Complications with Follicular Unit Excision

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Abstract

Hair restoration surgery (HRS) is typically a safe outpatient or office-based procedure when physicians follow high ethical standards and uphold community practice standards. Patients' clinical outcomes are mostly operator dependent, and temporary and permanent complications rarely occur. Follicular unit excision (FUE) donor harvesting, in particular, is a challenging harvesting technique requiring a long learning curve, physical stamina, higher than average hand–eye coordination and manual dexterity. The types of complications associated with FUE are comparable to linear strip excision (LSE). Similar to LSE donor harvesting, FUE complications may occur irrespective if standard precautions are followed by the physician. As in any skin and scalp procedure, injuries and poor cosmetic outcomes occur despite appropriate preoperative precautions and intraoperative technique. In increasing and greater instances, however, FUE complications are observed when the physician fails to follow hair restoration practice standards and routine surgical precautions. Physician induced, or iatrogenic complications occur more often when untrained licensed surgeons perform HRS, and who fail to meet practice standards and best practices. In the last decade, physician-influenced FUE complications, or iatrogenic cause of FUE injuries are increasingly observed which results in poor aesthetic outcomes. Higher than average FUE complication rates occur in cases involving inadequately trained physicians, as well as in cases where improper delegation of the FUE hair transplant procedure is performed by unlicensed and untrained individuals. In this chapter, we described commonly encountered HRS complications, as well as physician influenced, or iatrogenic causes of FUE complications.

Keywords
- donor depletion
- low unnatural and age-inappropriate hairline
- scalp necrosis
- FUE donor scaring
- unnatural hairline
- linear strip excision
- arteriovenous fistula
- synthetic hair fibers

Hair restoration surgery (HRS) is a very common outpatient cosmetic procedure performed on patients with hair loss due to a variety of origins, the most commonly being androgenic alopecia. HRS is generally a safe outpatient procedure with minimal complications when performed by a qualified physician who follows high standards of medical and surgical care. Intra- and postoperative complications (►**Table 1**) are well recognized for linear strip excision (LSE) and follicular unit excision (FUE) donor harvesting. Complications can also commonly include pain, bleeding, donor and recipient excessive crusting, graft dislodgement, postoperative effluvium, pruritus, and scalp hyper- or hypoesthesia.[1,2]

When performed properly and best practices are followed, the practicing physician rarely encounters complications with FUE surgery. HRS clinical outcomes and cosmesis are typically very good in competently trained hands. Uncommon postoperative complications occur when best practices are followed in performing HRS. As a minimally invasive surgery, when HRS complications occur from FUE donor harvesting, they often are due to physician's inadequate knowledge and training. Failure to recognize fundamental hair science, incompetence of performing the hair surgical operative procedure, delegation to untrained personnel, or poor understanding of the critical-to-quality

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Table 1 Complications in hair restoration surgery with linear strip excision or follicular unit excision harvesting

Paresthesia and pain of recipient/donor regions
Donor hypopigmentation or donor depletion
Infection, folliculitis
Cyst formation
Eyelid and forehead edema
Patient dissatisfaction
Vasovagal syncope
Donor depletion
Buried grafts
Postoperative effluvium
Hiccups
Anaphylactic shock
Hypertensive crisis

steps (CTQS) leads to cosmetic and medical complications. These complications leave the patient with an unpleasant cosmetic outcome which can result in a lifelong psychologically negative impact.

Historically, in the 1960s to 1980s, donor harvesting with 4-mm punch grafting resulted in a pluggy and unnatural appearing results. These early HRS harvesting techniques resulted in donor scaring and donor depletion (►**Fig. 1**). As punch grafting with large circular punches was abandoned to evolving newer harvesting techniques, for instance, LSE, flap, and scalp reduction-related surgeries, these techniques resulted in their own complications and undesired effects. Unusual complications known to occur in HRS include precipitation of potential scaring conditions such as lichen planopilaris,[3,4] as well as autoimmune activation of alopecia areata[5] and hair shaft abnormalities.[6]

Complications from Secondary Physician Influences or Iatrogenic Influences

FUE complications from physician-induced or iatrogenic causes necessitates a separate and distinct category of FUE complications and is well described in medical literature.[7] Ultimately, the expanding list of poor outcomes of iatrogenic FUE complications is a type of professional negligence by a health care provider that leads to substandard surgical aesthetic outcomes. We have observed in our clinical practices that FUE iatrogenic injuries and complications occur primarily by physicians beginning HRS. Most of these physicians lack proper training and exposure to hair surgery training during the residency or fellowship period. They possess little or no HRS experience in private practice. These physicians purchase FUE instruments from device manufacturers who advocate the practice of FUE delegation. The CTQS and elements of the hair restoration procedure are unknown to these physicians, and they often enter hair surgery practice with the intentions of delegating the entire FUE procedure to untrained and unlicensed individuals.

To avoid iatrogenic FUE complications, lifelong continuing medical education courses in the field of HRS are necessary. Similar to any surgical specialty, physicians are required to complete a scalp exam, medical history, proper patient selection, and ethically applied treatment plans. Consistent excellent surgical outcomes are achieved by qualified and

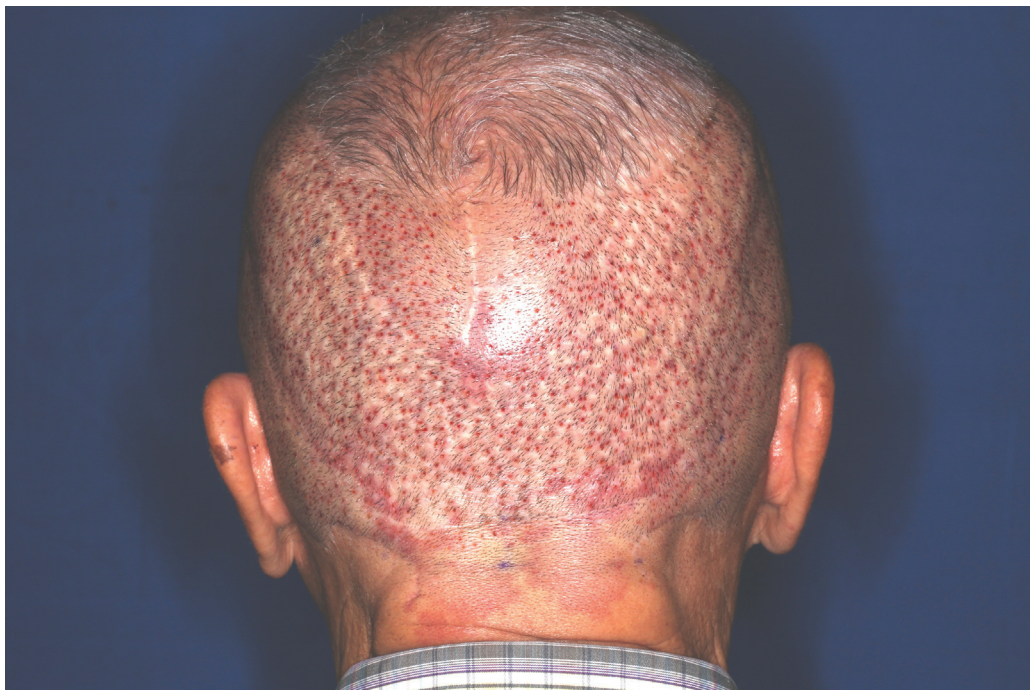

Fig. 1 The appearance of the SDA of patient who underwent punch grafting in the 1980s, and the appearance of small donor FUE harvesting sites in the immediate postoperative period. Noted is the extensive SDA scaring from the use of a 4-mm punch in contrast to contemporary smaller FUE punches that are less than 0.95 mm. (Photo Courtesy of K. Williams.) FUE, follicular unit excision; SDA, safe donor area.

properly trained hair surgeons who perform the surgery and personally manage the patient's preoperative, intra- and postoperative care. Unfortunately, thoughtful and purposeful application of surgical technique and planning is omitted, leading to serious and potentially lifelong injuries.

Follicular Unit Excision Complications: The Exclusion of Physician-directed Critical-To-Quality Steps

Ethical and clinical judgment are required when determining the surgical candidacy of a patient. The critical elements to successful surgery are when hair surgeons can properly diagnose the etiology of their patient's hair loss, understand the concepts of donor harvesting management, plan and properly execute the surgical procedure, and attend to postoperative care and complications. The fracture of high ethical standards and adequate training to perform hair restoration procedures has increased the type of iatrogenic complications we observe in clinical practice. The incidences of poor cosmetic complications that we observe in clinical practice are avoidable through the proper, established means of the patient–physician relationship, and by a physician performing the CTQS of HRS. The CTQS of hair surgery are (1) pre, intra, and post "hands-on" operative care and oversight, (2) hairline design and planning, (3) administration of sedation and anesthesia, (4) donor harvesting, and (5) recipient site creation and design. Knowledge of the patient's future hair loss and the risk of exhausting the donor harvesting potential is not an exact science and is dependent upon the clinical skills and knowledge of the hair surgeon. Physicians can avoid FUE complications by understanding these critical hair surgical principles, as failure to recognize these principles potentially results in patient injury or poor cosmesis (►**Table 2**).

Physician Influence or Iatrogenic Causes of Follicular Unit Excision Complications

Failure to Recognize Underlying Medical Conditions and Properly Establish the Scalp Diagnosis

Central to successful hair transplantation is making the correct diagnosis or etiology of hair loss for the patient, as well as identifying essential elements of the patient's medical history that influence past and future hair loss. The ability to obtain a full history and examination of the hair and scalp at the time of initial consultation is central to its success. It is beyond the intentions of this chapter to describe the various etiologies of hair loss and the impact of the patient's medical history on clinical outcomes, but needless to say, the proper diagnosis forms the foundations for future cosmetic outcomes and clinical success. The physician who does not understand their patient's past medical history and/or underlying medical conditions is at greater risk of intra- and postoperative complications.

Table 2 Follicular unit excision complications originating from physician or iatrogenic influences

Failure to recognize patient's underlying medical conditions and establish hair loss diagnosis
Poor understanding of the effects of local tumescence anesthesia
Absence of consideration in safe donor area management
Inadequate surgical planning and execution
Failure to perform dermoscopy
Use of artificial hair fibers

The first step in hair transplantation is establishing the patient–physician relationship and properly diagnosing the etiology of hair loss. In our opinion, this first step is necessary but often minimized by physicians entering into hair surgery. Failure to establish the proper diagnosis often leads to hair transplantation performed on patients with scaring alopecia and other etiologies of hair loss where surgical intervention is contraindicated. A dermatoscopic evaluation has become standard practice in the initial evaluation. The details of how to perform a dermatoscopic exam are beyond the purpose of this chapter, but failure to perform such exam results in the incorrect diagnosis and potentially results in failure of the hair transplant.

Best practices and guidelines have been suggested in the medical literature to reduce major cardiovascular complications.[8,9] Often not known or recognized by novice surgeons is that serious life-threatening complications potentially occur when a complete history and physical examination is not carried out. Fatal cardiac complications have been documented with HRS and failure to diagnose underlying cardiovascular disease can lead to an increased morbidity and mortality.

The most common surgical setting where HRS is performed is in the Class A facilities, such as the physician's office. HRS can also be performed in Class B facilities such as outpatient surgical centers, and less commonly in Class C facilities such as inpatient hospital centers. In some states, office-based surgeries are prohibited where life-preserving reflexes are compromised. HRS involves the protection of life-preserving reflexes with local anesthesia, a frontal or occipital ring block, or the use of antianxiety medications at low doses. It is common to perform HRS in Class A facilities as this meets community standards.

Complications from Failure to Recognize the Effects of Local Tumescence Anesthesia

Complications from the use of anesthesia is well documented in HRS[10] and patient safety is essential and foundational to any hair restorative surgery. Intraoperative sedation and anesthesia for hair surgery is important for preventing patient discomfort and anxiety during HRS. The patient's concurrent medication list and the knowledge of sedating medication and their metabolism is critical for patient safety. The lack of understanding of drug-to-drug interactions, drug metabolism and excretion will lead to complications, both life-threatening and benign. The types of problems or complications observed associated with anesthesia and sedation occur in both FUE and LSE (►**Table 3**).

Table 3 Complications form anesthesia and sedation

Dysthymias
Intraventricular blocks
Syncope–vasovagal event
Drug allergy
Cardiovascular collapse secondary to drug–drug interaction with lidocaine and bupivacaine

Table 4 Tumescence formula for hair restoration surgery

50 mL 0.50% Bupivacaine HCl (Marcaine)
50 mL 1% Lidocaine HCl (Xylocaine)
50 mL 0.9% Sodium chloride Inj., USP
2.8 mL Epinephrine 1:1,000

Diluted solutions for local anesthesia for HRS are called tumescence solutions and are often created with the use of other medications. Tumescent solutions are the most common means to achieve anesthesia for hair transplant procedures. Compared with linear strip harvesting, FUE donor harvesting requires larger doses of tumescent anesthesia because of the greater donor harvesting surface areas. A typical tumescence solution will vary in their exact concentrations and solutions from practice to practice (►**Table 4**).

Lidocaine and bupivacaine are the two most common anesthetic agents used in tumescent solutions for HRS. Epinephrine—the main active vasoconstrictive agent used to reduce scalp blood flow—has significant clinical consequences in patients with underlying ischemia and blood constriction. An understanding of the common amides and esters anesthetics is important (►**Table 5**). The early signs of toxicity are metallic taste and sensation in the mouth, tongue numbness, muscle trembling, visual alterations, and shivering. Later signs of toxicity are loss of consciousness, convulsions, coma, and respiratory arrest. Metabolic acidosis, hypoxia, and hypercarbia can trigger seizure before cardiopulmonary arrest.[11]

The disposition of a drug in the body involves absorption, distribution, metabolism, and excretion (ADME). The ADME of a drug and patient's medications are major mechanisms that underlie drug–drug interactions. A thorough review of ADME is beyond the purpose of this chapter but is important for hair surgeons to be aware of potential drug interactions to avoid patient complications.[12]

Toxic lidocaine levels may occur because two drugs taken concurrently may require the same enzyme for metabolism and excretion. Often overlooked and not understood by hair surgeons is the understanding of the P450 cytochrome systems and drug metabolism. To ensure patient safety, it is important to understand the influence of the P450 family of enzymes that are categorized into families, subfamilies, and individual enzymes that may increase the risk of systemic anesthetic toxicity. Drug metabolism occurs in many sites in the body. The primary site of drug metabolism is the liver, but also occurs in the intestinal wall, lungs, kidneys, and plasma. The cytochrome P450 enzymes are within cells and play a major role in induction or inhibitions of drug metabolism (►**Table 6**).

The use of lidocaine or bupivacaine in traditional tumescence solutions may produce potentially toxic plasma lidocaine or bupivacaine concentrations as medications metabolically compete for the same enzyme site for excretion and elimination. This may increase competition for metabolism and potentially increases the adverse drug reactions with elevated serum levels of these agents. Hair restoration surgical patients use multiple medications, and attention is necessary preoperatively in the screening of potential interactions between lidocaine and oral psychiatric medications such as serotonin selective reuptake inhibitors (SSRIs). The SSRIs class of medication may reduce the metabolism and excretion of lidocaine, thereby increasing plasma lidocaine concentrations above the threshold for toxicity. Lorazepam does not interfere with P450 pharmacokinetics of SSRIs. Therefore, it is safer to use than other well-known benzodiazepines such as midazolam, alprazolam, or diazepam.

Table 5 Comparisons of commonly used local anesthetics: esters and amides

	Maximum dose	Duration of effect (minutes)	Maximum dose with epinephrine	Duration of effect with epinephrine (minutes)
Amides				
Lidocaine	4 mg/kg	30 to 120	7 mg/kg	180
Bupivacaine	2 mg/kg	120 to 240	3 mg/kg	180 to 300
Ropivacaine	5 mg/kg	120 to 360	–	–
Mepivacaine	4 mg/kg	90 to 180	7 mg/kg	120 to 240
Prilocaine	7 mg/kg	30 to 120	8 mg/kg	120
Esters				
Procaine	5 mg/kg	20 to 30	7 mg/kg	30
Chloroprocaine	11 mg/kg	15 to 30	14 mg/kg	30

Table 6 A general overview of P450 drug interactions from Ogu and Maxa[12]

Function	CYP3A4	CYP2E1	CYP2D6	CYP2C9	CYP2C9	CYP1A2
Substrate of isoenzyme	Alprazolam	Acetaminophen	Amitriptyline	Celecoxib	Citalopam	Caffeine
	Buspirone	Chlorzoxazone	Clomipramine	Diclofenac	Clomipramine	Clozapine
	Ca^{2+} channel blockers	Dapsone	Codeine	Flurbiprofen	Cyclophosphamide	Cyclobenzaprine
	Erythromycin	Enflurane	Desipramine	Ibuprofen	Diazepam	Fluvoxamine
	Lovastatin	Ethanol	Dextromethorphan	Losartan	Imipramine	Imipramine
	Midazolam	Halothane	Imipramine	Naproxen	Lansoprazole	Mexiletine
	Nifedipine	Isofurane	Metoprolol	Phenytoin	Nelfinavir	Pimozide
	Simvastin	Isoniazid	Nortriptyline	Piroxicam	Omeprazole	Propranolol
	Fentanyl		Oxycodone	Sulfamethoxtazole	Phenytoin	Theophylline
	Carbamazepine		Paroxetine	Tolbutamide	Amitriptyline	Warfarin
			Risperidone	Warfarin		
			Tramadol			
			Thioridazine			
			Venflaxine			
Inhibitors of isoenzyme	Amiodarone	Disulfiram	Amiodarone	Amiodarone	Cimetidine	Ciprofloxacin
	Cimetidine	Water cress	Chlorpheniramine	Fluconazole	felbamate	Citalopram
	Danazol		Fluoxetine	Fluoxetine	Fluoxetine	Diltiazem
	Fluconazole		Haloperidol	Isoniazid	Fluvastatin	Erythromycin
	Grapefruit Juice		Indinavir	Metronidazole	Ketoconazole	Fluvoxamine
	Itraconazole		Paroxetine	Paroxetine	Lansoprazole	Mexiletine
	Ketoconazole		Quinidine	Propafenone	Omeprazole	ofloxacin
	Macrolides		Sertraline	Quinidine	Paroxetine	Tacrine
	Miconazole		Thioridazine	Ritonavir	Ticlopidine	Ticlopidine
	Ritonavir		Ticlopidine	Sertraline		
	Verapamil					
	Quinidine					
	Omeprazole					
Inducers of isoenzyme	Carbamazepine	Chronic Ethanol		Phenobarbital	Norethindrone	Carbamazepine
	Rifabutin	Isoniazid		Rifampin	Carbamazepine	Tobacco
	Rifampin	Tobacco		Secobarbital		
	Ritonavir					

Donor Area Management: Lack of Understanding of the Safe Donor Area and Donor Depletion

An understanding of the concept of safe donor area (SDA) and donor harvesting capacity is essential for successful cosmetic outcomes. As with any hair restoration procedure, it is critical that the surgeon be able to accurately predict the reservoir of donor harvesting capacity for transplantation. Primarily, this is a knowledge-based evaluation founded on experience, but objective measurements are available and subsequently described.

For FUE to be successful, the physicians must be able to predict how many grafts are available to transplant in a lifetime. We believe that the cosmetic appearance of the donor region is just as important as the frontal hairline. The number follicular units must be predicted prior to surgery to impart an aesthetic postoperative appearance in the donor region. To preserve maximal donor density and avoid unacceptable postoperative donor thinning, it is critical for the operator to avoid donor over depletion. A more thorough description of the preoperative evaluation of the donor area is outside of the scope of this chapter's objectives. Important considerations must be acknowledged that the SDA is not always stable, and miniaturization can occur in this region. In fact, miniaturization of the SDA can occur and is observed in patients with evolving coronet pattern and retrograde alopecia. The International Society of Hair Restoration Surgery Follicular Unit Excision Advancement Committee guidelines[13] provide a balanced and broad approach for new hair surgeons to avoid HRS complications that is beyond the intentions of the authors and purpose of this chapter (►**Table 7**).

Table 7 Guidelines for follicular unit excision donor harvesting

Summary: ISHRS FUEAC guidelines on the safe donor area
Grafts should be ideally removed from the Unger-defined SDA to decrease the risk of obtaining nonpermanent hair.
It may be clinically difficult to determine the actual safe donor zone, particularly in younger patients.
Assess the patient for retrograde alopecia and avoid harvesting from this region as well as other regions of the scalp that are subject to miniaturization and advancing balding pattern.
In larger FUE sessions, it is a common practice to harvest a small percentage of follicles outside Unger-defined SDA. It is ethical practice standards to inform the patient of long-term consequences of harvesting outside of safe zone.
Family history and examination to include dermoscopy assists in determining SDA.

Abbreviations: FUE, follicular unit excision; FUEAC, Follicular Unit Excision Advancement Committee; ISHRS, International Society of Hair Restoration Surgery; SDA, safe donor area.

Table 8 Factors impacting safe donor area appearance

Follicular density
Hair per follicle
Cross-section diameter of hair shaft
Hair character: straight, wave, curl

A first-time FUE patient with a medium-to-high SDA density typically is able to undergo a first-pass FUE without any noticeable loss of the donor density. Subsequent passes through the SDA, and how many future FUE procedures can be performed, however, will depend upon many factors (►**Table 8**). The absence of knowledge by the attending hair surgeon of these factors can lead to iatrogenic FUE complication such as donor overharvesting. These complications also occur when the hair surgeon fails to recognize the patient's age, current stage of hair loss, future hair loss potential, and donor harvesting maximum limits. An unofficial, nonmedical term, that is, "moth-eaten" appearance, is used to describe the appearance of depleted donor areas.

Iatrogenic FUE complications such as donor depletion are avoidable. The characteristics of the hair follicle such as wave-like or curly characteristics and hair shaft diameter are important to understand in avoiding donor depletion. Additional factors are donor density, average hair strands per graft, color, curl of hair shaft, shaft diameter, and the patient's usual length of hair. This experience-related information and evaluation assists the physician in determining the graft number requirements in the recipient areas.

SDA depletion is the most common complication observed from hair restoration surgeries and commonly arise from large FUE sessions. It is one of the most serious postoperative surgical complications we observe because donor depletion decreases future corrective surgeries (►**Figs. 2**–**4**).

FUE is not a scarless surgery, and excision of the dermis may leave changes in the color of the skin. Patients who style their hair length short will have a greater appearance of hypopigmentation (►**Fig. 5**) in the donor region. Hypopigmentation is characterized as an area of skin color that is lighter than the surrounding skin. It may be lacking pigment. This is not to be confused with depigmentation, which is characterized as the absence of all pigment. Although hypopigmentation is not an FUE complication, it is recognized in the donor region when the patient wears the hair very short. The patient's normal postprocedure hair length is essential in the SDA to minimize visible punctate scars.

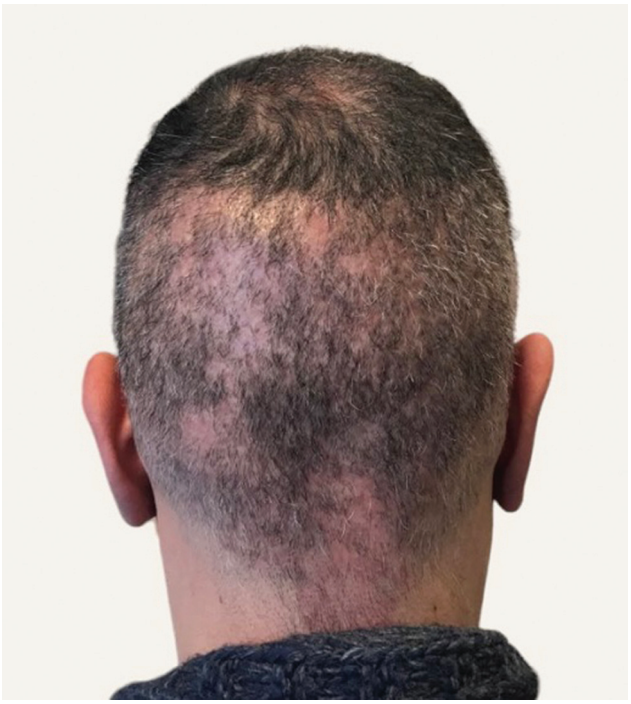

Fig. 2 The depleted donor region after a single, aggressive FUE session of almost 10,000 grafts that occurred at a Black Market clinic in Istanbul. (Photo Courtesy of S. El-Maghraby.) FUE, follicular unit excision.

Objective measurement of the donor harvesting capacity can be made using the hair diameter index (HDI),[14] or the hair coverage value (HCV).[15] The calculation of the HDI (►**Table 9**) and HCV (►**Table 10**) are significant concepts in FUE donor harvesting and understanding the limits of donor harvesting. Understanding these key concepts imparts insight into the number of follicular units that can be harvested to avoid complications such as an unacceptably thin donor region.

While not all physicians will use the HDI or HCV to objectively measure how many grafts can be harvested from patients, it is important to understand the awareness of donor capacity when the patient has had previous FUE

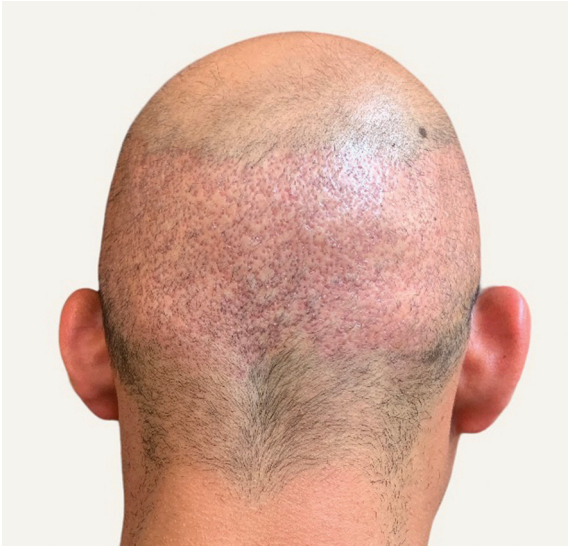

Fig. 3 Depleted donor area of patient after one session of FUE at a Black Market clinic in Istanbul. (Photo Courtesy of S. El-Maghraby.) FUE, follicular unit excision.

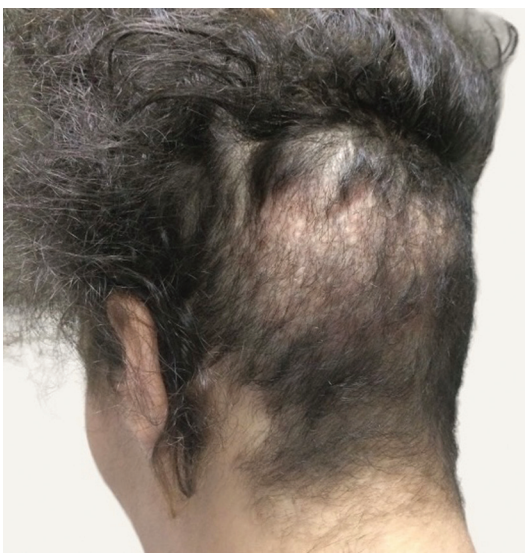

Fig. 4 The SDA of female patient undergoing FUE with noted donor depletion. (Photo Courtesy of S. El-Maghraby.) FUE, follicular unit excision; SDA, safe donor area.

procedures. This understanding ensures that the physician avoids overharvesting and leaves enough follicular units in their native sites to impart adequate donor area cosmetic coverage or density. When treating donor depletion as an FUE complication, performing subsequent surgical restoration procedure is more challenging and difficult. In most cases, the donor region of the scalp is so depleted that restoration cannot be done. In this situation, one can transplant hair from other areas of the body such as the face or chest to fill in the depleted donor area. This FUE technique is termed as body hair transplantation (BHT). Finally, the use of scalp micropigmentation (SMP) to add two-dimensional cosmetic density or camouflage is also a reasonable alternative. BHT and SMP are restoration techniques that can be used to restore iatrogenic complications from donor overharvesting.

Poor Surgical Planning and Execution: Creation of Unnatural Hairline Design

The creation of unnatural hairlines is an iatrogenic complication that occurs with both LSE and FUE harvesting techniques. With the consumer demand for FUE and inexperienced physicians or clinics performing a greater number of FUE cases, we are observing greater cases of poor graft survival and growth. Additionally, unnatural, age-inappropriate low hairlines, and incorrect hair direction and angles of the grafts are complications observed because of inadequate knowledge of the art of hair restoration. These complications pose challenges in restoring the difficult cases and planning future hair surgeries.

Poor hair growth in our experience can be secondary from failure to diagnose an underlying scalp disorder such as a scarring alopecia. Physicians need to recognize that undiagnosed and unsuspecting frontal fibrosing alopecia (FFA) may be present along with androgenetic alopecia. In rare cases, FFA can be precipitated by or has occurred after hair transplantation with obvious poor cosmetic outcomes and results.

Poor Planning and Design of Hairline

During the initial consultation, the hair surgeon should discuss with the patient the overall surgical goals, long-term plan, and establishing reasonable expectations. Many patients have unrealistic goals of a very low hairline and hair density close to their 20-year-old age. They expect a full head of dense hair along with the immediate and future possibility to have other hair transplant surgeries. As miniaturization advances over years, patients are not aware that SDA harvesting limitations must be considered, and a planned, staged approach is ideal for future surgeries. In some cases of advanced balding Norwood patterns and limited donor harvesting capacity, patients are not told it is impossible to restore the hair coverage or appearance of density to the appearance of when they were young adults. Equally important are that the use of medical management medications to stabilize miniaturization is never discussed.

Poor Surgical Execution and Graft Failure

Poor surgical execution and poor surgical technique are common causes for an unfavorable cosmetic outcome (►**Fig. 6**). Contributing factors to poor graft survival are most often due to graft desiccation, but trauma and crush-type injuries to the hair bulbs during recipient placement is common. Improper handling or storage of the grafts, high partial transection rate or poor-quality follicles that may lack adequate enveloping perifollicular fat, improper storage temperature of holding solution, and ischemia–reperfusion injury associated with extended out of body time of the grafts also contributes to poor cosmetic outcomes.

When performing HRS repair for patients who present to our offices with poor growth rate after a surgical procedure, we prefer to wait 1 year after the original surgery before any repair. Good surgical outcome requires maximal tissue

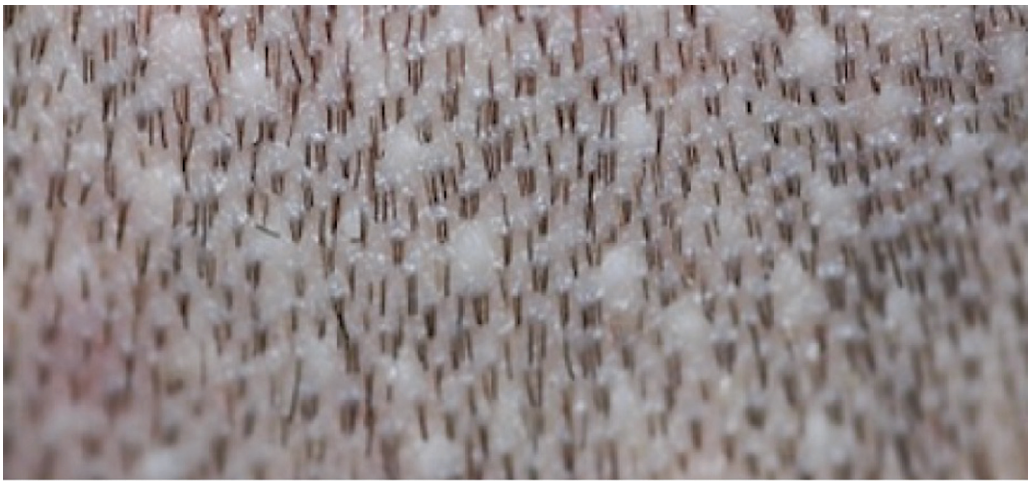

Fig. 5 The SDA of a patient with hypodense white scarring known as hypopigmentation. (Photo Courtesy of K. Williams.) SDA, safe donor area.

Table 9 Hair diameter index calculation

Hair diameter index = Average hair shaft diameter (in microns) × Hair/cm^2

Table 10 Hair coverage value

Hair coverage value = Follicular density (FU/cm^2) × Hair/follicular unit × Hair shaft diameter (microns)

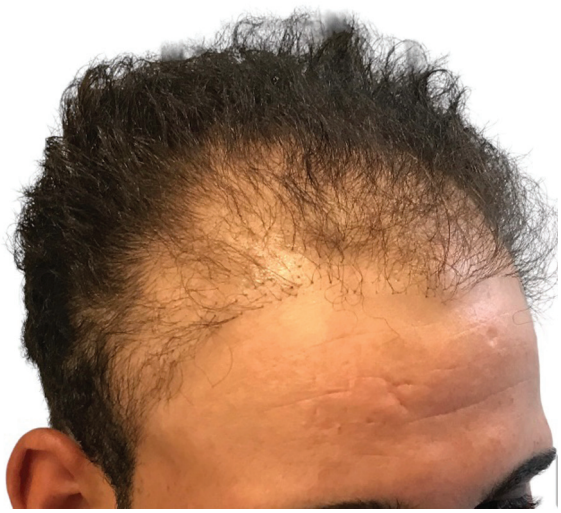

Fig. 6 This patient had a hair transplant with a bad outcome as a result of poor surgical planning and improper design. Note the wrong direction of hair along with the incorrect distribution of three-hair follicular units implanted in the frontal hairline. (Photo Courtesy of S. El-Maghraby.)

healing and a return to as close as possible to a state of normal physiologic blood flow. The importance of favorable tissue blood supply to the scalp cannot be underestimated for repair procedures.

Poor Surgical Execution: Recipient and Donor Necrosis

Scalp necrosis from hair transplant surgery is an uncommon occurrence but has been reported in the medical literature.[16] It is a rare complication of FUE scalp surgery, but it is considered one of the most severe complications of hair transplantation. If recipient necrosis occurs, it more commonly occurs toward the midline of the central forelock and the midscalp (►**Fig. 7**) where the vascular supply of the scalp is reduced. It might also arise in the donor area more often after LSE, and rarely in FUE donor area (►**Fig. 8**).

A well-trained and knowledgeable hair surgeon always creates recipient sites at the proper depth, considers the density of the incisions, and limits the concentration of epinephrine in the tumescent solution. Recognizing the possibility of necrosis is important. It is a rare complication, but without proper knowledge and recognition of potential underlying blood vessel injury, necrosis injuries are being recognized more frequently. It can occur by creating very deep recipient sites, high recipient densities, failure to observe decreased vascular supply to the scalp from plaque deposition in the intimal lining of scalp arteries, or tobacco use.

We have also observed the incidence of necrosis to have been exacerbated by the overaggressive use of injecting "Super Juice" with epinephrine concentration higher than 1:50,000 to stop bleeding and finish the surgery more quickly. The region of necrosis requires several months to heal completely and unfortunately leaves behind a scarred area with poor hair growth. Surgical debridement with wound care and using regenerative agents like ACell MatriStem Matrix (ACell Inc., Columbia, MD) and platelet-rich plasma may benefit the scar tissues' healing and regeneration.

Poor Surgical Execution: Use of Artificial Hair Implants

The repair of patients who were recipients of artificial hair transplantation is a growing occurrence that is unfortunately observed. The process of implanting synthetic fibers into the balding scalp requires a special device that attaches the synthetic fibers under the scalp at the galeal level using a

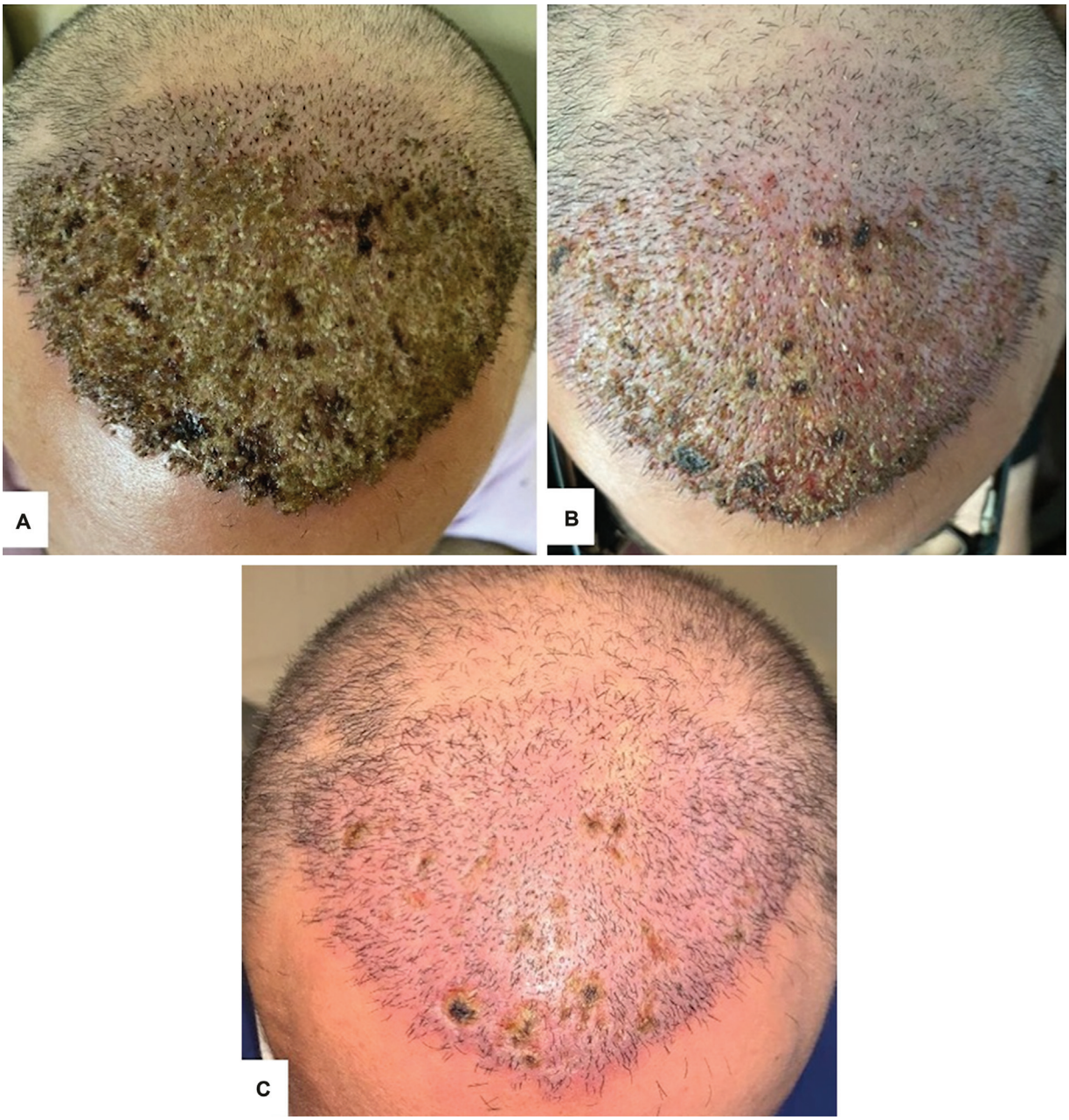

Fig. 7 (A) Necrosis and infection in the recipient area 10 days after surgery. A culture was done, and antibiotics were started with frequent daily shampooing. **(B)** The infection and scabs decreased 3 weeks postop. **(C)** The infection was controlled, scabs were cleared, and small necrotic areas can be seen scattered in the recipient area. (Photo Courtesy of S. El-Maghraby.)

knot at the lower end of the fiber.[17] This technique results in creating multiple blind sinuses containing foreign bodies through the scalp layers (►**Fig. 9**). Removing these fibers by FUE technique using a punch is not possible because the knots of the fibers are buried very deep at the galeal level where they cannot be reached by the punch safely. The resulting inflammation is usually severe and involves the whole thickness of the scalp.[18] The Food and Drug Administration banned the use artificial fibers in 1983 due to the numerous adverse events (AEs) that were reported. These AEs include recurrent infections, rejection, periodic loss of fibers, and frequent allergic reactions leading to severe contact dermatitis, irritant effects, possibility of carcinogenicity, cicatricial alopecia, granulomatous hypersensitivity, and cyst formation. All these factors may also cause further hair loss of the surrounding native hair. Despite the FDA warning, these fibers were approved in the European Union in 1996. They became very popular in the Middle East in the beginning of the 2000s but losing their popularity over time due to the very high rate of complications that result in oftentimes irreversible scarring and disfigurement (►**Fig. 10**).

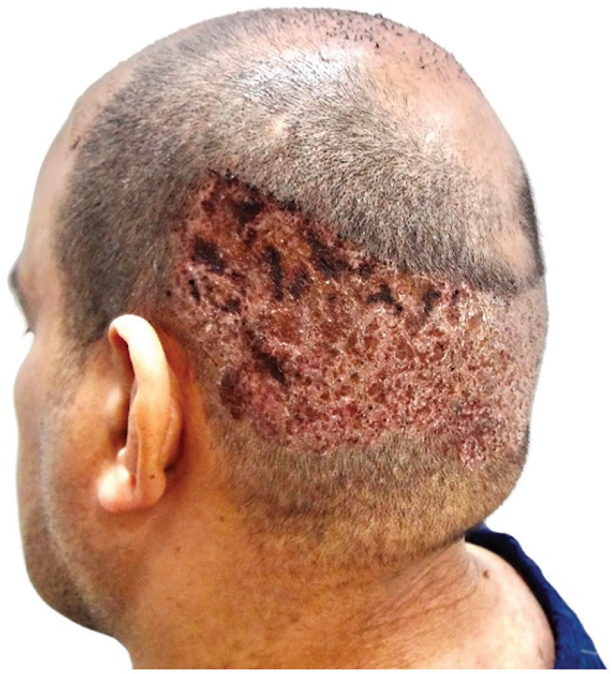

Fig. 8 Patient with donor area necrosis who underwent FUE harvesting at a Black Market clinic. (Photo Courtesy of S. El-Maghraby.) FUE, follicular unit excision.

During the first weeks after implanting the artificial fibers, patients typically present to the surgeon's office with acute suppurative inflammation and cysts. In our opinion during the phase of suppurative inflammation, it is probably the ideal time to remove the fibers by gentle traction. These synthetic fibers can be removed easily with simple traction through the inflamed, soft skin. The severity of inflammation differs according to the number of fibers implanted and the patient's foreign body reaction and hypersensitivity. Waiting beyond this period can make full extraction of these fibers very difficult if not near impossible

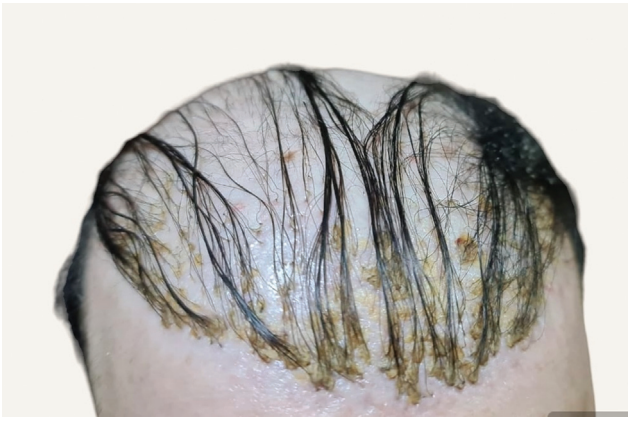

Fig. 10 Patient with artificial hair fibers implanted in the frontal zone. Extensive inflammation and foreign body reaction with sebaceous plugs are typically observed within the sites of the implanted fibers that resemble black comedones. (Photo Courtesy of S. El-Maghraby).

in many cases. Oral and topical antibiotics are prescribed after doing a culture.

Follicular Unit Excision Complications from Noniatrogenic Causes

Arteriovenous Fistula

An arteriovenous fistula is an abnormal connection between an artery and a vein and is a rare cause of postoperative complications in HRS. It may clinically demonstrate itself in the form of swollen, throbbing blood vessels, which are usually visible either in the donor or recipient areas (►**Fig. 11**). Sometimes an audible swishing sound can be heard by a stethoscope. It can be best avoided by limiting the depth of the placement sites and by injecting enough tumescent solution into the dermis to increase the thickness of the skin to protect the underlying blood vessels.

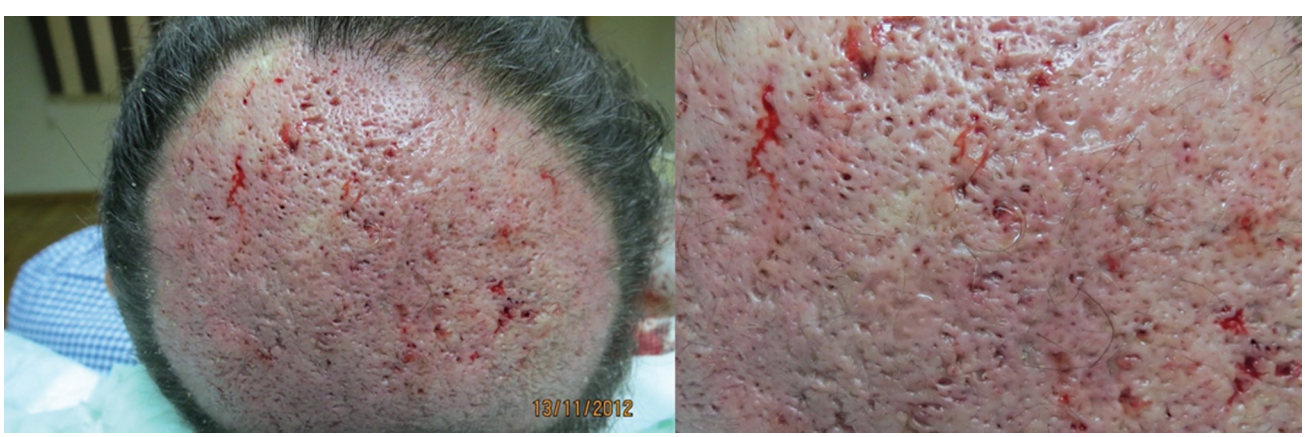

Fig. 9 Superior view of scalp after removing the artificial fibers and cleaning the scalp. Observed are typical findings of extensive sinus tracts or surface wounds scattered throughout the recipient region. The scarring was larger than anticipated. (Photo Courtesy of S. El-Maghraby.)

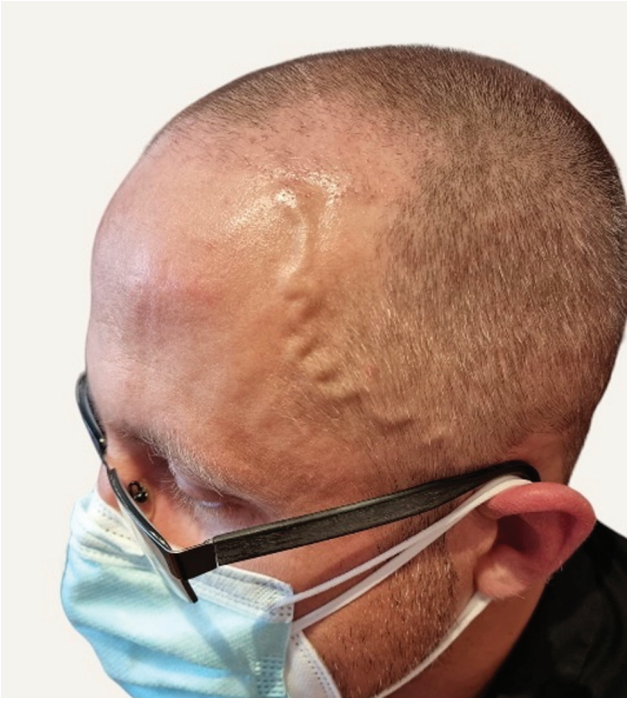

Fig. 11 The postoperative appearance of superficial vessels at the left frontal temporal region of the scalp most likely secondary to recipient site creation in the fontal hairline. The patient complained of throbbing blood vessels in the forehead caused by an AV fistula due to an abnormal connection between an artery and vein. (Photo Courtesy of S. El-Maghraby.) AV, arteriovenous.

Thoughts and Pearls

- Hair transplant surgery is a very safe procedure with a low rate of serious complications if done by qualified and experienced physicians.
- The rate of rare complications is increasing due to the spread of Black Market (BM) clinics where technicians and unlicensed individuals perform the entire surgery without an operating physician.
- Most patients need a lifelong plan that might include several hair transplant procedures and medical treatment to sustain a natural look with aging and progression of hair loss.
- Depleted donor hair is the most common complication seen after surgeries when performed by inexperienced surgeons or in BM clinics.
- Using body hair as donor might save many patients with depleted donor scalp, but preference is given to transplant scalp hair into the frontal zone to achieve a natural-looking hairline.
- Preoperative trichoscopic examination is very important in diagnosing scalp disorders that contribute to poor growth in past surgeries.
- Dense packing should be avoided in repair surgeries in the previously transplanted area with poor growth or in scarred tissues as it might cause very poor hair growth.
- Implantation of artificial hair fibers was banned by FDA due to numerous complications that have been reported in many published papers. This procedure should be avoided.

Conflict of Interest
None declared.

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