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What is This?
Hair Restoration Surgery: The State of the Art

James E. Vogel, MD; Francisco Jimenez, MD; John Cole, MD; Sharon A. Keene, MD; James A. Harris, MD; Alfonso Barrera, MD; and Paul T. Rose, MD, JD

Abstract
Hair restoration is a highly sophisticated subspecialty that offers significant relief to patients with hair loss. An improved understanding of the aesthetics of hair loss and cosmetic hair restoration, hair anatomy and physiology, and the development of microvascular surgical instrumentation has revolutionized the approach to surgical hair restoration since the original description. Additional elements that contribute to the current state of the art in hair restoration include graft size, site creation, packing density, and medical control of hair loss. The results of hair restoration are natural in appearance and are provided with a very high level of patient satisfaction and safety. This aspect of cosmetic surgery is a very welcome addition to a traditional aesthetic practice and serves as a tremendous source for internal cross-referral. The future of hair restoration surgery is centered on minimal-incision surgery as well as cell-based therapies.

Keywords
hair transplant, alopecia, follicular unit graft, hairline, CME

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Alopecia, the term for generic hair loss, involves a diminution of visible hair. There are numerous types of alopecia. The most common form of surgically treatable alopecia is androgenic alopecia (AGA). Throughout time, the presence of scalp hair has represented attributes of health, vigor, vitality, and strength. Accordingly, loss of hair in men (MAGA, or male pattern androgenic alopecia) and especially women (FPHL, or female pattern hair loss) can have significant psychosocial effects. The overwhelming majority of procedures for hair restoration are hair transplants, and the advent of microvascular surgical instrumentation as well as an improved understanding of the anatomy and physiology of hair loss has revolutionized the art of surgical hair restoration since the original description and early refinements.

Androgenic alopecia is characterized by progressive visible thinning of scalp hair in genetically susceptible men and in some women. The current scientific data support the thesis that AGA is a polygenic trait. Significant associations have been reported with variant regions of the androgen receptor gene, which is located on the X chromosome. Epidemiologic surveys of AGA reveal the highest incidence in Caucasians, followed by Asians and then Africans, with the lowest incidence in Native Americans.

For the purpose of hair transplantation, the scalp may be divided into the frontal, midscalp, vertex, and temporal areas (Figure 1A-C). Hair thinning and subsequent shedding is due to gradual miniaturization of genetically...

ANATOMY, GENETICS, AND PHYSIOLOGY OF HAIR LOSS

Androgenic alopecia is characterized by progressive visible thinning of scalp hair in genetically susceptible men and in some women. The current scientific data support the thesis that AGA is a polygenic trait. Significant associations...
marked hair follicles and represents shortening of the anagen (growth) phase of the hair follicle with an increase in the telogen/anagen ratio of the affected scalp. An understanding of the normal hair follicle life cycle is critically linked to an appreciation of the physiology of hair loss.9-14

Miniaturization results in the conversion of terminal (large) hairs into smaller, barely visible, depigmented vellus hairs (Figure 2).15 At the cellular level, follicle miniaturization is thought to be caused by a reduction in dermal papilla volume, as a consequence of a decrease in the number of cells per papilla. Nonetheless, hair follicles are still present and cycling, even in bald scalps.16,17 Although testosterone is the major circulating androgen that causes hair loss, to be maximally effective, it must first be converted to dihydrotestosterone (DHT) by the enzyme 5α-reductase. The importance of DHT as an etiologic factor in male pattern hair loss is shown by the absence of AGA in men with congenital deficiency of type II 5α-reductase inhibitor.18 Balding scalp contains excessive concentrations of 5α-reductase, DHT, and the DHT androgen receptor. The action of DHT is mediated by intracellular nuclear androgen receptors.19

In women, there is no consensus on whether hair loss is truly androgen dependent. Most women with FPHL do not have biochemical hyperandrogenism. In fact, some women without detectable circulating androgens may also develop FPHL, suggesting a possible role for non-androgen-dependent mechanisms. Based on this evidence, it seems appropriate to replace the term androgenic alopecia in women with the previously mentioned, more contemporary and scientifically descriptive term female pattern hair loss (FPHL), to include this recognized heterogeneity.4,6-8,19-26

On a macro level, the majority of human hair shafts emerge from the scalp as single-, 2-, and 3-hair groupings (Figure 3). The groupings are the visible superficial portion of a distinctive histologic structure, known as the follicular unit (FU). Present-day hair transplants almost exclusively use follicular units as the transferred element.

Figure 1. Surgical anatomy of the scalp. (A) Frontal view emphasizing the level of the hairline, relationship to the temporal triangle, and the lateral canthal line. (B) Profile view to illustrate the relationship between the lateral hump and lateral aspect of the forelock. (C) Caudal view to illustrate the relationship with the lateral canthal line and lateral extent of the anterior hairline.
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of tissue, and thus the contemporary nomenclature for this procedure is a follicular unit hair transplant (FUT).\textsuperscript{27-34} The clinically observed patterns of MAGA have been well described by Norwood,\textsuperscript{35} after whom the most common classification system for this condition is named. On the other hand, hair loss patterns in women are typically characterized by maintenance of the anterior hairline and diffuse central thinning over the midfrontal scalp, as described and originally classified by Ludwig.\textsuperscript{36,37} Exceptions to these patterns occur. Some men will exhibit a Ludwig pattern of loss, and some women will display a typical Norwood pattern.

**NONSURGICAL OPTIONS FOR TREATING HAIR LOSS**

There are currently only 2 medications approved by the US Food and Drug Administration (FDA) to promote hair growth in the scalp. These medications are finasteride and minoxidil. Other options for medications claiming to treat hair loss are extensive but also of questionable value.\textsuperscript{38-40} Finasteride (Propecia; Merck & Co, Inc, Whitehouse Station, New Jersey) is a medication that lowers DHT through blockades to the 5α-reductase type 2 pathways (Figure 2). In a prospective randomized study by the manufacturer, finasteride was shown to reduce hair loss or have positive effects related to hair growth in 90% of patients, and the drug’s safety and efficacy have also been reported by independent research.\textsuperscript{41} Propecia is FDA approved for men only. The FDA only allows the manufacturer to make claims regarding growth in the vertex area of the scalp, but many physicians have noted that this medication has a global effect on the scalp hair.

Side effects reported with finasteride include a decrease in libido, erectile dysfunction, testicular pain, and benign...

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**Figure 2.** Progression of hair loss. In youth, testosterone is limited in concentration; however, during puberty and adulthood, testosterone is converted to dihydrotestosterone (DHT). Exposure of susceptible hair follicles to DHT results in miniaturization and ultimately hair loss. The enzyme 5α-reductase is responsible for the conversion of testosterone to DHT. Finasteride is an oral medication that blocks this pathway and prevents hair loss.

**Figure 3.** Magnification view of in situ follicular units (FUs). A 4-hair FU has been scored in preparation for a follicular unit extraction (FUE) donor harvest.
growth in the male breast. The side effects associated with the drug generally disappear with discontinuation of finasteride. Some controversy exists regarding its relation to breast and prostate cancer as well as the temporary nature of sexual side effects.42,43

Minoxidil (Rogaine; McNeil-PPC, Inc, Morris Plains, New Jersey) has been available since 1988 as a topical medication indicated to treat hair loss. It has been used in men and women. The mechanism of action is unclear, but it is recognized that the vasodilatory effects of minoxidil do not fully explain its positive action on hair growth. Observed benefits include increased proliferation of dermal papillae cells, increased hair caliber, and diminished telogen phase during the hair growth cycle.

**EVALUATION AND PLANNING**

**Photography**

Photography of the hair restoration surgery (HRS) result is the principal measure by which results are objectively documented. The use of lighting and standard positions for hair photography has been described.44 The use of a light gray or blue-colored background is recommended, so that the top borders of dark hair will not blend into the background. This background will also work for white and blond hair.

**General Evaluation**

Young men and women are particularly distraught by the signs of hair loss.55,46 Low self-esteem and vulnerability to a fantasized outcome place this subset of patients at particular risk for quick decision making and unrealistic expectations. Managing these expectations and formulating a realistic surgical plan for patients with hair loss is a critical component to the long-term success of the procedure.

A fundamental concept that physicians and patients are advised to maintain during the evaluation and planning for HRS is that hair loss is progressive. The appearance of hair loss in the office during consultation is merely a snapshot along a continuum that began years earlier and will progress until death. Communication regarding the quality of the patient donor hair is also an additional essential component in managing expectations. The qualities of the hair that should be reviewed include curl, hair shaft diameter, color, texture, follicular unit density, and the telogen/anagen ratio of in situ donor hair. These aspects of the donor hair should be not only reviewed but also documented as a means to predict how well the transplanted hair will camouflage areas of scalp alopecia.

Lab tests for diagnosis are generally unnecessary in men with typical pattern AGA. However, a differential diagnosis for nonandrogenic causes for hair loss should be maintained for consideration during the evaluation.57,58 Finally, most men younger than 60 years will also be encouraged to consider the use of finasteride, 1 mg daily, to reduce crown hair loss.

In women, the pattern of hair loss with FPHL, especially in the early stages, can be mimicked by a variety of other conditions. These include frontal fibrosing alopecia, diffuse alopecia areata, and telogen effluvium (acute and chronic).51,54 Women with bitemporal recessions, as seen with male pattern baldness, should be screened for hormonal imbalances. Finally, women with typical FPHL in a Ludwig pattern should be checked for iron deficiency as well as thyroid function to rule out other causes of diffuse hair loss.55

**Recipient Area**

The first step in assessing the recipient area is to determine where to place the grafts. A conservative and principled surgical plan for the recipient site is an initial forelock distribution hair transplant. The forelock is the area bounded anteriorly by the frontal hairline, posteriorly by the anterior crown region, and laterally by the parietal fringe (Figure 1). This is a commonly maintained, normal distribution of hair seen in male patients with mild hair loss. A forelock pattern hair transplant is initially planned when there is anticipation of considerable future hair loss, especially in a young patient. For the same reason, this approach is also very appropriate for older patients who present with extensive baldness and limited donor supply. The rationale for this approach is that the distribution of grafts in a forelock limits the requirements from the donor supply. Creation of a forelock pattern also provides an opportunity for a large, single-session procedure to achieve the 2 fundamental goals of hair restoration surgery—namely, to recreate a normal pattern of hair loss seen in nature and to create a frame of hair for the face (Figure 4).56-58 The beauty of this conservative and safe surgical approach is that this graft distribution can be expanded posteriorly for additional crown coverage as desired.

Determining the number of grafts for the initial procedure and over the lifetime of the patient is the next step in recipient planning and evaluation. This assessment depends on a number of factors. These include current degree of baldness, donor hair characteristics, degree of anticipated hair loss, patient’s goal for density and ultimate coverage, technical expertise of the hair transplant team, and financial considerations of the patient. A good visual transplant result will be apparent with densities between 25 and 40 FU/cm². To put this into perspective, in adult men with no “visible” hair loss, the typical density in the frontal hairline ranges between 38 and 78 FU/cm² (average 52 FU/cm²), whereas the average frontal density of prepubertal males is approximately 80 to 100 FU/cm².59

**Donor Area**

It cannot be overemphasized to the patient that his or her own intrinsic donor hair characteristics will dictate the fullness of the hair transplant result. Patients with a thick
**Figure 4.** This 38-year-old man with male pattern hair loss requested hair restoration. He underwent a 2200-follicular unit forelock transplant in 1 session and is shown intraoperatively in part A. (B, D) Preoperative views. (C, E) At 10 months postoperatively, the patient’s face is framed with hair in a natural distribution. This result could be a stand-alone outcome or additional grafts could be added for more coverage as desired.
Hair Transplant Technique

As with any surgical procedure, the techniques of the operation will vary based on personal preference and clinical circumstances. Although the fundamental approach described herein is nearly universally applicable, the specific techniques do reflect most closely the methodology preferred by the lead author (JEV).

Anesthesia

Hair transplantation can be performed under local anesthesia alone or with supplemental sedation. The local anesthesia solution is a 40-mL mixture of 0.25% bupivacaine with 1:200,000 epinephrine + 20 mL 1.0% lidocaine with 1:200,000 epinephrine. This solution is used in the donor and recipient sites, and supplementation with additional bupivacaine 0.25% is performed in both regions of the scalp prior to discharge from the operating room. If conscious sedation is included with the procedure, the patient is premedicated with 1 to 2 mg PO aprazolam. In the operating room, an intravenous cocktail of ketamine 5 mg/mL, midazolam 0.5 mg/mL, and fentanyl 10 mcg/mL is titrated to achieve the desired level of sedation. All patients receiving any type of sedation are continuously monitored during the procedure with oximetry and receive supplemental nasal oxygen.

Donor Site Harvest

In contemporary practice, follicular units can be obtained either through strip excision of the donor scalp with subsequent microscopic tissue dissection26-28 or by removal using a technique called follicular unit extraction (FUE).62-69

Strip excision. In preparation for the strip harvest, the selected area of donor hair is trimmed to 4- to 5-mm length and the patient is positioned in a lateral decubitus position. An ellipse of donor scalp is outlined, and following the administration of local anesthesia, tumescent saline solution is infiltrated. Tumescence in conjunction with precise knife blade angulation parallel to the hair shafts reduces follicle transection. Dissection level of the donor strip should be at the superficial fat to avoid injury to the occipital neurovascular bundle. The wound is closed in 2 layers, with an absorbable suture in the deep layer and a monofilament suture of choice at the level of the skin. Staples or dissolving sutures are also options.

Trichophytic closure. With the advent of shorter hairstyles, there has been an increased interest in minimizing (or maximally concealing) the donor scar. The trichophytic closure technique has been described to promote scar camouflage by allowing hair growth through the scar.70,71 After the first layer of the donor wound is closed, the entire lower edge of the incision epithelium is excised. The final running suture is then completed, with care taken to avoid deep “bites” of scalp that have the potential to damage underlying follicles (Figures 5A-F and 6A-C). This important anatomic detail is worth emphasizing to maximize the results with the trichophytic closure technique. Deepithelization as well as suture depth should not exceed 1 mm, to avoid injury to the follicle “bulge” zone. Although the bulge was originally described as the portion of the hair follicle to which the arrector pili (AP) muscle attaches, this important region has lately attained significant interest because it is where follicular epithelial stem cells have been identified.9 The bulge region starts at a depth of approximately 1 mm and extends down to 1.8 mm.29,31 Recently, a double-layer trichophytic closure technique was described.72

Graft preparation. Once the donor tissue has been harvested using the strip excision method, the tissue is immediately immersed in chilled isotonic saline or another type of preferred “holding” solution. Graft preparation is performed using stereomicroscopes and microsurgical instrumentation. Initially, the donor strip is subsectioned into slivers, each being 1 FU in width (approximately 1.2 mm). Considerable skill and experience are required to avoid transection of grafts during slivering and at the same time maintaining an efficient pace of preparation. Each sliver is then dissected into FU grafts (Figure 7). These grafts are placed back into a holding solution until they are planted. It is imperative that these grafts stay moist in order for them to avoid desiccation.

Follicular unit extraction. Follicular unit extraction is an alternative method of donor harvest. This technique is essentially a refined “micropunch grafting” version of the older punch graft technique. Using the current technique
of FUE, 1 FU is removed at a time. There are several techniques and instruments to perform FUE. These include manual, power-assisted, and automated methods. No matter which technique is employed, the net result is still the isolation and removal of a single FU (Figures 3 and 7). The remaining puncture is left to heal by secondary

Figure 5. Donor site harvest and trichophytic closure technique. (A) Patient is shown in decubitus position with donor hair shaved to 4 mm. (B) Excised donor strip. (C) The first of the 2-layer donor site closure is complete. (D, E) The intraoperative technique is shown and illustrated, with deepithelization of the donor wound margin. (F) The final closure is shown, with superficial bites of 1 mm. Superficial needle entry into the scalp is performed to avoid injury to the follicle “bulge” zone.
intention. Some hair transplant surgeons choose to employ FUE on a selective basis for small cases (Figure 8), whereas others select this donor harvest technique for their larger sessions (Figure 9). The increased popularity of FUE has been linked to the development of power-assisted technology as well as a general trend toward minimally-invasive techniques. The indications, outcomes, and techniques for FUE as a donor harvest option are found elsewhere.62-69

Follicular unit extraction comprises approximately 22% of all hair restoration donor harvest procedures performed, as reported in a worldwide poll of hair restoration surgeons.73 As with any emerging technology, there is debate regarding this methodology. Controversy related to this donor technique includes the idea that this method is a return to earlier methods of punch harvesting, the specific indications, the ideal harvesting tools (blunt vs sharp), and the survival and growth of the grafts themselves as compared with those obtained with strip harvesting. Depletion of donor density as well as overharvesting of

Figure 6. A healed donor harvest site is shown after strip excision and closure with the trichophytic closure technique. (A) Eight months postoperatively. (B) Diagram of healed donor scar following trichophytic closure. (C) Reexcision of the donor scar shown in part A, illustrating hair growth through the initial closure site on tangential view of the specimen.

Figure 7. Microscopic dissection of donor “sliver” and subdissected individual follicular units containing 1, 2, and 3 hairs.
hair vulnerable to AGA is also a concern with extensive FUE harvesting. However, increased acceptance and popularity of FUE are emerging as a result of evolving patient interest and technical refinements. In fact, a novel robotic automation of the FUE technique is in the developmental stage. Most hair restoration surgeons feel this donor
Hairline Design and General Recipient Area

The first landmark that needs to be determined is the height of the anterior hairline (AHL) (Figure 1). In most instances, the location of the most anterior, midfrontal portion of the hairline is between 7.5 and 9.5 cm above the glabella. The shape of the head, predicted future hair loss, and donor capacity are factors to consider in this creative decision. One must place the hairline in such a location that it will look natural as the patient matures and continues to lose hair.

If the temporal point is expected to recede, a higher hairline should be considered because a low hairline with a lost temporal point suggests a hairpiece. The temple point should be even or slightly posterior to the frontal hairline. Along with the aforementioned principles, a gently curving hairline should be created, with care taken to always maintain a significant frontal-temporal recession. Restoration of the temporal triangle is performed according to the personal preference of patient and surgeon.

The design should begin by ensuring the presence of a lateral hump (Figure 1). If the lateral hump is absent, this should be designed first. The lateral hump is the superior extension of the inferiorly directed hair of the temporoparietal fringe. The superior extent of this important landmark is even with or just medial to a line drawn vertically from the lateral canthus. This landmark is important because it represents the lateral extent of the AHL. The intersection of the lateral AHL and the lateral hump is the apex of the frontotemporal recession and should always be convex in a male AHL design (Figure 10).

The single most important component to achieving a natural appearance to the hair transplant is the creation of an outstanding AHL (Figure 11). This is accomplished through proper location and design of the hairline as well as the use of large numbers of small grafts. The shape of the frontal hairline should not be linear but should be broken up with major irregularities (triangles and gaps). The hairline should consist of a transition from the bald forehead to a zone consisting of random placement of single hair grafts from the softest hair available in donor supply. Typically, these single hairs are taken from the temporal donor fringe. Posterior to the single hair grafts are FU containing 2 and 3 hairs with stronger physical characteristics (Figure 12). Recreating a female hairline requires a design that includes a more rounded temporal infill and lower hairline than the one normally created for men (Figures 13 and 14).

When a forelock pattern is created, the rear border should be located somewhere along the midscalp. Whether or not there is a plan to graft the vertex, the rear hairline should be constructed with an irregular border of small grafts. The lead author prefers to create a tapered posterior forelock pattern of trailing design that renders the crown less circular and mimics a natural variation on the balding process (Figure 15). A distribution of grafts recreating a natural whorl pattern can be constructed at the posterior aspect of the forelock. The crown area can be further grafted as indicated but should always be considered as an extension of the posterior forelock to maintain a natural distribution of hair (Figure 15).

Recipient Site Creation

There are numerous instruments and methods with which to create a site in which a hair graft is placed. The fundamental principles that should underlie any technique include matching the size of the individual recipient site with the length and width of the patient’s FU. For example, if short, single hair grafts are placed at the anterior hairline in a thin scalp, a smaller and more shallow site is created than would be required to accommodate a larger 3- to 4-hair FU placed in the thicker scalp. The most simple and cost-effective instrument for recipient site creation is a hypodermic needle. Needle sizes ranging from 23 to 18 gauge are typically used. A 19-gauge needle will produce a 1.1-mm slit that will accommodate the size of the majority of FU of average density (Figure 16). Another popular instrument for site creation is the sharp-point, 22.5-degree or the “mindi” knife. These instruments, as well as microscopes designed for hair restoration surgery, are available through different vendors (Ellis Instruments, Madison, New Jersey; Tiemann-Bernsco & A to Z Surgical, Hauppauge, New York). Customized recipient blades can also be cut to specific size from flat surgical prep blades using specialized cutting devices. In some circumstances, a 0.8-mm to 1.5-mm hole punch might be utilized as well.

The angle of the recipient site should mimic the angles of the nontransplanted, existing hair growth. When hair is absent, a natural flow of hair is created. On most hairlines, the angle of graft site creation should be approximately 30 to 45 degrees anteriorly off the scalp. This results in the illusion of more coverage as well as a natural angle. The hair on the left side of the hairline should be angled anteriorly and toward the midline. As the hair progresses to the right side, a switch should be made so that the hair on the opposite side is angled toward the midline. As mentioned above, a whorl is created at the midpoint of the crown vertex area through a spiraling of the angulation of recipient sites through a 360-degree rotation (Figure 15).

Most patients will require a follicular density of approximately 25 to 40 FU/cm² for satisfactory coverage. However, as mentioned above, the individual hair characteristics play an important role in this regard. Although highly variable between surgeons, the typical density of site packing in a completely bald scalp is approximately 25 to 35 sites/cm²/hair transplant session. The density for optimal site packing as well as the use of “skinny” (closely trimmed) or “chubby” (containing more fat and sebaceous tissue) grafts is controversial. The considerations in this debate are based on limited reports of survival at different densities, surgeon’s preference, and also the skill of the transplant team.

Graft Planting

As with site creation, numerous techniques and instruments are available for graft placement. The different
Figure 10. This 58-year-old man with male pattern alopecia who underwent a 2500-graft follicular unit hair transplant is shown during immediate preoperative planning (A, C) and immediately postoperatively (B, D, E). Note the design of the posterior forelock taper and fill of the temporal hump.
forceps used for planting are essentially adaptations of those used in microvascular surgery. The fundamental principles of this aspect of the procedure include gentle grasping of the grafts, maintenance of graft hydration, placement of grafts in the identical angle of site creation, and also maintaining appropriate rotation of the natural curvature of the hair graft. As with graft preparation, considerable skill is required to perform this delicate task in a repetitive, atraumatic, and efficient manner. Frequently, several “planters” work simultaneously to complete the procedure in an efficient manner. An experienced assistant or physician can plant 200 to 300 grafts per hour. Typically, the recipient sites are designed first and the grafts are placed as a following step. However, another technique known as the “stick-and-place” method incorporates both maneuvers in a sequential manner. The “sticker” creates the site with a blade of choice, and the “placer” inserts the graft immediately before the next slit is developed.

Figure 11. (A, C) This 63-year-old man with male pattern alopecia requested restoration of his anterior hairline. (B, D) Eight months after receiving 3200 grafts in 2 sessions.

Conclusion of Procedure, Postoperative Care, and Emergence of Results

Hair transplants are lengthy procedures. A typical session of 1500 to 2500 grafts utilizing 4 assistants will last approximately 6 to 7 hours. The procedure is conducted using a clean technique with sterilized or disposable instruments. Postoperatively, the recipient sites and donor area are typically not bandaged, and perioperative antibiotics are not prescribed on a routine basis. Patient instructions include head elevation and icing of the forehead and donor area, along with analgesics. Aloe ointment administration to the grafted area and gentle shampooing in the shower should commence on postoperative day 2. Most of the recipient site eschars are gone by day 10, and donor sutures are removed on day 14. Although there are exceptions to the rule, most grafts enter a telogen phase for the first 3 months prior to entering their anagen phase. Full growth and evaluation of transplant results cannot reliably be assessed for 8 to 12 months following the procedure (Figure 17).
Body Hair as Donor

Body hair is useful to treat areas of hair loss when the scalp donor area supply is near or at exhaustion. The results of body hair transplants are impossible to predict with certainty because of the intrinsic physical and short life cycle characteristics of this type of hair. In general, the beard is the best source of body hair because its intrinsic life cycle and physical characteristics most closely resemble that of scalp hair. Follicular unit extraction as a donor technique is particularly well suited to the submental area when beard hair is harvested.

Reconstructive Applications

Hair transplantation can have a significant role in correcting alopecia associated with scars from previous aesthetic surgery, burns, radiation, trauma, and congenital deformities. Hair transplants do grow in scar as well as radiated tissue; however, the survival rate is lower than in noninjured recipient beds. Formal studies on this topic have not been published (Figure 18).

In the case of hairline reconstruction for female-to-male gender reassignment, androgen supplementation and ensuing temporal recession or thinning is generally all that is necessary. In male-to-female reassignment, the hairline design includes a typical rounded temporal infill and the lower hairline described earlier for restoring FPHL (Figure 14).

Flaps/Scalp Reduction/Expanders

In contemporary practice, hair-bearing scalp flaps and alopecia reductions for elective aesthetic hair restoration surgery are primarily of historic interest. A comprehensive

Figure 12. This 48-year-old man demonstrates the irregularity required for graft distribution at the anterior hairline. (A) The patient is shown intraoperatively, after a single session of 2200 grafts. Note the distribution of grafts containing 1 and 2 hairs per follicular unit at the leading edge of the hairline and larger grafts posteriorly. (B) The patient’s hairline is shown preoperatively. (C) Eight months after grafting, the irregularity and distribution of graft size clearly contribute to the natural appearance of the patient’s transplanted hairline.
review of the previous use of these techniques in the treatment of AGA can be found in 2 studies. In some cases, these procedures have resulted in an excellent outcome for the patient. However, as a result of poorly designed surgical incisions as well as naive surgical planning in the face of progressive hair loss, the long-term results of these procedures have also resulted in exposed, unattractive scars as well as misdirection of hair flow. The use of scalp expanders, reductions, and flaps for reconstruction of traumatic hair-bearing scalp defects remains well entrenched in the scalp surgeon’s armamentarium.

**COMPLICATIONS AND PATIENT SAFETY**

Fortunately, the incidence of complications in HRS is quite low. Unfortunately, there are no published reports of significant size detailing the frequency of complications in large series. Nevertheless, the types of complications seen have been well described and can be categorized into surgical and aesthetic complications. In contemporary practice, the incidence of primary surgical problems is estimated to be less than 2% to 3% and includes bleeding, arteriovenous fistula, cysts, pustules, infection, frontal necrosis, neurosensory changes, and scarring. Primary aesthetic complications include poor growth of grafts, postsurgical effluvium, and unnatural appearance. The incidence of poor growth ranges from 0% to 25%, but this number is highly subjective. These complications and other patient safety concerns have been reviewed in detail elsewhere.

**Surgical Complications**

**Folliculitis/Cysts/Pustules**

A variety of cysts and pustules can present within the first few weeks or months following a transplant. They can be isolated or occur as clusters of diffuse lesions. The causes are not clear. Theories include “ingrown” hair, foreign body reactions, epithelium logged into slit sites during recipient site creation, piggybacked grafts, and the “idiopathic” intrinsic properties of the host scalp. In the majority...
of cases, a pathogen cannot be cultured from the lesions, but a secondary, uncultured bacterial agent cannot be excluded as having a secondary role in pathogenesis. Oral antibiotics, warm compresses, and unroofing of the cysts are the mainstays of treatment.

**Neurosensorv Complications**
A certain amount of pain, especially in the strip harvested donor site, is to be expected. Occasionally, some patients will experience severe pain in the donor site, requiring prolonged periods of narcotics. Although some patients report headaches following the transplant procedure, there have been reports of a decrease in this symptom as well. Neuralgias and hypoesthesia symptoms are uncommon and almost always resolve within the first 6 to 8 months. Neuromas have been rarely reported and are treated with steroid injection or excision.

**Scarring**
Scarring in the donor area remains the primary concern, even with modern strip harvesting techniques. The advent of the trichophytic closure technique and the awareness of the critical importance of avoiding tension in donor site closure have reduced the incidence of donor scar complications. True keloid scarring is rare in the donor site and interestingly has never been reported as occurring in the recipient area. Reduction in donor density secondary to extensive punctate scarring is a potential risk of FUE harvesting.

**Aesthetic Complications**

**Poor Growth**
It is unrealistic to expect 100% of grafts to survive. Accurate measurement of growth requires precise hair counts using magnification, scalp tattooing, and macro-photography. Studies of this caliber are small in size and very limited. However, most would agree that growth rates less than 85% to 90% would be considered poor growth. Causes for poor growth are numerous but generally focus on follicular trauma and dehydration during the different stages of the lengthy procedure. Some limited studies on out-of-body time indicate that graft growth is not effected until 6 to 8 hours following harvest. Different holding solutions are being investigated to maximize graft integrity. Other factors for poor growth include host factors such as vascularity of scalp, smoking, and the presence of scar tissue.
Occasionally there can be a shedding of the in situ, non-transplanted hair. This postsurgical shedding can be either an anagen or a telogen effluvium and typically takes place 2 to 6 weeks following the transplant procedure. This situation most frequently occurs in female patients with diffuse pattern hair loss but can be seen in men as well. In addition, effluvium can also be seen in the donor harvest sites. Fortunately, the effluvium is usually temporary. In some instances, the hair will grow back with a more narrow caliber or not at all. To reduce the likelihood of effluvium, the surgeon can minimize the number of recipient sites, as well as their size, and also consider the use of minoxidil (Rogaine) or finasteride (Propecia) during the perioperative period.

**Unachieved Patient Expectations**

As in any type of aesthetic surgical procedure, the expectations of the patient need to be realistic. However, unique for the hair restoration patient is the importance of appreciating the progressive nature of nontransplanted hair loss over time, the inherent qualities of their donor hair as a source for scalp coverage, and their individual limitation in donor supply.

**Poor Cosmetic Appearance of the Transplant**

The expected outcome using contemporary techniques of hair transplantation is a result that is generally indistinguishable from the appearance of native scalp hair.

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**Figure 15.** (A) This 43-year-old man with primary alopecia in the crown region presented for hair restoration. (B) Eight months after posterior forelock grafting and creation of crown whorl pattern with approximately 2000 grafts.

**Figure 16.** Relationship of size between 1-, 2-, and 3-hair follicular unit grafts and the 19-gauge and 1.0-mm blades used to create recipient sites. It is important to create recipient sites with a depth and width that match the graft size.
Figure 17. (A, C, E) This 28-year-old man with male pattern alopecia presented for hair restoration. (B, D, F) Eight months following a single session of hair grafting with 2500 grafts placed in a forelock distribution. Note the beneficial effect from finasteride in the nontransplanted posterior crown region. The benefit to forelock grafting is that additional grafts can be placed in the crown region if desired or the result can stand alone.
Unfortunately, older techniques as well as some poorly performed recent transplants have not resulted in a natural appearance. As a consequence, there are a considerable number of patients who bear the visual and psychological burden of an unnatural hair transplant. A complete review of these types of problems and their management was published elsewhere.98-105

The most frequent type of cosmetic problems following hair transplants are

1. Unsightly appearance of plugs
2. Wide scars in the donor area
3. A poorly designed hairline
4. Errors in surgical planning and inappropriate distribution of grafts at a young age, in which the progressive nature of hair loss was not considered

All of the above cosmetic complications result in the same fundamental problem for the patient: an unnatural appearance to the scalp hair that yields a strange and unnatural appearance. Patients are plagued with these unnatural results, which become worse over time as their surrounding hair recedes and thus further exposes the original unnatural hair grafts. Understandably, these patients are angry with the original surgeon and themselves for submitting to the original transplant; they often wish they could trade the unnatural appearance for simple baldness. Correction of these tragic results is difficult and time-consuming, requires a special relationship of trust between the surgeon and patient, and often requires 3 or more surgical procedures. The techniques and approach for correction of these challenging cases are beyond the scope of this current review. The references cited in this section provide the principles and fundamental techniques for restoring normalcy to a patient whose life has been undesirably transformed by the initial hair transplant procedures (Figure 19).

THE FUTURE OF HAIR TRANSPLANTATION

FUE

Currently, a minority of hair transplant surgeons provide FUE for all patients. Most practices use FUE for selected indications. However, the future direction appears to be moving toward a greater interest in and application of FUE. Improved instrumentation, automation, and an ever-increasing interest in minimally-invasive techniques are driving this trend.

Cell-Based Therapy

In the foreseeable future, hair restoration surgery will be intermingled with some type of cell-based therapy. The concept of the hair follicle as a mini-organ is recognized by cell biologists pursuing hair replication research. Biotech and basic research labs are currently investigating pathways for hair induction, hair development, and hair follicle regeneration. The results of this research will undoubtedly make their appearance into clinical trials and, theoretically, daily practice. It should be recalled that androgenic alopecia is, at least in principle, a reversible condition. Although the terminal hairs have become miniatu-ray beyond recognition by the naked eye, the same hair follicles (with fully intact stem cell machinery) continue to be present in the balding scalp. The ultimate solution to finding a cure for androgenic alopecia would be a product that is able to switch on the differentiation mechanism from vellus to terminal hair. The ability to

Figure 18. (A) This 28-year-old man presented for beard reconstruction after a burn injury and secondary chin reconstruction. (B) Twelve months after placement of approximately 1000 grafts in 2 sessions. Reprinted with permission from Barrera A. The use of micrografts and minigrafts in the aesthetic reconstruction of the face and scalp. Plast Reconstr Surg. 2003;112(3):883-890.
Figure 19. (A) The patient’s preoperative markings are shown prior to the first procedure. The dots indicate the location where plugs are to be removed and recycled into new follicular unit grafts for immediate grafting. The irregular anterior hairline was also marked for creation of a new leading edge hairline. Dome marking in the area of the lateral hump above the ears indicates planned distribution of grafts to fill in bald “alleys” of scalp. (B, D, F) This 38-year-old man had previously undergone a hair transplant at age 20 but was cosmetically dissatisfied with the appearance of his scalp. The patient had experienced progressive hair loss with resulting exposure of previously transplanted 4-mm “plug” grafts. In addition, progressive hair loss above his ears resulted in “alleys” of baldness. He desired correction of this unnatural appearance. (C, E, G) Eight months after the third procedure; all procedures consisted of primary hair grafting from the occipital donor site, plug reduction, and recycling of 4-mm plug grafts. In total, the patient underwent removal and recycling of approximately 252 four-mm previously grafted transplant “plugs” and 2000 follicular unit grafts over a 2-year period. The patient was also maintained on finasteride oral medication.
Figure 19. (continued) (A) The patient’s preoperative markings are shown prior to the first procedure. The dots indicate the location where plugs are to be removed and recycled into new follicular unit grafts for immediate grafting. The irregular anterior hairline was also marked for creation of a new leading edge hairline. Dome marking in the area of the lateral hump above the ears indicates planned distribution of grafts to fill in bald “alleys” of scalp. (B, D, F) This 38-year-old man had previously undergone a hair transplant at age 20 but was cosmetically dissatisfied with the appearance of his scalp. The patient had experienced progressive hair loss with resulting exposure of previously transplanted 4-mm “plug” grafts. In addition, progressive hair loss above his ears resulted in “alleys” of baldness. He desired correction of this unnatural appearance. (C, E, G) Eight months after the third procedure; all procedures consisted of primary hair grafting from the occipital donor site, plug reduction, and recycling of 4-mm plug grafts. In total, the patient underwent removal and recycling of approximately 252 four-mm previously grafted transplant “plugs” and 2000 follicular unit grafts over a 2-year period. The patient was also maintained on finasteride oral medication.
enhance hair graft growth and survival through the use of platelet-derived growth factors is an additional area for research and development.¹⁰⁶

**Cloning**

Initial enthusiasm for replication of a single hair into thousands of hairs suitable for transplantation has been tempered by the difficulties of culturing and replicating hair in vivo. Even when this biological task has been minimally accomplished, the effective number of viable hairs created as well as the subsequent delivery techniques into tissue has been disappointing thus far.

**Incorporating HRS Into Plastic Surgery Practice**

A traditional aesthetic surgery practice that includes hair restoration surgery enjoys excellent internal marketing opportunities and patient crossover between the 2 practices. For this and other reasons, HRS often piques the interest of plastic surgeons. However, lack of exposure to HRS in plastic surgery residency training renders this field difficult to fully incorporate into practice. The fact is that HRS is a “subspecialty” in itself and does not exclusively reside within the domain of any one of the specialties endorsed by the American Board of Medical Specialties (ABMS). The International Society of Hair Restoration Surgery is the largest organization dedicated to education and training in HRS. Six- and 12-month fellowships in HRS as well as annual educational meetings and local surgical workshops are offered through this organization. Although not recognized by the ABMS, the American Board of Hair Restoration Surgery does offer an excellent educational curriculum leading to certification. This later curriculum is a particularly good educational track for a board-certified plastic surgeon to expand his or her knowledge base in this subspecialty that offers significant relief to patients ticated subspecialty that offers significant relief to patients.

**CONCLUSIONS**

Hair restoration surgery has developed into a highly sophisticated subspecialty that offers significant relief to patients with hair loss. This aspect of cosmetic surgery is a very welcome addition to a traditional aesthetic practice and serves as a tremendous source for patient satisfaction and internal cross-referral. The results of contemporary hair restoration surgery are natural, enduring, and are performed with a very high level of patient safety. This degree of refinement has been established through an improved understanding of hair biology and physiology as well as the incorporation of standard microsurgical techniques. The combination of graft size, site creation, packing density, and selected donor hair are the key elements the hair restoration surgeon utilizes to artistically craft the transplant. The future of HRS and the treatments for alopecia are centered on minimal-incision surgery as well as cell-based therapies.

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