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ARTICLE

Donor site of follicular unit excision hair transplantation: the relationship between appearance and actual hair density, and hair diameter

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ABSTRACT

Donor site morbidity is an important consideration for follicular unit excision (FUE). We examined 103 male patients with adult androgenic alopecia. Patients were divided into three groups (Good, Fair, and Poor) based on visual assessment of the donor site. Hair density and hair diameter were measured using digital photography. A total of 72, 21 and 10 patients were classified into the Good, Fair and Poor appearance groups. The average hair density of each group was 127.8 ± 22.6 hair/cm^2, 114.8 ± 23.1 hair/cm^2 and 94.9 ± 25.4 hair/cm^2. The hair density of the Good group was significantly higher than that of the Poor group ($p = 0.003$). The average hair diameter of each group was 0.0968 ± 0.0267 mm, 0.0754 ± 0.0299 mm and 0.0473 ± 0.0158 mm. The hair diameter of the Good group was significantly higher than that of the Poor group ($p = 0.001$). Thirty-three of 72 patients whose hair density was >130 hair/cm^2 belonged to the Good group. Seven of 10 patients whose hair density was <105.0 hair/cm^2 belonged to the Poor group, while 31 of 72 patients whose hair diameter was <0.101 mm were included in the Good group. Eight of 10 patients whose hair diameter was less than 0.070 mm were in the Poor group. Donor sites rated Good on appearance had both high hair density and thick hair diameter. To maintain a good appearance after FUE, donor site hair density should not be less than 105.0 hair/cm^2.

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Hair restoration; follicular unit excision; hair density; hair diameter; donor site

Background

The follicular unit excision (FUE) method is one of the most effective hair restoration surgeries for androgenic alopecia (AGA) because FUE results in less scarring compared to other methods [1]. Since FUE was first introduced by Rassman et al. [2], many other studies have confirmed its effectiveness [1–3]. In FUE, hair follicular units are harvested from the occipital scalp region and transferred to the recipient site. Hair density is one of the most important factors for successful FUE because the number of follicular units in the occipital region will decrease postoperatively. To perform FUE safely and successfully, the surgeon should always be concerned about donor site morbidity. The ability to estimate preoperatively how many hair follicular units can be harvested safely and how much the remaining hair volume will decrease postoperatively would improve FUE outcomes. We have addressed the need for preliminary data about hair density based on visual appearance of the donor site in AGA patients. We measured hair density and hair shaft diameter using digital photography to analyze the relationship between visual assessment of the FUE donor site and actual hair density and hair diameter measurements. We believe that this information is useful for FUE surgeons.

Patients and methods

We treated 103 Japanese male patients (average age 39.0 ± 9.2 years) with AGA who were referred to our clinic. None of the patients had previously undergone hair restoration surgery. The posterior region was shaved using electric clippers, and the hair length at the donor site was <1 mm (Figure 1). Before and after shaving the FUE donor site, digital photographs of the donor site were obtained using a camera with a measurement reference scale.

Outside appearance evaluation

Before shaving the posterior scalp, an evaluation of the outside appearance was performed. The preoperative donor site appearance was then categorized into three groups (Good, Fair or Poor) depending on appearance assessment. Patients whose donor site had enough hair volume so that the scalp was not showing through were categorized as Good (Figure 2). Patients whose donor site had evidence of slight hair volume loss or whose scalp showed through in a few places were categorized into the Fair group (Figure 3). Patients whose donor site had hair moderate to severe volume loss and scalp showing through in multiple areas were categorized into the Poor group (Figure 4). Three FUE surgeons judged donor site appearance using digital photographs.

Evaluation of hair density and hair shaft diameter measurement

Hair density was measured using image processing software Image J (National Institutes of Health, Bethesda, MD) as follows: an 8×8 cm^2 area in the center and middle occipital region was cropped from the original picture using photo editing software

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Figure 1. Donor site of follicular unit extraction after shaving.

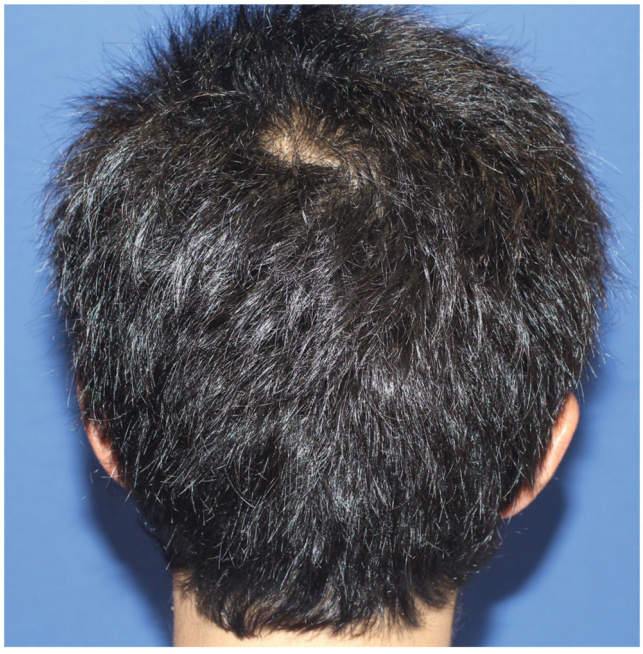

Figure 2. The scalp surface was completely covered with hair and showed good appearance. Patient was categorized as Good.

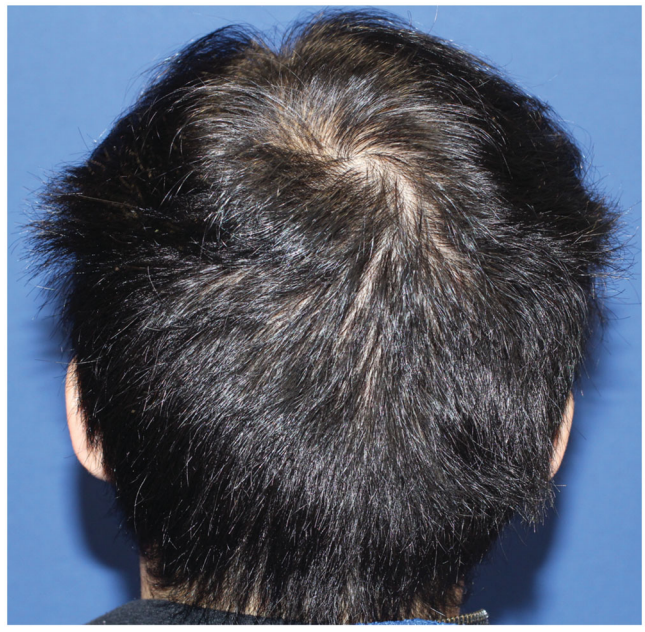

Figure 3. Most of the scalp's surface was covered with hair. However, some parts of the donor site were not covered. The hair volume was not rich. Patient was categorized as Fair.

Figure 4. The hair volume was poor and most of the scalp was externally visible. Patient was categorized as Poor.

Photoshop (Adobe, San Jose, CA). The cropped image was opened in Image J and converted into a 32-bit integer grayscale image. Image thresholding was performed using Image J, using the Analyzed Particles command. A strand of hair was recognized by the software as an elliptical shape, and the number of elliptical shapes was counted.

More than 15 hair that were clearly in focus were selected from the center and middle occipital region from each patient, and the hair width was measured using the number of pixels. The measured width of the picture was divided by the number of pixels in the photograph. The hair shaft diameter was then calculated from these values, and the average hair shaft diameter was recorded.

Donor site photographs were divided into three groups according to hair density. Patients whose hair density was $>130.1/cm^2$, 130.0–105.1/cm^2, and $<105.0/cm^2$ were categorized as the HD group, MD group, and LD group, respectively. Patients whose hair shaft diameter was >0.101 mm, 0.100–0.071 mm, and <0.070 mm were categorized as the Thick group, Medium group, and Thin group, respectively.

Statistical analysis

Hair density was determined by counting the number of hair in a 64 cm square area. Differences in the mean values were compared using the Mann–Whitney *U*-test with a *p*-value of <0.05 indicating significance. All statistical procedures were performed using SPSS (IBM Japan, Tokyo, Japan).

Results

The average patient age was 39.2 ± 9.2 years. The average hair density was 12.9 ± 24.6 hair/cm^2, and the average hair shaft diameter was 0.0874 ± 0.0373 mm. Seventy-two cases were included in the Good group, 21 in the Fair group, and 10 cases were included in the Poor group. The average age of each group was 37.5 ± 8.6 (Good), 42.7 ± 12.1 (Fair), and 42.0 ± 7.6 years (Poor). The average hair density of each group as 127.8 ± 22.6 (Good), 114.8 ± 23.1 (Fair), and 94.9 ± 25.4 hair/cm^2 (Poor). The average hair shaft diameter was 0.0968 ± 0.0267 (Good), 0.0754 ± 0.0299 (Fair), and 0.0473 ± 0.0158 mm (Poor) (Table 1). There were no significant age differences between groups. Mean hair density and mean hair shaft diameter were significantly higher for the Good group compared to the Poor group (Table 2).

There were 43 patients in the HD group, 29 patients in the MD group, and 32 patients in the LD group. In the HD group, 33, 7, and 2 cases were categorized as Good, Fair, and Poor, respectively. In the LD group, 17, 9, and 7 cases were categorized as Good, Fair, and Poor, respectively. The proportion of patients in the LD group who belonged to the Poor group was higher than the same proportion in the HD group ($p = 0.028$) (Table 3).

There were 37 patients in the Thick hair shaft diameter group, 33 in the Medium group, and 27 patients in the Thin group. In the Good group, 31, 25 and 10 cases were identified as Thick, Medium, and Thin, respectively. In the Poor appearance group, 10, 9, and 8 cases were identified as Thick, Medium, and Thin, respectively (Table 2). In both the Thick and Medium groups, the proportion of patients who belonged to the Good group was higher than that of the Thin group (Thick versus Thin: $p = 0.004$, Medium versus Thin: $p = 0.022$) (Table 4).

Discussion

Hair restoration surgery is one of the most popular cosmetic surgeries for men [1–3]. FUE is one of the most successful techniques for hair restoration, but to perform FUE safely, accurate information about hair density at the donor site is essential [1]. We analyzed the relationship between actual hair density and subjective appearance assessment of the donor site for FUE in 103 Japanese males with AGA. And, we divided our patients into three groups according to hair density (HD group, MD group, and LD group) and hair diameter (Thick group, Medium group, and Thin group). We defined the cut-off values so that each of the three groups was approximately the same size. We found that the average hair density in the occipital region was 121.9 hair/cm^2 and about 70% of our patients had a visual assessment rating of 'good'. On the other hand, less than 10% of our patients had a visual assessment rating of 'poor'. There was a correlation between both high hair density and hair shaft diameter measurements and good visual assessment of the donor site.

Table 2. Patients' distribution of the result of outside appearance, hair density and hair diameter.

	Good ($n = 72$)	Fair ($n = 21$)	Poor ($n = 10$)
Hair density			
HD (>130.1/cm^2)	33	7	2
MD (130.0−105.1/cm^2)	22	5	1
LD (<105.0/cm^2)	17	9	7
Hair diameter			
Thick (>0.101mm)	31	5	1
Medium (0.100–0.071mm)	25	7	1
Thin (<0.070mm)	10	9	8

Table 3. Differences of patient's age, hair density and hair diameter among outside appearance.

	p-Value		
	Age	Hair density	Hair diameter
Good versus fair	0.148	0.063	0.073
Good versus poor	0.124	0.003	<0.001
Fair versus poor	0.800	0.104	0.014

Table 4. Distribution of outside appearance result was compared among thick, medium, and thin group.

	p-Value
Thick versus medium	0.687
Thick versus thin	0.004
Medium versus thick	0.022

Thick: hair shaft diameter was more than 0.101 mm; Medium: hair density was 0.100–0.071 mm; Thin: hair density was less than 0.070 mm.

Table 5. Distribution of outside appearance result was compared among thick, medium, and thin group.

	p-Value
Thick versus medium	0.687
Thick versus thin	0.004
Medium versus thick	0.022

Thick: hair shaft diameter was more than 0.101 mm; Medium: hair density was 0.100–0.071 mm; Thin: hair density was less than 0.070 mm.

Table 1. Average age hair density and hair diameter of total and patients belonged to each group.

	Total ($n = 103$)	Good ($n = 72$)	Fair ($n = 21$)	Poor ($n = 10$)
Average age ± SD	39.0 ± 9.2	37.5 ± 8.6	42.7 ± 12.1	42.0 ± 7.6
Hair density ± SD (/cm^2)	121.9 ± 24.6	127.8 ± 22.6	114.8 ± 23.1	94.9 ± 25.4
Hair diameter ± SD (mm)	0.0874 ± 0.0373	0.0968 ± 0.0267	0.0754 ± 0.0299	0.0473 ± 0.0158
Hair density				
HD (>130.1/cm^2)	42	33	7	2
MD (130.0 − 105.1/cm^2)	28	22	5	1
LD (<105.0/cm^2)	33	17	9	7
Hair diameter				
h (>0.11 mm)	37	31	5	1
m (0.10–0.071 mm)	33	25	7	1
l (<0.070 mm)	33	10	9	8

SD: standard deviation.

Erdogan describes the FUE procedure in the Asian population in detail in his book [4]. He divides the Asian population into three groups: East Asian, West Asian, and South Asian. He suggests that greater hair density and larger hair diameter are very important for achieving good results and avoiding donor site morbidity, because hair volume is affected by both hair density and hair thickness. Ko et al. reported hair density differed between Taiwanese and Korean populations [5] and suggested that hair density might be different in other east Asian populations. However, there are few reports on donor site hair density in male Japanese AGA patients and there are no guidelines about how many hair should be extracted from the donor site in Japanese patients.

Previous studies have found that hair density differs among different races [6]. The average hair density of Asian people in these studies was found to be [5,7–9] 120–140 hair/cm^2. These results are lower than the results from studies in Caucasian [10] and African American groups [11]. However, they included healthy people and women [10,11]. Tsai et al. [12] reported that the average hair density of healthy Chinese males was 140.7 hair/cm^2, while the average hair density of Chinese males with AGA was 123.5 hair/cm^2. Birnbaum et al. reported evaluation of hair density (and distribution of hair density) among healthy Caucasian, Hispanic, and African people [5]. They found no significant differences between the three groups. Ko et al. also examined the distribution of hair density in AGA patients and found that the hair density was the highest at the occipital region [5]. The hair density measurements in our study were consistent with the results from other reports. Ko et al. [5], Aslani et al. [13], and Garcia et al. [14] performed small scalp biopsies and then counted numbers of follicles and hair under the microscope to analyze hair density. This method has two advantages: the true hair density is counted, and hair density can be compared between anatomical sites. However, the specimen size was limited in these studies. Tsai et al. [12] and Jimenez et al. [15] measured hair density by directly counting the number of hair visible in a digital image. This counting procedure is useful for examining hair density directly and precisely. However, counting the number of hair in a large area requires a long counting time. Performing this counting procedure also requires taking digital pictures that are neither too bright nor too dark. The scalp brightness in the picture should be homogeneous. In our study, we used digital image processing software to address these issues. Cropping the image allowed us to estimate hair density for a larger area in a large number of cases without donor site morbidity.

Yun et al. and Park et al. analyzed hair diameter in the occipital scalp in Korean subjects [8]. They found that hair thickness differed between the midoccipital region and neck regions and that hair thickness was greater in the upper occipital region than in the lower occipital and neck regions. Because we used digital photographs, we could not measure hair diameter directly. Our measurement results were affected by image focus and brightness. Hence, we believe that our method is useful for analyzing the relationship between visual appearance and hair diameter and hair density. We also believe that our study may provide useful preoperative information for FUE hair restoration surgery.

We found that patients in the Good appearance assessment group had both dense and thick hair. 26 of 33 patients whose hair density was less than 105 hair/cm^2 were assessed as Fair or Poor by appearance. Based on these results, to maintain good hair appearance after FUE, hair density should be greater than 105.0 hair/cm^2 after the follicular units are harvested. The average hair density of the patients who belonged to the Good group was 127.8/cm^2. Based on our results, no more than 22 hair should be harvested from a 1 cm square donor site in patients whose hair density was assessed as fair or good by appearance. Mohmand and Ahmad counted the number of hair at donor sites in Iranian patients with AGA and concluded that hair follicles should not be extracted when the hair density is $<$35.44 hair/cm^2 [16]. Devroye suggested that to perform FUE safely, the number of donor site hair excised should be no more than 10–15 per cm^2 [17]. Harris reported that 20–30 hair per cm^2 can be extracted without problems [18]. We found that donor site morbidity in the Japanese subjects was very similar to results from studies in other ethnicities. In his book, Dr Erdogan introduced the concept of coverage value, which is calculated based on hair density and hair diameter. Keene et al. also reported on the usefulness of this value for determining donor site morbidity after FUE [16]. Our results may also provide information that is useful for determining coverage values in the Japanese population.

Conclusion

Visual appearance of the donor site correlates with both hair density and hair diameter. In our study, patients who achieved high hair density also had high hair diameter measurements. Based on our results, to maintain a good postoperative appearance, the hair density of the donor site should exceed 105 hair/cm^2 after follicular extraction for FUE.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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