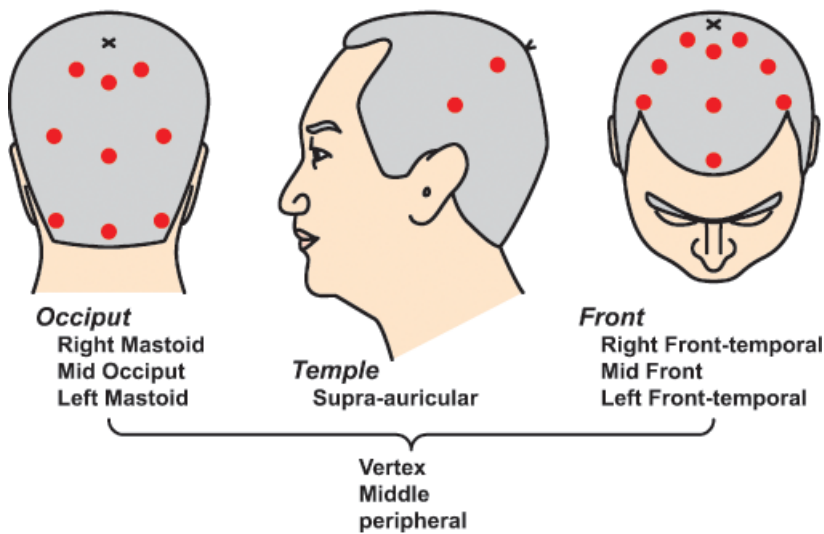


Figure 3. Examined 22 points in the whole scalp. Natural hair follicles were examined in the eight areas of the scalp. They were the mid-occipital area, the right and left mastoid areas, the right and left supra-auricular areas, the right and left front-temporal areas, and the mid-front area. In each area, the orientation of 50 multi-hair follicles was analyzed at the peripheral points, the middle points, and at the points in the vertex.

Fifty follicular units (FU) or follicular groups (FG) were examined at each point: 1,100 follicles at 22 points per person. The total number of multi-hair follicles examined in this study was 110,000 follicles in 100 people altogether. The orientation of multi-hair follicles was divided into four types (Figure 4): the perpendicular orientation to the radial line, the parallel orientation to the radial line, and the right and left oblique orientation to the radial line. The ratios of these four types of orientation were calculated and expressed in percentages at each point in each person.

All of the results were expressed as the mean \pm standard deviation. Results were analyzed by analysis of variance. Differences in per-

centages of each orientation between different points within the same group were tested for significance using Student's *t*-test; *p* values less than .05 were considered to be significant.

Results

Natural orientation of multi-hair follicles was a mixture of four different types in the whole scalp. It was not simply coronal, sagittal, or tangential. There was an individual difference in the percentage of major orientation of multi-hair follicles. Most hair follicles were in the perpendicular orientation in 95 people. Many of the follicles were in the perpendicular orientation in four cases.

Four types of orientation of multi-hair follicles.

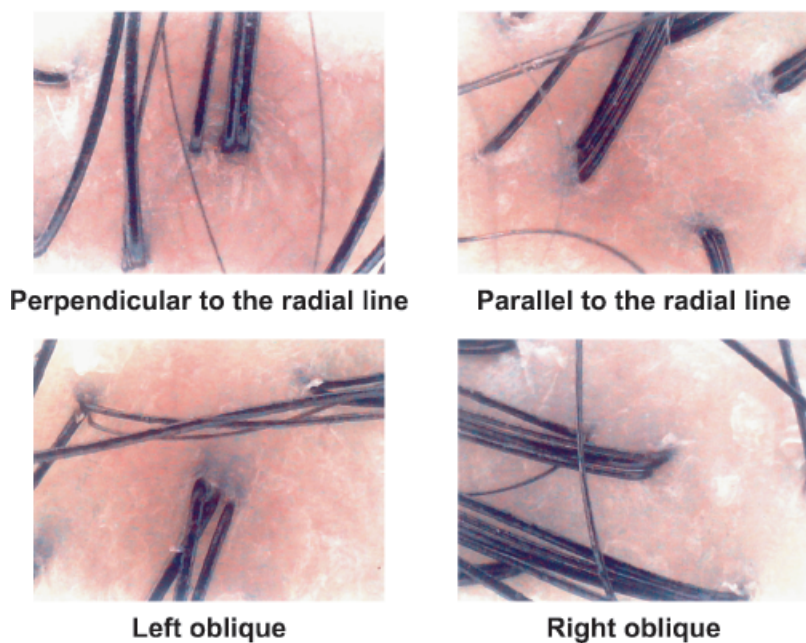


Figure 4. Four types of orientation of multi-hair follicles. The orientation of follicular units or follicular groups was divided into four types: perpendicular to the radial line, parallel to the radial line, and right and left oblique to the radial line (original magnification $\times 100$).

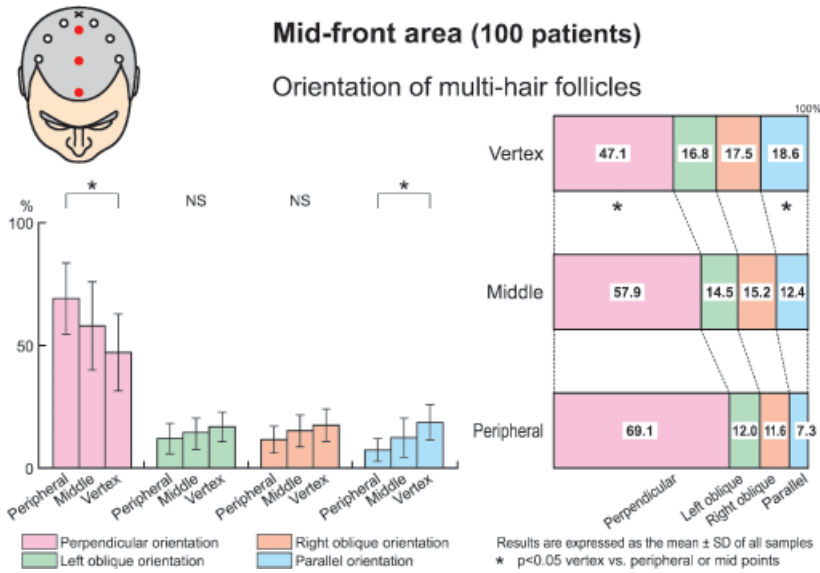


Figure 5. Orientation of multi-hair follicles in the mid-front area. The majority of follicles were in the perpendicular orientation at the peripheral and middle points in 100 patients, and the percentage of the perpendicular orientation decreased at the vertex. Percentages of the other orientations were small at the peripheral and middle points, which showed increasing tendency at the vertex.

Mixed-type orientation was observed in one case. The average results of every patient are shown in Figures 5–7.

Orientations of multi-hair follicles in the mid-front area of 100 persons are shown in Figure 5. Perpendicular orientation is shown in red and parallel orientation is shown in blue. Left and right orientations are shown in green and orange, respectively. The difference in the percentages of each type of orientation was compared statistically between different points. The percentage of perpendicular orientation was $69.1 \pm 14.5\%$ at the peripheral point and $57.9 \pm 18.0\%$ at the middle point. It decreased to $47.1 \pm 15.6\%$ at the vertex ($p < .05$). The parallel orientation was $7.3 \pm 4.6\%$ at the peripheral point and $12.4 \pm 8.0\%$ at the

middle points. It increased to $18.6 \pm 7.1\%$ at the vertex ($p < .05$). The percentages of right and

left oblique orientation showed increasing tendency from 11.6 to 12.0 ± 5.5 to 6.2% at the peripheral points to 16.8 to 17.5 ± 6.0 to 6.6% at the vertex, but the difference was not significant statistically.

The results in the whole front area of 100 people are shown in Figure 6. The results in the right and left front-temporal areas were put together and shown in this figure. The orientation of hair follicles was mainly perpendicular to the radial line at the peripheral and middle points. The percentage of perpendicular orientation was 69.1 to 72.4 ± 13.6 to 17.5% at the peripheral points (hairline area). It decreased to 49.4 to 57.9 ± 16.9 to 20.0% at the middle points (frontal core, central,

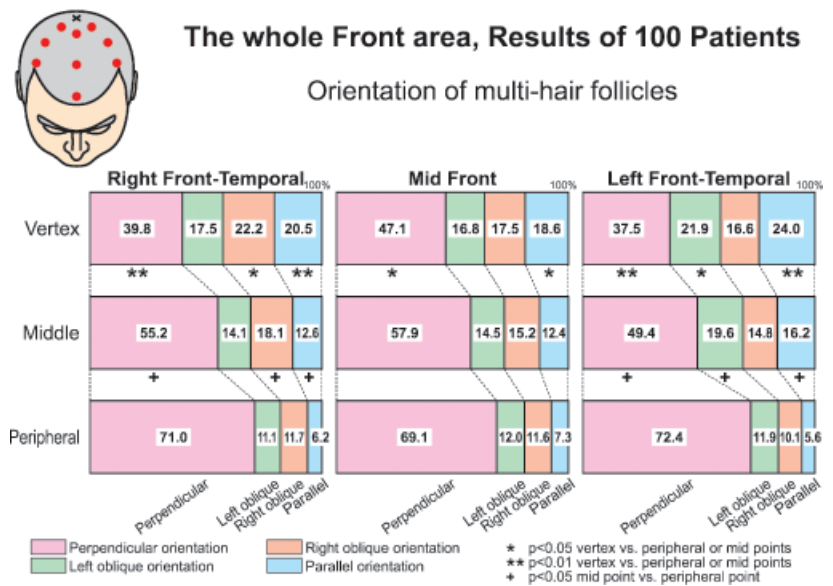


Figure 6. Orientation of multi-hair follicles in the whole front area. The results in the right and left front-temporal areas are put together in this figure. The percentage of perpendicular orientation was about 50 to 70% at the middle and peripheral points in 100 patients, and it decreased to around 40 to 50% at the vertex. Percentages of the other orientation were less than 10 to 20% at the peripheral and middle points, which increased to about 20% at the vertex.

or mid-scalp areas)($p < .05$). It decreased further to 37.5 to 47.1 ± 15.6 to 18.9% at the points in the vertex (crown area) ($p < .01$ or $.05$). The percentage of parallel orientation was 5.6 to 7.3 ± 4.6 to 5.2% at the peripheral points. It increased to 12.4 to 16.2 ± 6.2 to 8.9% at the middle points ($p < .05$), and it increased further to 18.6 to 24.0 ± 7.1 to 9.6% at the vertex ($p < .01$ or $.05$). The percentages of right and left oblique orientation were 10.0 to 12.0 ± 5.9 to 7.9% at the peripheral points. They increased to 14.1 to 19.6 ± 6.4 to 7.9% at the middle points and 16.6 to 22.2 ± 5.0 to 8.5% at the vertex ($p < .05$).

The results for the whole scalp of 100 people are put together and shown in Figure 7. In this way, we could compare the results for the whole scalp in one figure. Similar changes were observed throughout the scalp. The majority of multi-hair follicles were oriented perpendicular to the radial line from the crown swirl. The percentage of perpendicular orientation was 69.1 to 79.0 ± 11.8 to 17.5% at the peripheral points and 49.4 to 77.1 ± 13.2 to 20.0% at the middle points. It decreased to 37.5 to 49.0 ± 14.8 to 20.7% at the vertex ($p < .01$ or $.05$). The percentage of parallel orientation was 3.4 to 7.3 ± 4.3 to 6.2% at the peripheral points and 3.8 to 16.2 ± 4.3 to 8.9% at the middle points. It increased to 17.5 to 24.0 ± 7.1 to 12.0% at the vertex ($p < .01$ or $.05$). The percentages

of right and left oblique orientation were 7.6 to 12.0 ± 5.5 to 9.1% at the peripheral points and 7.8 to 19.6 ± 5.3 to 9.5% at the middle points. They increased to 14.4 to 22.2 ± 5.0 to 10.4% at the vertex ($p < .05$).

It is known that natural hair in the front area flows toward the right anterior direction in people with clockwise crown swirl flow, and it flows toward the left anterior direction in people with a counter-clockwise crown swirl (Figure 8). We compared the orientation of multi-hair follicles between these two groups, and we analyzed the results to confirm whether these two different patterns of natural crown swirl flow would influence

the percentages of each follicular orientation in the recipient area. The results of the orientation of multi-hair follicles in the front area of each group are shown in Figures 9 and 10. Similar results were obtained in both the groups as the results shown in Figure 6. The percentage of the perpendicular orientation in the front area in both the groups was 66.3 to 75.1 ± 12.1 to 20.2% of all follicles at the peripheral points (hairline area). It decreased to 48.0 to 63.8 ± 14.8 to 19.7% at the middle points (frontal core, central, or mid-scalp area) ($p < .05$). It decreased further to 35.5 to 49.1 ± 16.4 to 20.2% at the points in the vertex (crown area) ($p < .05$ or $.01$). The percentage of

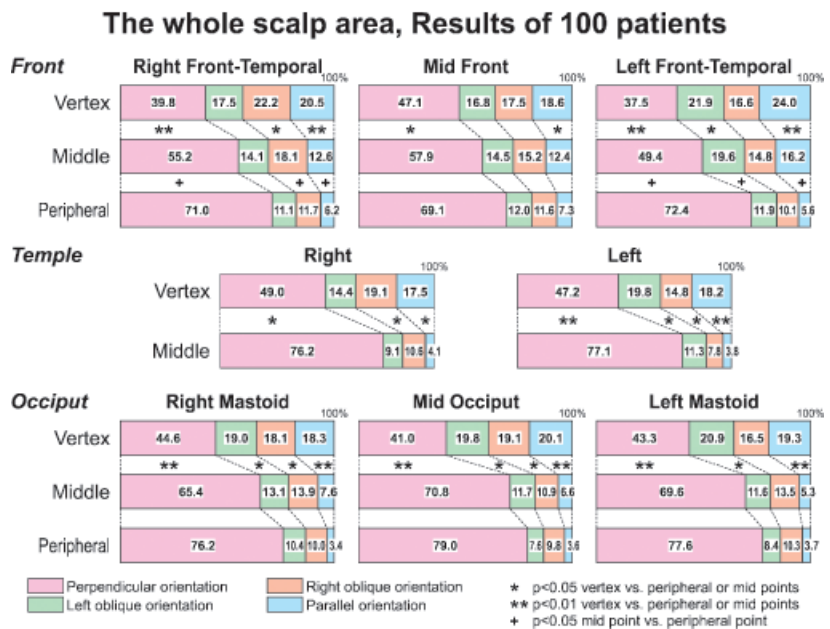
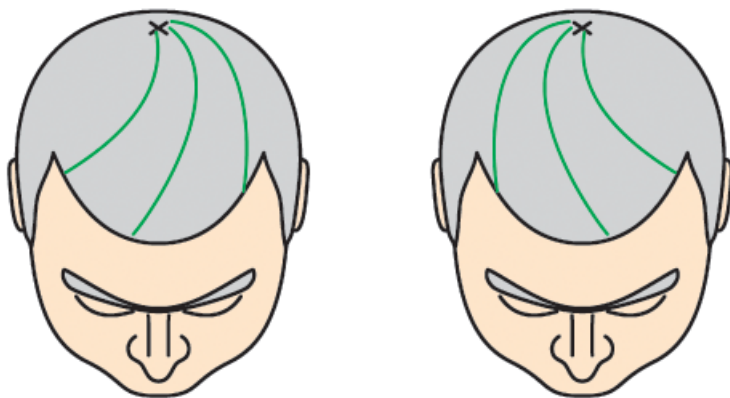


Figure 7. Orientation of multi-hair follicles in the whole scalp. The results in the whole scalp of 100 patients are put together in this figure. In this way, we could compare the results in the whole scalp in one figure. The majority of multi-hair follicles were oriented perpendicular to the radial line at every point. The percentage of perpendicular orientation was about 60 to 80% at the middle and peripheral points, and it decreased to around 40 to 50% at the vertex. Percentages of the other orientation were less than 10 to 20% at the peripheral and middle points, which increased to about 20% at the vertex.

Natural hair flow in the front area



Clockwise crown swirl hair flow Counterclockwise swirl hair flow

Figure 8. Natural hair flow in the front area. Natural hair in the front area flows toward the right anterior direction in people with a clockwise crown swirl, and it flows toward the left anterior direction in people with a counterclockwise crown swirl.

parallel orientation was 4.3 to 7.9 ± 4.2 to 5.8% at the peripheral points. It increased to 9.9 to 17.2 ± 6.9 to 10.7% at the middle points ($p < .05$). It increased further to 18.4 to 26.1 ± 6.1 to 10.9% at the vertex ($p < .05$ or $.01$). The percentages of the right and left oblique orientation were almost the same, and they increased slightly from 8.5 to 13.2 ± 5.1 to 9.4% at the peripheral points to 15.4 to 24.3 ± 6.0 to 10.0% at the vertex ($p < .05$). Similar changes were observed in the temporal and occipital areas in both the groups. The results in the whole scalp area of both the groups were almost the same as in Figure 7, and there was no statistically significant difference in the percentages of each orientation between the clockwise and counterclockwise groups.

The results of this study revealed that the major orientation of

multi-hair follicles was perpendicular to the radial line from the whorl at every peripheral and middle point throughout the scalp both in the clockwise group and in the counterclockwise group. There was no difference in the percentages of each type of orientation in the whole scalp area. The percentages of the right and left oblique orientations were small at every point in both the groups. There was no difference in the dominance of the right or left oblique orientation between the two groups.

Discussion

A higher density of hair is aesthetically critical after hair restoration surgery. The visual density of hair is dependent on the absolute number of hairs in a given area and the hair volume, which is determined by the hair shaft diameter and length. The total supply of donor hair, however, is limited, and the amount of donor

hair that can be moved in a single procedure is also limited. One of the major challenges in hair restoration surgery is to create the illusion of density at lower than normal mathematical density. The issue is important especially in people with high-color contrast and coarse hair. The effectiveness of the hair's ability to create an illusion of density is determined by the optical effects of a number of factors, including the angle of hair leaving the scalp, orientation of hair, distribution, spacing between individual follicular units, and hair shaft characteristics such as color contrast and hair curl. Orientation of hair follicles is one of the important factors that can be controlled by surgeons without affecting the other factors. This is the reason why this study addressed the issue of orientation of multi-hair follicles in the recipient area.

Many papers have been published about the coronally placed multi-hair grafts and the appearance of effective coverage in the recipient area.¹⁻³ It has been concluded that coronally placed grafts created a greater illusion of density than sagittally placed grafts if the patients were viewed from the front.^{2,3} However, what would the appearance be if the same patients were viewed from the right or left side? The appearance of effective coverage would appear poorer if the patients were viewed from the side. The appearance of fullness and effective coverage in the recipient area would appear variable from a better one to a

poorer one depending on the direction from which the patients are viewed.

The results of this study have offered us an alternative idea. The natural orientation of multi-hair follicles (FU and FG) was mainly perpendicular to the radial line in the peripheral and middle scalp areas. If we transplant FU and multi-FU grafts according to this original orientation, the fullness and coverage in the recipient area would appear constant regardless of different observational directions.

There seems to be some confusion about the meaning of the coronal orientation among hair restoration surgeons. The word coronal has been used meaning the direction right and left on the scalp and the direction perpendicular to the sagittal plane. The direction coincides with that used by radiologists in magnetic resonance imaging or axial computed tomography. However, some hair transplant surgeons have changed the meaning of the word in recent years. For example, they argue that coronal graft orientation, which is perpendicular to the original hair flow, enabled better covering and looked more natural. When they use the word coronal meaning the direction perpendicular to the hair flow, they mean that the coronal orientation itself rotates and changes its direction more than 60° or 90° among different points in the scalp according to the crown swirl

flow. This incorrect usage of the word was clearly pointed out by W. P. Unger at the annual meeting of the International Society of Hair Restoration Surgery in 2004. He emphasized that we should not use the word coronal orientation but should use the word perpendicular orientation when we mean the direction perpendicular to the hair flow.

The next issue is the relationship between the follicular orientation and the crown swirl hair flow. It is known that natural hair in the front hairline area and the central area flows toward the right anterior direction in people with a clockwise crown swirl flow, and it flows toward the left anterior direction in people with a counterclockwise crown swirl (see Figure 8). Then what would the orientation of natural multi-hair follicles look like in patients with a clockwise or a counterclockwise swirl hair flow? If the natural

multi-hair follicles are oriented in the perpendicular orientation to the natural hair flow, the orientation of follicles would be different between the clockwise crown swirl group and the counterclockwise group. The majority of natural hair follicles would look left oblique in patients with clockwise crown swirl flow, when we observe natural multi-hair follicles in the radial direction from outside toward the whorl, and right oblique in patients with counterclockwise crown swirl. However, the results of this study revealed that the major orientation of natural multi-hair follicles was not right or left oblique, but it was perpendicular to the radial line in both the groups. The percentages of left and right oblique orientation were small in both the groups. There was no difference in the percentages of various orientations between the clockwise and counterclockwise groups (see Figures 9 and 10). These

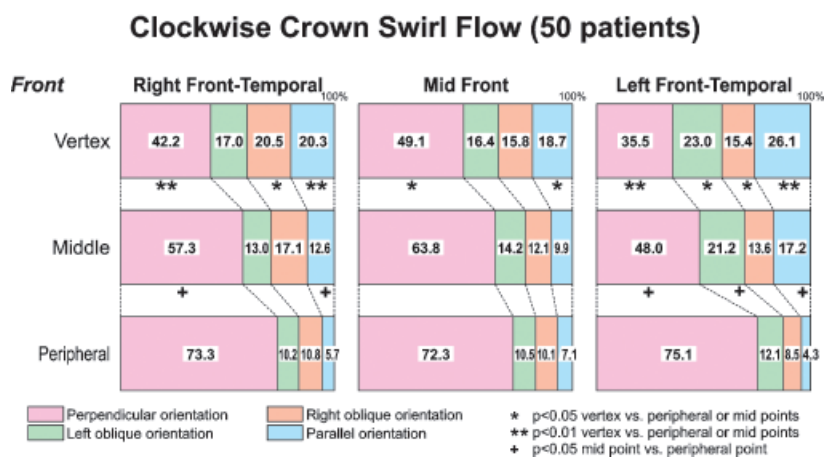


Figure 9. Orientation of multi-hair follicles in the front area of patients with a clockwise crown swirl flow. Similar results were obtained in this group as the results in Figure 6. The majority of follicles were oriented perpendicular to the radial line at every point.

Counterclockwise Crown Swirl Flow (50 patients)

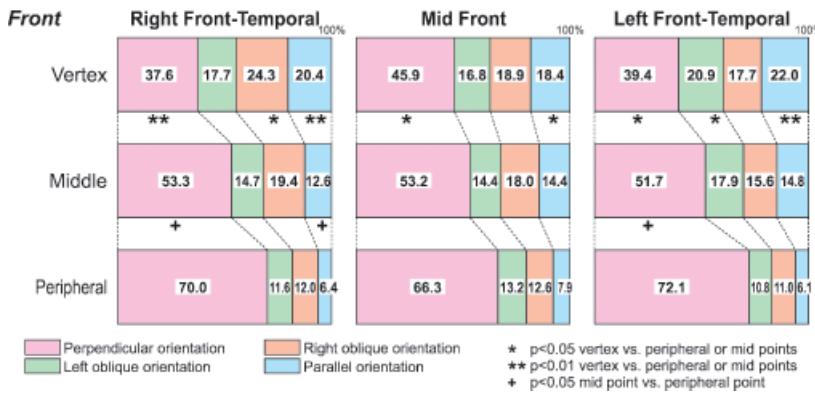


Figure 10. Orientation of multi-hair follicles in the front area of patients with counterclockwise crown swirl flow. Similar results were obtained in this group as the results in Figures 6 and 9. The majority of follicles were oriented perpendicular to the radial line. There was no difference in the dominance of the right or left oblique orientation between Figures 9 and 10.

Radial line from the crown swirl and perpendicular slits for multi-hair grafts in the front half of the scalp.

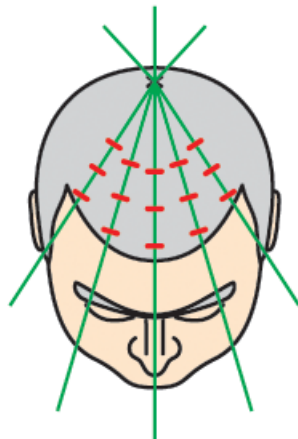


Figure 11. Radial line from the crown swirl and perpendicular slits for multi-hair grafts in the front half of the scalp.

results suggest that the natural orientation of multi-hair follicles is not perpendicular to the hair flow from the crown swirl, but it is perpendicular to the radial line. Multi-hair grafts transplanted in the orientation perpendicular to the radial line would look similar to the natural hair follicles in the front area and mid-scalp area.

According to this result, we would like to propose perpendicular orientation in the front half of the scalp for FU and multi-FU grafts (Figure 11). We do not need to pay attention to the direction of the clockwise or counterclockwise crown hair swirl. The radial line from the whorl is simple and easy to detect. We can easily decide the

direction of slits in the front and mid-scalp recipient areas irrelevant to the crown swirl hair flow.

Natural appearance in the recipient scalp area can be addressed on two levels: the state of an individual graft standing alone and the distribution and orientation of multiple grafts placed together. With knowledge of natural patterns of hair follicular orientation in the recipient area, the potential for unnatural appearance would be low and a natural look could be created after the hair transplantation.

We analyzed natural hair orientation in an Asian population in this study. A similar type of orientation has been previously described by Stough and Nelson.⁴ Based on their clinical experience of over 400 Caucasian and African-American patients, they advocated concentric slits with the incisional slits grafting technique to achieve a more natural and aesthetically appropriate appearance.

The results of this study indicated that most of the natural multi-hair follicles oriented in the perpendicular direction. Perpendicularly oriented FU and multi-FU grafts would obtain similarity with original hair follicles because it is the orientation found in nature. The next theme will be the effect of perpendicularly oriented multi-hair grafts to cover the recipient area. Would FU and multi-FU grafts effect better covering on the recipient area in the perpendicular

orientation than in the other orientations after the hair restoration surgery? Scientific studies that compare the illusion of density between perpendicular, coronal, lateral, and sagittal orientation at higher densities are lacking and sorely needed. To have clinical relevance, these need to be performed in the future with examination of full transplant procedures.

Another important issue of perpendicular slits would be the possibility of amputation of pre-existing hair in the recipient zone. Close attention should always be paid to the angle and direction of thinning hair. The handle of blades should be pointed to the direction of natural hair flow, and the angle of incision must match the normal forward angle of the existing hair shaft to minimize transection. The optimal acute angle used to make recipient sites would be variable in individual cases depending on the recipient area or the height of the hairline. The angle of graft insertion should be slanted to the tangential plane. We usually choose an angle of about 20° to 40° in the front hairline area, about 40° to 60° in the central and mid-scalp area, and about 60° to 80° in the vertex.

In the vertex, many hair transplant surgeons would prefer to make slits for multi-hair grafts parallel to the radial and curvilinear outward direction of the natural hair flow from the crown

swirl. Theoretically, if the natural multi-hair follicles were oriented parallel or perpendicular to the curvilinear outward direction of the hair flow, the probability of four types of orientation would be equal, and it would be 25% each in the vertex. We have no data to discuss about the hair orientation in the central zone of the vertex at this moment. According to the results in this study, the percentages of four different orientations were not equal in the peripheral zone of the vertex. The percentage of perpendicular orientation was about 40%, and parallel or oblique orientation was about 20% each in this area. This fact indicates that the orientation of multi-hair follicles in the peripheral zone of the vertex might be an intermediate type between the mixture of four equivalent types and the predominantly perpendicular type. The percentage of hair orientation in the vertex seemed to be different from that in the front half of the scalp. We need further investigation to analyze the details of hair follicular orientation in the vertex.

In the era of minigrafts, sagittal slits were inevitable to achieve dense packing of grafts because perpendicular slits of the large size might cause perfusion problems with resulting scalp necrosis. In the recent FU grafting, smaller blades and appropriate distance between slits have improved the safety of dense graft packing even if we transplant with perpendicularly oriented slits.

As for the donor area, the results of this study revealed that the majority of multi-hair follicles are oriented perpendicular to the radial line in the middle of the occipital area, right and left mastoid areas, and temporal areas. These results mean that the majority of hair shafts of multi-hair follicles are oriented parallel to the curved incision line of a concave type in the safe donor area. This orientation contributes to decrease the transection of hair shafts in strip harvesting by hair transplant surgeons if the angle of the blade is inserted and kept parallel to the hair shafts as the strip is progressively cut. The results of this study also mean that the majority of multi-hair follicles are oriented parallel to the direction of slivering in graft preparation by proficient technicians. This orientation protects the hair and decreases the percentage of transection and damage of hair shafts, and it insures better yield of FU and FG grafts.

This study was conducted on the orientation of natural multi-hair follicles in men. Many studies have also been conducted to elucidate the characteristics of hair in males. Further study would be necessary to investigate the details of the angle, orientation, and direction of natural hair follicles in women.

Conclusion

The natural orientation of multi-hair follicles (FU and FG) was mainly perpendicular to the radial

line from the whorl in the peripheral and middle scalp areas, irrespective of the crown swirl hair flow. There was no difference in the percentages of each type of orientation in the clockwise and counterclockwise groups. Multi-hair grafts transplanted in the orientation perpendicular to the radial line would look similar to the original hair follicles in the front half of the scalp (Figure 11).

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