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REVIEW

Follicular Unit Hair Transplantation: Current Technique

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Abstract
Since 1959, when Norman Orentreich described the phenomenon of donor dominance in androgenic alopecia and opened the way to hair transplantation, the field of hair replacement surgery has been evolving continuously. Advances in the last 15 years, and particularly the microscopic dissection of donor strips into follicular units, have eradicated the idea that follicular transplantation is an aggressive procedure that produces an artificial result. Hair transplantation procedures involving the transplant of only follicular units can now achieve natural, undetectable, and reproducible results, very different from the outcomes achieved with earlier techniques. Consequently, there is no excuse today for not offering hair transplantation to patients with androgenic alopecia, both male and female, who are good candidates for this technique. This review provides a general overview of the current procedure for follicular unit hair transplantation.
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Técnica actual del trasplante de pelo de unidades foliculares

Resumen
Desde que en 1959 Norman Orentreich describiera el fenómeno de dominancia donante en la alopecia androgenética, abriendo así el camino a los trasplantes capilares, el campo del trasplante de pelo ha estado en permanente evolución. Con los avances surgidos en estos últimos 15 años, principalmente con la disección microscópica de los injertos en unidades foliculares, se ha conseguido desterrar la idea de que el trasplante es una técnica agresiva que produce un resultado artificial. Gracias al uso exclusivo de unidades foliculares como el único elemento de trasplante, el trasplante de pelo se ha convertido en una técnica con resultados naturales, indetectables y reproducibles, muy diferentes a los alcanzados con las técnicas anteriores. Por todo ello, hoy día no existe excusa para dejar de ofrecer la

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posibilidad del trasplante a aquellos pacientes con alopecia androgenética, tanto hombres como mujeres, que sean buenos candidatos al mismo. En este artículo de revisión describimos de forma general el procedimiento actual del trasplante de pelo con unidades foliculares.

A Brief History of Hair Transplantation From Its Origins to the Present Day

We tend to think that the first hair transplant procedures were carried out in the United States of America, but in fact the first doctors to use hair transplants were Japanese (Sasagawa[1] in 1930 and Okuda[2] in 1939). In the earliest hair transplants, a punch was used to extract donor hair follicles for the reconstruction of areas of the eyebrows, moustache, and beard scarred by burns. In 1943, Tamura,[3] who was very advanced for his time, described the use of single-hair grafts (which would later become known as micrografts) to transplant pubic hair using a technique very similar to that used today. However, none of the Japanese authors mentioned the usefulness of these techniques in the treatment of androgenic alopecia and their work was published only in Japanese. Consequently, these advances were not generally known in the West.

After an intervening period during which no articles were published on the topic, the period of development of hair transplantation techniques started some 50 years ago in 1959 when New York dermatologist Norman Orentreich published a very interesting study on the subject of donor and recipient dominance in various dermatological conditions, including alopecia.[4] Orentreich described the phenomenon of donor dominance in androgenic alopecia, the scientific basis for hair transplantation. The term *donor dominance* refers to the fact that autografts retain their integrity and characteristics after transplantation to another site, while *recipient dominance* refers to the acquisition by autografts of the characteristics of the recipient site after transplantation. Orentreich observed donor dominance in all cases of androgenic alopecia, that is, hairy skin transplanted to areas without hair resulted in hair growth, while hairless skin transplanted to parts of the body with hair remained bald. Moreover, it was shown that hair growth remained stable in these transplanted grafts despite the fact that the indigenous hair in the surrounding area continued to disappear, affected by the process of alopecia. Orentreich's experiments confirmed that transplantation of hair autografts in androgenic alopecia produced stable and permanent growth (eg, transplanted hair lasted as long as the hair in the donor area from which the graft was taken). These discoveries led many doctors from different specialties to become interested in hair transplant surgery.

Since Orentreich used 4-mm punches in his trials, these soon became the essential instrument both for extracting grafts from the donor area and for making the holes to receive the implants in the recipient balding area. Although the grafts made with these punches achieved spectacular hair growth, which made the technique very popular in the early years, the cosmetic result was not natural. Each 4-mm punch graft contained between 15 and 20 hairs and the resulting tufted growth came to be known as "doll's hair." This problem led a number of surgeons (Shiell et al,[5] Nordstrom,[6] Marrit,[7] Uebel,[8] and Lucas[9]) to use smaller grafts, known as minigrafts and micrografts. These new techniques became more widespread throughout the 1980s. Initially, minigrafts and micrografts were only used along the frontal hairline and larger punch grafts continued to be implanted further back on the scalp. Later, however, surgeons started to use them as the only transplant unit throughout the recipient area. The transition from 4-mm punch grafts to minigrafts and micrografts was slow and there were many detractors, but the smaller grafts did eventually become the norm because they produced better cosmetic results.[10] In the 1980s, a group of physicians in Spain (most of whom were Catalan dermatologists) started to use minigrafts and micrografts.[11] Notable in this group were Emilio Villodres[12] and Vila Rovira (a plastic surgeon), who started to use only minigrafts and micrografts in 1985. Within a short time, their example was followed by Alex Camps, Ramón Singla, Manuel Asín, and Romero Nieto (personal communication with Emilio Villodres).

Fifteen years ago, Bobby Limmer[13] published a very important article that changed hair transplantation technique. It described the use of the stereomicroscope in the dissection of the donor strip. Limmer did not dissect the grafts on the basis of size, but rather on the basis of follicle groupings that usually contained 1, 2, or 3 hairs. While he did not use the term follicular unit, he in fact he described the concept of follicular unit hair transplantation. Finally in the 1990s, Bernstein and Rassmann[14-16] defined the concept and surgical techniques further and popularized the method.

By definition, follicular unit hair transplantation is a technique that uses the follicular unit as the basic element that is transplanted from the donor area to the recipient site. The follicles are transplanted exactly as they are extracted from the donor area, maintaining the integrity of the natural groupings known as follicular units. (The term was originally coined by Headington[17] and we will describe these units in more detail below.) Mega-sessions involving the transplantation of a much larger number of follicular units were required to obtain appropriate density with these very small grafts.[14,18] In spite of the opinion of detractors, who considered that follicular unit transplantation could never achieve the density obtained with larger grafts, the technique continued to gain ground and is now used by most hair transplantation surgeons in the world.

The Follicular Unit: the Basic Element of Transplantation

A magnified view of the scalp reveals that hairs emerge from the skin in groups (Figure 1). Each small group of hairs is the visible portion of the more complex underlying histologic structure described in 1984 by Headington,[17] who coined the term *follicular unit*. Each unit is composed of terminal and vellus hairs, the associated sebaceous glands, and the arrector pili muscles, all surrounded by a band of collagen fibers known as the perifolliculum (Figure 2). Poblet et al[19,20,21] observed that all the arrector pili muscles in each follicle come together to form a single muscle structure, meaning that each follicular unit has only 1 muscular unit (Figure 3).

Although there are significant differences between races in the density of follicular units in the occipital region of the scalp (the donor area), most Caucasians have between 70 and 90 follicular units per square centimeter.[21,22] Each unit contains 1 to 5 terminal hairs, although most (approximately 80%) have 2 or 3. It is therefore important to distinguish between follicular unit density (the number of units per square centimeter) and hair density (the number of hairs per square centimeter). For example, when we talk about transplanting 1000 follicular units, we should remember that the number of hairs being transplanted will be greater—approximately 2500 hairs. As a general rule, the number of hairs transplanted is approximately 2.5 times the number of follicular units transplanted.[22]

The Initial Hair Transplantation Interview

As in any type of cosmetic surgery, the initial interview with a patient seeking hair transplantation plays a vital role in the eventual success or failure of the intervention. During the initial interview, the physician establishes whether or
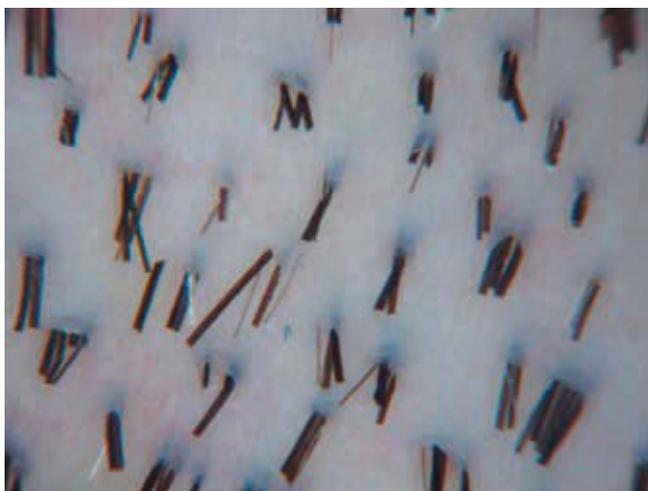

Figure 2 Histologic view showing the organization of hair follicles into follicular units (outlined by red circles). Transverse section of the scalp taken at the mid dermis. Each follicular unit is made up of terminal hairs, vellus hairs, sebaceous glands, and arrector pili muscles.
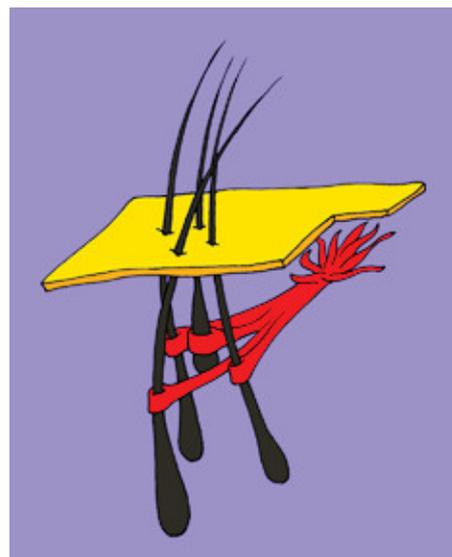

Figure 3 The arrector pili muscles from each follicle join together to form a single muscle unit. Image from Poblet et al.[20]

Figure 1 Photograph of the occipital scalp taken using a Dermlite Pro HR dermoscope showing how hair emerges from the skin in groups—in most cases with 2-4 hairs per group. These groups of hairs correspond to the portion of the follicular unit that is visible on the surface.

Table 1   Key Issues in the Informative Interview

Determine whether or not the patient is a good candidate
   for transplantation
Describe the technique:
   Show photographs or drawings of the procedure
   Show photographs of results at 6 to 12 months
   Show photographs of the scar left on the donor area
Decide whether the patient will require 1 or more
   sessions and estimate how many follicular units will
   be transplanted per session

not the patient is a candidate for the procedure and explains what can be achieved (Table 1). It is important to describe the intervention and to discuss the number of follicular units that can be transplanted and whether the patient would require one or more sessions depending on the size of the bald area to be covered. All patients are informed that a strip of skin must be surgically removed from the back of the head leaving a fine but permanent scar. This scar has no cosmetic repercussion unless the patient wishes to shave his head, in which case the follicular unit extraction technique described below is recommended. The patient is also told that transplanted hair will only start to grow 3 or 4 months after the procedure and that growth will continue to improve gradually until 8 or 12 months later, which is when the final result will be evident.

During this informative interview, the patient's medical history is recorded, and preoperative (Table 2) and postoperative (Table 3) instructions are given.

It is very important during this initial consultation to evaluate the caliber and density of the hair in the donor area to determine whether the patient is a good candidate. Individuals with scant donor density (<40 follicular units/cm^2) or with very fine hair (caliber <50 μm) are not good candidates and transplantation will not result in dense growth. Conversely, individuals with thick donor hair (>80 μm) and a density of more than 70 units/cm^2 are excellent candidates (Table 4).

The suitability of the candidate is also influenced by the characteristics of the recipient area. Individuals with very little hair in the recipient area are better candidates for transplantation because a patient with more advanced baldness will tend to notice the positive cosmetic change much more than one with incipient alopecia which has only recently become apparent. The latter patient is a better candidate for medical treatment.

It is important to explain to all patients the irremediable progressive nature of androgenic alopecia and the importance of combining transplantation with medical treatment to try to slow down hair loss (using currently available drugs such as finasteride and minoxidil). The physician must emphasize that the goal of transplantation is to cover bald areas and that this procedure will not prevent existing nontransplanted hair from continuing to suffer the consequences of androgenic alopecia so that

miniaturization and hair loss may continue. Accordingly, young patients (under 25 years of age) with incipient baldness are not considered by most surgeons to be candidates for transplantation because it is very likely that

Table 3 Postoperative Instructions

During the first 24 hours, moisten the transplanted area every 2 or 3 hours with physiological saline solution

Avoid rubbing the transplanted area. If a graft is accidentally pulled out and the incision bleeds, apply continuous pressure with a gauze pad for 10 minutes

Do not engage in strenuous physical exercise for 5 days after the intervention

Shampoo gently every day. Do not rub the scalp for the first 4 days. Massage shampoo in lightly from day 4 to day 7, and wash normally thereafter

The small scabs that form around the grafts will start of fall off by the end of the first week

New hair will start to grow from the transplanted follicles after 3 to 4 months. The growth rate will be 1 cm/mo

The results will become more noticeable after 8 to 12 months

Table 4 The Characteristics of Ideal Candidates for Hair Transplantation

Good hair density in the donor site (>70 follicular units/cm^2)

Hair in donor area of adequate thickness (ideally >80 μm)

Patient aged more than 25 years with androgenic alopecia whose condition is stable or who is receiving medical treatment (finasteride and minoxidil)

Androgenic alopecia with clinically visible bald patches in the recipient area (Norwood II-VI)

Female pattern androgenic alopecia classified as Grade II or III on the Ludwig scale so long as the patient has good donor density

Realistic expectations

Table 2 Instructions Prior to Transplantation

Preoperative workup: complete blood count, coagulation study, and serology for human immunodeficiency virus, and hepatitis B and C viruses

Allow hair to grow to at least 2 cm in the donor area (to cover sutures)

Do not take anticoagulant medication such as Aspirin, Plavix or their derivatives from 7 days before the procedure

The night before and the morning of the procedure wash hair with an antiseptic shampoo, such as Betadine

One hour before the intervention take a prophylactic antibiotic. (This measure is optional because the procedure is clean cutaneous surgery)

Figure 4 A patient who underwent transplantation at 20 years of age with 4-mm punch grafts along the frontal hairline. With the passage of time, the indigenous hair has undergone the normal involution characteristic of androgenic alopecia, making the grafted hair look out of place. This example illustrates the permanence of transplanted hair and the problems that can arise when young patients with incipient baldness undergo these procedures.

the small area of hair transplanted to cover the initial bald area will in time become an isolated island and look out of place (Figure 4).

Finally, as in all cosmetic procedures, it is essential to know whether the patient has realistic expectations or whether, on the contrary, they are anticipating a result that the surgeon cannot achieve. It is always preferable to lower the patient's expectations during the preliminary interview and to discuss the possibility that more than 1 transplantation session may be required to achieve the desired result.

Follicular Unit Hair Transplantation: Current Surgical Technique

Transplantation is a clean surgical procedure that does not require a sterile operating theater environment. It is normally performed in a suite suitable for outpatient dermatologic surgery. In reality, the only surgery involved is the removal of the donor strip. The rest of the process is minimally invasive: recipient incisions are made and the follicular grafts are inserted. The patient is usually premedicated with an oral anxiolytic such as diazepam 10-20 mg 30 minutes before the intervention to help them to relax and bear the hours of surgery more easily. In the very few cases in which a patient for some reason wants to receive monitored intravenous sedation, the procedure must be performed in a facility with the necessary accreditation for this purpose.

As a general rule, a session of follicular unit hair transplantation takes 4 to 6 hours depending on the scope of the intervention (the number of grafts implanted). During the procedure, the patient needs a comfortable and relaxing environment and can listen to music or watch a film.

The procedure can be divided into 4 steps:

1. Extraction of the donor strip
2. Microscopic dissection of the donor strip into follicular units
3. Creation of recipient incisions
4. Implantation of follicular grafts

Extraction of the Donor Strip

The donor area is the part of the scalp from which the follicular units for transplantation are extracted. In androgenic alopecia, the donor area is a band some 5 to 6 cm wide and 25 to 30 cm long extending from ear to ear across the occipital and temporal zones of the scalp. In general terms, this can be said to be an area of permanent hair growth, that is, the hair at the center of this band is most likely to continue growing in the future. The hair above this permanent-growth zone may be lost as the bald patch on the crown of the head grows bigger, and the hair below it may disappear if baldness starting at the nape of the neck spreads upwards (Figure 5).

The size of the donor strip extracted will depend on the number of follicular units required. Before deciding on size,

Figure 5 The donor area should be assessed on a case-by-case basis. A, it may be large and dense. B, it can also be narrow. In the latter case, it should be borne in mind that hair can also be lost when the balding area at the nape of the neck extends upwards.

the surgeon should assess the density of the follicular units on the patient's scalp (units/cm^2) using loupe magnification or a videomicroscope. Next, once the recipient area has been determined, the size of the donor strip needed can be calculated using the following formula, which takes into account the density of the hair in the donor area:

Number of follicular units required = Density of follicular units $\times$ Area of the donor strip in square centimeters

For example, if we want to transplant 1500 follicular units in a patient with a density of 80 follicular units/cm^2 in the donor site, the area of the donor strip required will be calculated as follows:

1500=80 $\times$ area of donor strip
Area of donor strip = 1500/80 = 19 cm^2

The width and length of the donor strip can be adjusted using the following formula: area=length × width. The width of the donor strip is usually limited to 1 cm to ensure that there are no problems closing the wound with minimum tension. However, in procedures requiring more than 2000 grafts per session and if the patient has a sufficiently lax scalp, the width of the strip can be enlarged to 1.5 or even 2 cm. Closure of the donor area with minimum tension is always very important because this is the only way of ensuring a fine, cosmetically acceptable scar.

Once the size of the strip required has been established and the surgeon has outlined the area to be excised, a local anesthetic is administered. The agent most often used is lidocaine 1% with adrenaline (1:100 000 or 1:200 000), which will achieve immediate anesthesia with good vasoconstriction. After administering lidocaine, we also inject bupivacaine 0.25% with 1:200 000 adrenaline, a combination that increases the duration of action of the anesthetic to approximately 3 to 4 hours.

To minimize patient discomfort during infiltration, we recommend injecting the anesthetic slowly using 1-cc Luer lock syringes with 30-gauge needles and simultaneously applying vibration anesthesia, that is, stimulating the area of skin adjacent to the injection site with a vibrator device at the moment of injection (Figure 6). According to the gate control theory, pain impulses are attenuated by the response of the fast fibers activated by the vibration emanating from the same dermatome. Vibration anesthesia is a very effective technique currently being used to reduce injection pain in other dermatologic procedures.[23] Once the scalp has been anesthetized, we infiltrate 20 to 30 cc of saline solution into the subcutaneous tissue to make it tumescent (turgid). This gives rise to immediate hemostasis.

We then excise the donor strip using a number 10 scalpel blade. The incision should be clean and run parallel to the line of the hair follicles at a depth of 5 to 7 mm to reach the deep subcutaneous tissue just below the follicular bulbs. It is rarely necessary to cauterize blood vessels when
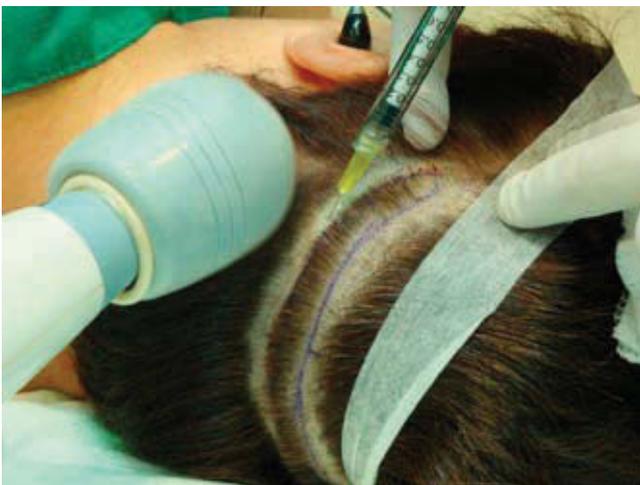

Figure 7 Excision of the donor strip. The incision should be made parallel to the hair follicles and reach a maximum depth of 5 to 7 mm.

Figure 8 Detaching the donor strip from the underlying tissue.

Figure 6 Injection of anesthesia into the donor area. This figure shows the application of a handheld massage device to the skin adjacent to the injection site (vibration anesthesia).

making an incision of this depth because we avoid the deep vessels of the galea. The angle of the incision should be parallel to the angle of the follicles to minimize as far as possible the likelihood of follicle transection (Figure 7). The strip is then cut free of the underlying tissue using a scalpel or surgical scissors (Figure 8).

Trichophytic closure is a minor modification that has been widely adopted in recent years.[24] In this technique, after the strip has been excised and before the wound is sutured, a small strip (1 mm) is trimmed from the upper or lower edge of the surgical wound with a fine-tipped scissors so that, after closure, hair will grow through the scar making it less visible (Figures 9 and 10).

Finally, we normally close the wound on a single plane with 4-0 nylon sutures or 3 M staples (Figure 11) joining the edges carefully and precisely. However, when a certain amount of tension is observed, we bring the 2 edges closer together initially with absorbable deep sutures (3-0 Vicryl). The sutures or staples are removed after 10 to 12 days.
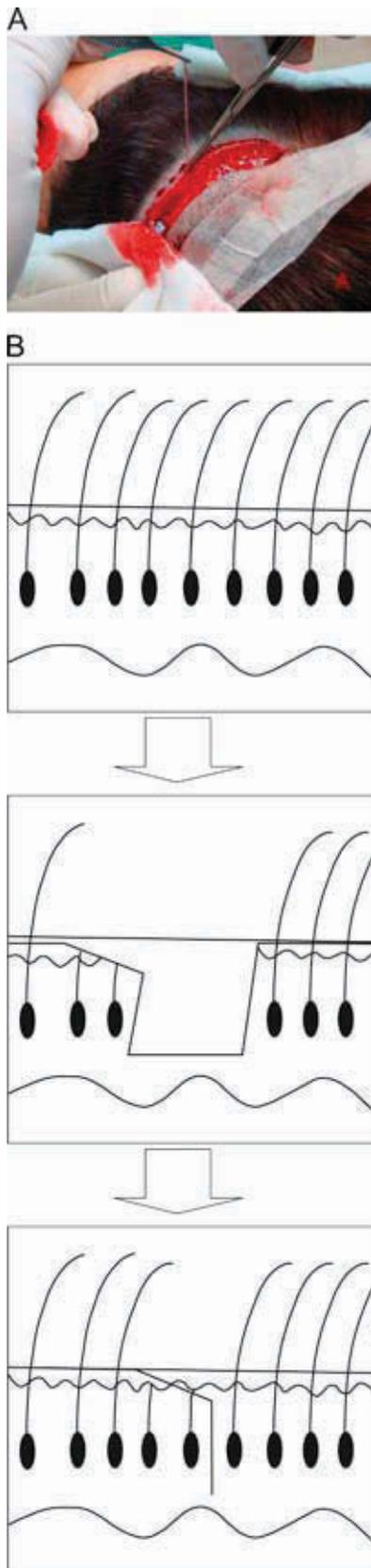
Figure 10 After trichophytic closure, hair will grow up through the scar in the donor area making it less visible.

Figure 11 The wound in the donor area can be closed with sutures or staples. Staples were used in this case. The borders should be joined carefully and precisely.

Figure 9 Trichophytic closure. A, a narrow strip 1 mm wide is trimmed from the lower edge of the surgical wound with fine-tipped scissors. B, this closure technique is used to make hair grow up through the scar.

Figure 12 Two technicians use Zeiss Stemi DV4 stereo microscopes to dissect the donor strip into follicular units.

Figure 13 The first step is to divide the donor strip crosswise into smaller slivers containing 1 or 2 rows of follicular units.
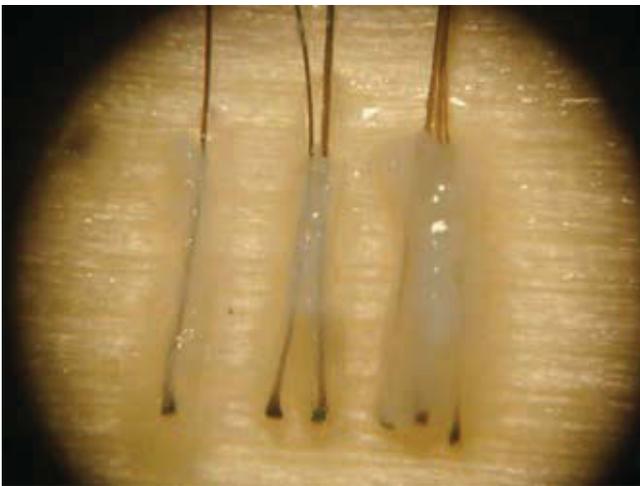

Figure 14 Follicular units containing 1, 2, and 3 hairs after microscopic dissection.

Microscopic Dissection of the Follicular Units

The excised donor strip is then dissected using stereo microscopes to obtain the follicular units for implantation in the recipient area (Figure 12). In the first step of this process, the donor strip is divided crosswise into slivers, each containing 1 or 2 rows of follicular units (Figure 13). The fragments are then further dissected to separate the follicles, and the dermal tissue around the follicles is trimmed away (Figure 14). This process must be carried out carefully and meticulously by trained technicians (dissectors), who group the units on the petri dishes according to the number of follicles they contain (1, 2, and 3 or more hairs). The units are kept moist in physiological saline or Ringer lactate solution until they are implanted (Figure 15).

Typically, a skilled technician can dissect over 250 follicular units per hour. Depending on the size of the area to be transplanted, we generally use, on average, a team of 4 to 6 dissectors.
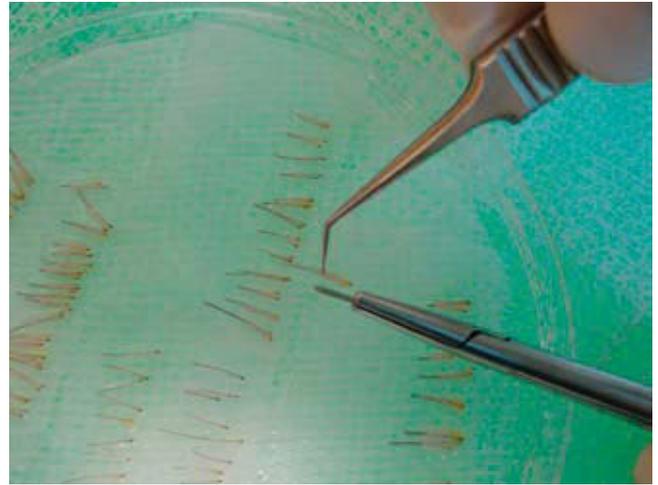

Figure 15 The follicular grafts are placed in Petri dishes according to the number of hairs they contain and are kept hydrated until implantation.

To save time, while the technicians are dissecting follicular units, the surgeon starts to prepare for the next step in the procedure by making incisions in the recipient area.

Creation of Recipient Incisions

Before starting to make incisions in the recipient area, the physician marks the frontal hairline on the scalp. The following 3 basic rules should be observed to ensure a natural looking hairline: a) the implanted hairline should be created at a specific distance from the glabella; b) the line of the temple angles must be respected; and c) the hairline should be irregular.[25] The surgeon should bear in mind that the newly created hairline will be permanent and must therefore appear natural not only 1 year after transplantation but throughout the patient's whole life. A very common error among inexperienced surgeons dealing with young patients is that they accede to the patient's wishes and create an excessively low hairline which, with the passage of time, may appear too low for the patient's age. As a general rule, the frontal line of implantation should be located at least 7 to 9 cm from the glabella (Figure 16).[26]

While the technicians are dissecting the donor strip, the recipient area must be anesthetized before the incisions are made. We administer the same combination of anesthetics described above for the anesthesia of the donor area and also use vibration to reduce pain. Regional anesthesia (a ring block) is achieved by anesthetizing the whole area anterior to the line of implantation. Many surgeons also use a bilateral supraorbital nerve block.[27]

Before the incisions are made, the recipient area is infiltrated with a tumescent mixture of physiological saline and 1:200 000 adrenaline. The resulting tumescence of the cutaneous tissue minimizes bleeding when the incisions are made.

Two different procedures are used for making recipient incisions. In the so-called stick and place method, the surgeon makes a single recipient incision and immediately introduces the graft. In the second method, all of the incisions are made

Figure 16 The following 3 basic rules should be observed to ensure a natural-looking hairline: the new hairline should be situated at a predetermined distance from the glabella (7-9 cm); the temple angles should be respected; and the hairline should be irregular. A, the planned outline before transplantation. B, a year later showing the natural-looking frontal hairline created.
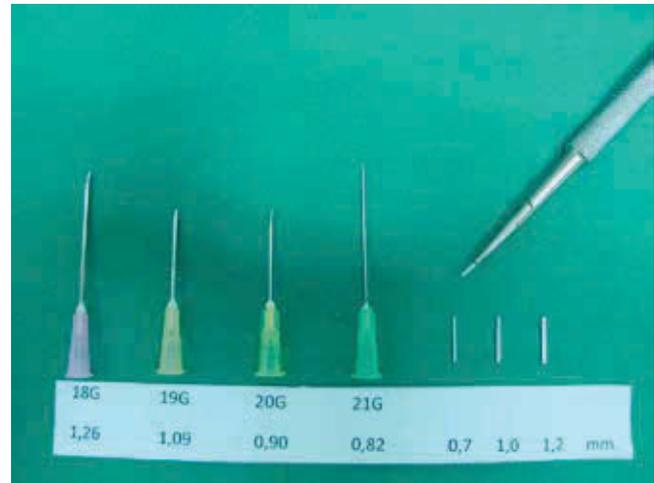

Figure 17 Hypodermic needles and rectangular blades used to make the recipient incisions. The caliber of the needles and the diameter of the incision created are shown. The blades fit into the scalpel handle shown on the right.

prior to starting graft insertion and the follicular units are then inserted into the previously prepared slits.

A number of different instruments can be used to create incisions.[28] We most often use hypodermic needles and rectangular chisel-shaped scalpel blades (Figure 17). Scalpel blades can be used to cut perpendicular to the direction of hair growth[29] (a coronal incision, the method we prefer) or parallel to the direction of hair growth (a sagittal incision).

To facilitate insertion, the size of the incision should be adjusted to the size of the follicular unit to be implanted. If the incision is larger than the follicular unit, the graft will tend to fall out easily when other grafts are inserted close by. However, if the incision is too small, placement will be slower and more difficult. A 1-hair follicular unit has a diameter of approximately 0.7 mm while a 2- or 3-hair unit is approximately 1 mm in diameter. For 1-hair follicular grafts, 21- and 22-gauge needles are most often used while 19- and 20-gauge needles are used for grafts containing 2,

3, or more hairs. The scalpel blades used for 1-hair grafts are 0.6 to 0.7 mm while those used for grafts containing 2, 3, or more hairs are 0.9, 1.0, and 1.1 mm.

All incisions are made to a depth of 4 to 6 mm in the anterior-posterior direction, following as closely as possible the direction of natural hair growth on the scalp. If the patient has some hair in the recipient area, this can serve as a guide to the correct orientation and angle of the incisions. In the frontal area, incisions should be slanted forward at an acute angle of 30°. The farther back the location on the scalp, the more the angle of the incision approaches the perpendicular (in the posterior parietal zone the incision is angled 60° to 70° with respect to the surface of the skin).

The incisions along the frontal hairline are made to accommodate 1-hair follicular units, and the incisions farther back are adjusted to the size of follicular grafts with 2 or more hairs. This distribution produces a gradual and natural transition from the hairless skin of the forehead to the hair-covered scalp.

Density in the transplanted area is affected by 2 factors, the caliber of the transplanted hair and the number of follicular units implanted per square centimeter of recipient area. To achieve acceptable density, our target is to implant between 20 and 40 units/cm^2 (Figure 18). If the recipient area is small, this can be achieved in a single session, but in patients with extensive bald areas (more than 100 cm^2), 2 or more sessions are generally need to achieve acceptable density.

Insertion of Follicular Grafts

The insertion of the grafts into the recipient incisions is the part of the procedure that requires the greatest manual dexterity and skill. It can be the most frustrating work for an inexpert surgeon or assistant. Typically, 2 members of the team work together, 1 on either side of the patient,
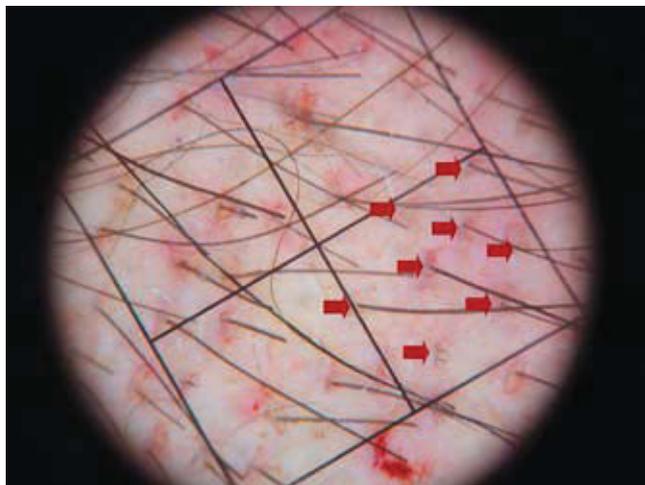
Figure 18 Magnified image of the recipient area after graft implantation. The grid is 1 cm^2 and is divided into 4 quadrants. The arrows indicate the grafts implanted in 1 quadrant (density, approximately 30 grafts/cm^2).

introducing the follicular grafts into the incisions one by one. Special, fine-tipped jeweler's forceps are usually used to place the grafts. The tip of the forceps can be either straight or angled (Figure 19). In Asia, hair implanters are more commonly used for this task.[30] The graft is inserted using high quality loupe magnification and without exerting any pressure on the root of the follicle to avoid damage. With practice, an experienced technician can insert between 6 and 10 units/min.

Once all of the grafts have been inserted, the donor area is protected with a dressing held in place by a headband. The patient returns the following day to have the dressing removed.

Indications for Follicular Unit Hair Transplantation

Androgenic Alopecia

Androgenic alopecia is the primary indication for hair transplantation in both men and women. The results obtained are highly dependent on the skill and experience
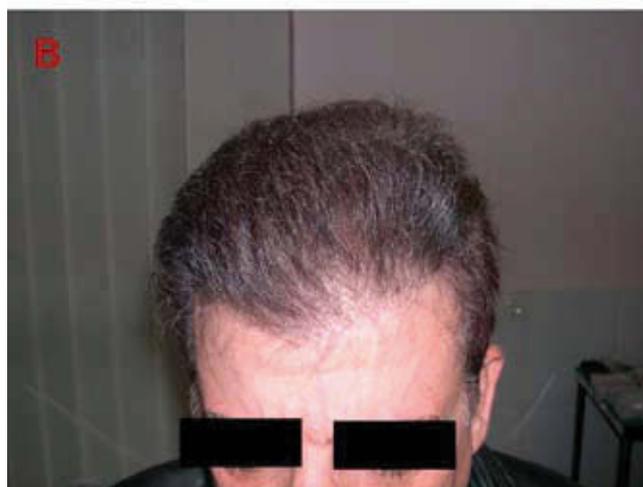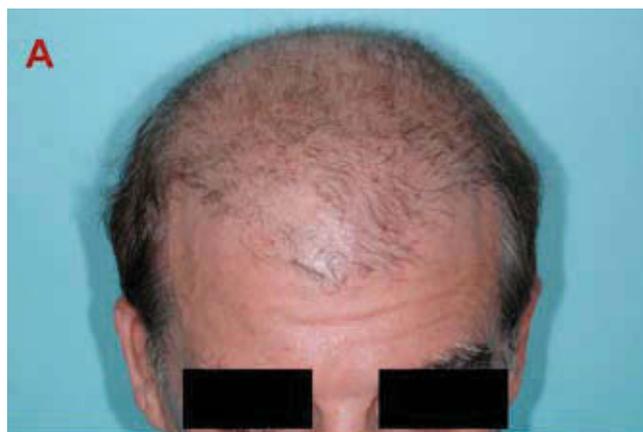

Figure 19 A, incisions along the hairline before the grafts are inserted. B, placement of the grafts with special ultrafine-tipped forceps.

Figure 20 Androgenic alopecia is the chief indication for hair transplantation in both men and women. A, in this patient 5212 follicular units were transplanted in 4 sessions performed at 6-month intervals. B, the final result is a dense and completely natural head of hair.
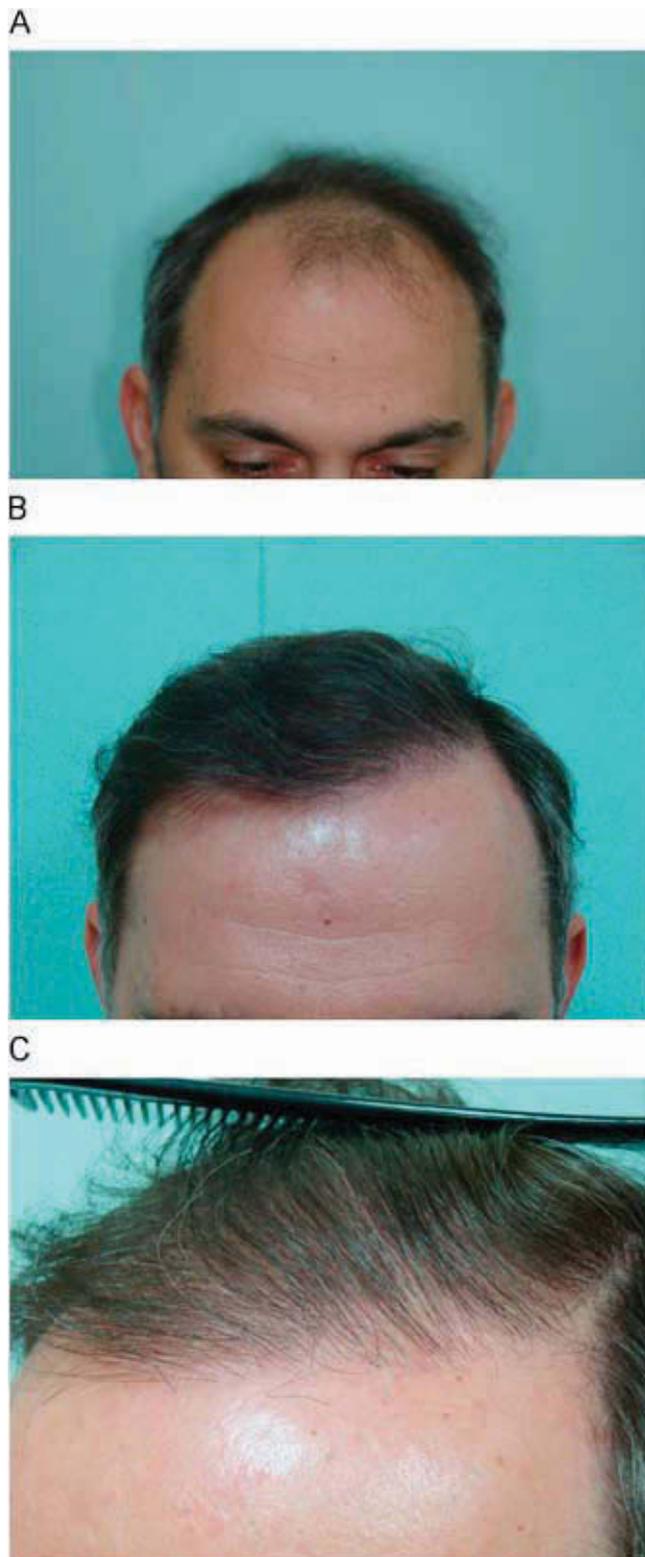
Figure 21 A, patient with androgenic alopecia before follicular unit hair transplantation. B, result after the procedure (2626 grafts in total). C, a more detailed picture of the same patient showing how the hairline is composed of single-hair follicular units.

of the surgeon and the use of the proper technique. The 2 key considerations are the natural appearance and undetectability of the result (when follicular units are used a natural and undetectable result can be guaranteed) and the coverage or density achieved (Figures 20 and 21).

All patients with androgenic alopecia who have a good donor area are candidates for hair transplantation, especially those with moderate or advanced levels of baldness (Norwood type II-VI; see Appendix). In young patients it is important to keep in mind that androgenic alopecia is progressive, making the indefinite use of a combination of oral finasteride and topical minoxidil necessary in these patients.

Unlike men, women generally retain the frontal hairline but experience more diffuse thinning over the whole parietal zone (Ludwig pattern; see Appendix). In women, most of the follicular units are transplanted to sites distributed among existing hairs, mainly in the anterior half of the scalp. Coverage of a receding hairline at the temples is also frequently required in many women (Figure 22).

Cicatricial Alopecias

Another excellent indication for hair transplantations is cicatricial or scarring alopecia caused by burns (Figure

Figure 22 Transplant in a woman with androgenic alopecia. A, receding frontal hairline. B, result a year after the procedure.

A

B

23), trauma, surgery, or radiotherapy.[31,32] Scarred patients are very happy with the results of transplantation given the esthetic problem this type of alopecia generally represents.

In patients with primary scarring alopecias, such as lupus erythematosus, lichen planopilaris, and folliculitis decalvans, hair transplantation should not be performed until all clinical signs of active inflammation have disappeared. The procedure is therefore only recommended in primary scarring alopecias that have been clinically stable for at least 1 to 2 years. We also recommend carrying out a preliminary test by transplanting 20 to 30 grafts to an affected area to make sure that the growth and permanence of the transplanted grafts is adequate.

Hair Transplantation in Alopecias Affecting Other Areas

Transplantation can also be used to increase hair density in the eyebrows (Figure 24), eyelashes, moustache, beard, and pubic area.[33-36] In the case of eyebrows, single-hair grafts are used almost exclusively and it is very important to make the incisions at a very acute angle and to follow the natural hair direction closely. Hair loss in the sideburns caused by facelift surgery is also a good indication for transplantation.[36]

Triangular Alopecia of the Temples

Congenital triangular alopecia or temporal triangular alopecia is a rare form of alopecia circumscripta. The usual clinical picture is a round or oval plaque of alopecia, with no inflammation or scarring, generally located in the anterior temporal area. This bald spot may grow in size in proportion to the growth of the child and generally reaches a diameter of some 2 to 4 cm. It does not respond to medical treatment and hair transplantation is the most satisfactory solution.[37]

Complications Associated With Hair Transplantation

All surgical interventions are associated with complications. Fortunately, when performed carefully by expert technicians, hair transplantation is a safe procedure and very few complications ensue (Table 5). Infection of the surgical wound in the donor area is extremely rare. The scar in the donor area is usually 1 to 2 mm wide if the surgeon can precisely match the edges and close the surgical wound without excessive tension. Edema in the forehead is one of the most common complications. This usually appears on the second day after transplantation and lasts about 3 to 4 days. It gradually spreads downwards, in some cases

Figure 23 Burn scars on the scalp are an excellent indication for transplantation if the patient has a sufficiently large donor area. A, the patient's scalp was burned at 18 months of age giving rise to permanent scarring alopecia. B, in spite of the extent of the alopecia, this image shows a radical and very favorable cosmetic change after 3 transplantation sessions of approximately 1500 follicular units per session.

Figure 24 A, a patient with eyebrow alopecia caused by local radiation therapy for an ocular tumor. B, image taken during the intervention in which 232 follicular grafts were transplanted (158 with 1 hair and 74 with 2-hairs). C, result 9 months after transplantation.

reaching the eyelids. The incidence of edema is usually reduced if the patient receives 30 mg of oral prednisone during the 3 days following the transplantation.

The most disappointing complication for both the doctor and the patient is scant growth of the transplanted grafts (for example, less than 70%). Currently, with good technique, it is possible to obtain hair growth in more than 90% of the transplanted follicles after the first intervention.[38,39] When the growth rate is lower than expected, all the steps of the transplantation procedure must be carefully assessed since every step has a bearing on the final result.[40]

Three of the most important factors that may affect the survival of transplanted grafts are dehydration, physical trauma, and the length of time spent outside the organism.[40] When grafts are not continuously well hydrated in physiological saline solution throughout the entire process from extraction to implantation they may dry out; this will reduce the survival rate.[41] Incorrect handling of grafts, particularly during implantation, can damage the follicular bulb and have a negative impact on growth. Finally, as in any organ transplant procedure, it is important to take into account the length of time the graft spends in an ischemic state outside the organism. In 1992, Limmer[42] studied the survival rate of grafts according to the length of time they were outside the patient's body. The results of that study showed a survival rate of 95% after 2 hours, 90% after 4 hours, 86% after 6 hours, 79% after 24 hours, and 54% after 48 hours. The transplantation procedure should not therefore last longer than 6 hours.

Even when all of the steps are carried out correctly, inexplicable cases of scant growth are found in 1% to 3% of patients due to unknown causes (X factor).[43]

Follicular Unit Extraction

Follicular unit extraction, a technique described in 2002 by Rassman and Bernstein, is an alternative method of harvesting follicular units from a donor site.[44,45] Instead of surgically removing a donor strip, which is described above and is still the most commonly used and standard method, the surgeon extracts individual follicular units with circular punches (0.8 to 1 mm in diameter). The tiny holes created heal by second intention within a few days (Figure 25).

Follicular unit extraction is an interesting technique that makes transplantation surgery less invasive. However, while the chief advantages of this method are that no sutures are needed and no linear scar is produced, in the hands of an inexperienced technician it will result in a very high percentage of transected follicles. Moreover, it is a very slow method because the follicular grafts are extracted individually.

Figure 25 In follicular unit extraction, an alternative method, individual follicular units are extracted using a circular punch 0.8 to 1 mm in diameter. The figure shows the donor area after follicular unit extraction. The punch holes heal rapidly by second intention.

To carry out this procedure, we use the blunt-tipped punch described by Harris[46] because it reduces the percentage of transected follicles (Figure 26). In this two-step technique, the superficial dermis is first scored using a sharp 1 mm punch and then a blunt-tipped punch is used to separate the graft from the dermis and surrounding subcutaneous tissue. Finally, forceps are used to remove the follicular unit. The difference between follicular unit extraction and the traditional method is only the method used to harvest the grafts because the procedures used to make the recipient incisions and to insert the grafts are the same as those described above.

In our opinion, a view shared by other authors,[47] follicular unit extraction is indicated mainly in the following situations:

1. In patients who shave their heads or wear their hair so short that the linear scar left by the excision of a donor strip would be visible.
2. In patients with multiple scars in the donor area from previous sessions who no longer have sufficient scalp laxity to permit the excision of another donor strip.
3. To repair wide scars in the donor area.

Future Trends

There are still many aspects of hair transplantation that could be improved, in particular the development of new tools to further automate the procedure, shortening the intervention and making it less dependent on the manual skill of assistants. Robotic devices are being developed that will extract individual follicular units using a method similar to that of follicular unit extraction. The target is to achieve an extraction rate of 1000 follicular grafts per hour.[48]

Figure 26 Instruments used for follicular unit extraction: on the left a blunt-tipped Harris punch, in the middle a conventional 1-mm Miltex punch; on the right, they have been joined together.

For approximately the last 5 years, researchers have been investigating the possibility of multiplying follicular cells in culture with a view to implanting them in balding areas (follicular neogenesis or follicle cloning). This advance would make it possible to create an almost unlimited reserve stock of follicles. The 2 companies currently investigating follicular regeneration are Intercytex (www.intercytex.com) and Aderans Research (www.aderansresearch.com). Follicular cell implantation is based on the inductive capacity of dermal papilla cells [49] and the presence of epithelial stem cells with high proliferative potential in the external sheath of the hair follicle, mainly in the bulge zone.[50] These cells can be grown in culture making it theoretically possible to extract cells from a few dozen donor follicles and multiply them to generate enough new cells to induce the growth of several thousand new hair follicles. The aim would be to combine keratinocytes and dermal papilla cells to generate thousands of follicles to restore the hair. Two strategies are current being investigated: inducing follicular neogenesis in vivo by infiltrating inductor cells into the scalp; and the creation of protohairs in culture before implantation. Since the process is currently in the preclinical research phase, it is unlikely that these techniques will become commercially available for a long time.

Learning the Transplantation Technique

Entering the field of hair transplantation has never been so difficult as it is today. The chief problem for a physician is not just to find good training, but also to build a skilled team because transplantation is not a technique that can be carried out by a single surgeon with a single assistant. The procedure requires a team skilled in the dissection of follicular units and graft implantation. Moreover, it is impossible to be competitive in the initial stages in a market in which many hair transplantation clinics currently offer mega-sessions of 2000 to 4000 grafts per session.

The first step for a physician is to acquire good training through workshops and conferences or by enrolling in specialized programs offered by accredited centers. Some of these courses last up to a year. Undoubtedly, the best scientific association offering such training is the International Society of Hair Restoration Surgery (ISHRS, www.ishrs.org). This group, which represents more than 700 physicians throughout the world whose chief area of work is the medical and surgical treatment of alopecia, organizes an annual conference with a high scientific level and publishes a bimonthly journal called *Hair Transplant Forum International* with original articles, commentary, and editorials dealing exclusively with hair transplantation. Specialist textbooks on the subject are also available, and these are highly recommended to anyone interested in becoming proficient in this technique.[52-55]

Once physicians have received the basic training, they need to train a minimal staff. It is possible to start with 3 dissectors, 1 of whom can also assist with the insertion of the grafts. The novice team should start with patients requiring coverage of only small areas to ensure that the number of grafts to be transplanted is not beyond their capacity. The number of grafts transplanted per session can then be gradually increased as the team acquires skill and experience.

Conclusions

The field of hair transplantation is evolving continuously. Over the last 15 years, we have at last managed to eradicate the idea that hair transplantation is an aggressive procedure that produces an artificial result. Thanks to the use of follicular unit transplantation, it has become a much less invasive technique that produces natural, undetectable and reproducible results.

However, follicular unit transplantation is a technique still little known to many dermatologists. We often encounter patients who have not been properly informed about this technique or have even been discouraged from undergoing transplantation by their own physician. In view of the results that can be obtained, there is currently no reason not to offer, in addition to medical treatment, the possibility of hair transplantation to patients who are good candidates for the procedure and wish to improve their appearance. We hope that this review may serve as a source of objective information on the current state of hair transplantation and may also encourage many dermatologists to consider entering this field.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix. Hair Transplantation Terminology

Follicular unit graft: follicular units are the natural groups of follicles on the human scalp. Typically, each follicular unit has between 1 and 4 terminal hairs.

Frontal hairline: an area approximately 1-2 cm wide of transitional density between the hairless forehead and the frontal area of hair-covered scalp.

Follicular unit hair transplantation: a technique in which only follicular units are transplanted.

Follicular unit extraction: a technique that involves the direct extraction of follicular units from the donor area using a small punch (0.8-1 mm).

Donor area: the area of the scalp not genetically susceptible to hair loss from which the hair follicles for transplantation are extracted. This area is located in the mid and temporal occipital areas of the scalp.

Recipient area: the area in which the follicular unit grafts harvested from the donor site are implanted.

Norwood classification: the standard classification scale for male pattern baldness since it was introduced by Hamilton in 1941.[56]

Ludwig classification: a classification that describes a pattern of female alopecia characterized by diffuse thinning of hair over the whole upper area of the scalp with no hair loss in the frontal area or recession at the temples.[57]

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