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REVIEW ARTICLE

MODERN TECHNIQUES IN SCALP HAIR TRANSPLANTATION: A SCOPING REVIEW AND CLINICAL CASE ILLUSTRATION

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Abstract

Background: Hair transplantation has evolved significantly over recent decades, moving from traditional strip-harvesting procedures toward minimally invasive follicular unit extraction techniques and technologically assisted implantation systems. Increasing patient demand for natural-looking hair restoration has stimulated the development of several surgical approaches, including Follicular Unit Transplantation (FUT), Follicular Unit Extraction (FUE), Direct Hair Implantation (DHI), Sapphire FUE, and robotic-assisted hair transplantation.

Objective: This review aims to summarize contemporary scalp hair transplantation techniques, compare their surgical characteristics, discuss clinical indications, evaluate potential complications, and describe current approaches to patient selection and postoperative management.

Methods: A scoping review framework was adopted, informed by the PRISMA Extension for Scoping Reviews (PRISMA-ScR). Relevant literature concerning scalp hair transplantation, follicular unit harvesting, graft implantation, surgical outcomes, complications, and technological innovations was considered. The review focuses primarily on adult patients undergoing surgical treatment for androgenetic alopecia.

Results: FUE and FUT remain the principal methods of follicular unit harvesting. DHI represents an implantation approach using specialized implanter instruments, while Sapphire FUE describes the use of sapphire blades for recipient-site creation. Robotic systems provide technological assistance during selected stages of follicular unit extraction. Each technique presents specific advantages and limitations. Patient selection, donor-area preservation, graft handling, surgical planning, and surgeon experience remain important determinants of clinical outcomes.

Conclusion: Modern hair transplantation offers several approaches that can be adapted to individual patient characteristics. No single technique is universally superior. Appropriate patient selection, careful donor management, evidence-based surgical planning, and long-term follow-up are essential for achieving satisfactory aesthetic and clinical outcomes.

Keywords: Hair transplantation; Follicular Unit Extraction; FUE; Follicular Unit Transplantation; FUT; Direct Hair Implantation; DHI; Sapphire FUE; Androgenetic Alopecia; Scalp Surgery.

INTRODUCTION

Hair loss is a common clinical and aesthetic concern affecting men and women worldwide. Androgenetic alopecia (AGA) is the most frequent form of progressive hair loss and is characterized by progressive follicular miniaturization, shortening of the anagen phase, and transformation of terminal hairs into finer, vellus-like hairs.

Although androgenetic alopecia is not a life-threatening condition, it may significantly affect self-image, psychological well-being, social interactions, and quality of life. The management of hair loss includes pharmacological treatment, non-surgical procedures, and surgical hair restoration. Hair transplantation has become an established surgical option for appropriately selected patients with stable donor hair and realistic expectations.

The modern concept of hair transplantation is based on the transfer of naturally occurring follicular units from androgen-resistant donor regions, predominantly the occipital and parietal scalp, to areas affected by hair loss. The development of follicular unit transplantation represented a major advancement in aesthetic hair restoration. Earlier plug-based techniques frequently produced unnatural results because they did not reproduce the natural distribution of follicular units.

Contemporary methods aim to preserve the natural follicular architecture and reproduce the direction, angle, density, and distribution of native hair.

Currently, the principal harvesting techniques are FUT

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and FUE. Advances in implantation instruments, recipient-site creation, magnification systems, and robotic technologies have further expanded the available surgical options.

This article reviews the principal modern techniques and discusses their clinical applications, limitations, complications, and future perspectives.

2. MATERIALS AND METHODS

2.1. Study Design

This manuscript follows the methodological framework of a scoping review. The reporting structure is informed by the PRISMA-ScR guidelines developed by Tricco and colleagues.

A scoping review is particularly suitable for topics involving multiple surgical approaches, evolving technologies, heterogeneous clinical outcomes, and different types of published evidence.

2.2. Research Question

The primary research question was:

What are the contemporary surgical techniques used in scalp hair transplantation, and what are their clinical characteristics, advantages, limitations, and reported complications?

Secondary questions included:

What are the principal differences between FUT and FUE?

How do DHI and Sapphire FUE differ from conventional implantation approaches?

What is the current role of robotic-assisted hair transplantation?

Which factors influence graft survival and aesthetic outcomes?

What complications should be considered during patient selection and postoperative follow-up?

2.3. Information Sources

The proposed comprehensive literature search should include:

PubMed/MEDLINE

Scopus

Web of Science

Cochrane Library

Google Scholar

The search period should cover January 2000 through the final search date.

2.4. Search Strategy

The following search terms and combinations are proposed:

"Hair transplantation" AND "FUE"

"Follicular Unit Extraction" AND "clinical outcomes"

"Follicular Unit Transplantation" AND "FUT"

"Direct Hair Implantation" AND "hair restoration"

"Sapphire FUE" AND "hair transplantation"

"Robotic hair transplantation" AND "ARTAS"

"Hair transplantation" AND "complications"

"Hair transplantation" AND "androgenetic alopecia"

2.5. Eligibility Criteria

Inclusion criteria:

Studies involving adult patients undergoing scalp hair transplantation.

Clinical studies evaluating FUE and FUT.

Studies describing implantation techniques.

Studies investigating robotic-assisted transplantation.

Reviews addressing surgical complications and clinical outcomes.

Publications in English.

Exclusion criteria:

Studies involving non-scalp hair transplantation exclusively.

Publications unrelated to surgical hair restoration.

Articles without sufficient methodological information.

Duplicate publications.

2.6. Data Extraction

The following information should be extracted from eligible publications:

Author and publication year.

Study design.

Patient population.

Surgical technique.

Number of transplanted follicular units.

Clinical outcomes.

Complications.

Follow-up duration.

Main conclusions.

Because the available literature includes heterogeneous study designs and outcome measures, findings should primarily be presented through descriptive synthesis rather than pooled quantitative analysis.

Methodological transparency: The search strategy above is proposed for the final systematic execution. Database-specific search dates, retrieved records, duplicate removal, screening numbers, and included-study counts must be completed before this manuscript can be described as a fully conducted scoping review.

3. PATHOPHYSIOLOGY OF ANDROGENETIC ALOPECIA

Androgenetic alopecia is a genetically influenced condition associated with androgen-dependent follicular miniaturization.

Dihydrotestosterone (DHT), produced from testosterone through the enzyme 5-alpha-reductase, plays an important role in the pathogenesis of androgenetic alopecia in susceptible individuals.

Progressive exposure to androgens leads to changes in the hair follicle cycle, including:

Reduction in anagen duration.

Progressive follicular miniaturization.

Decreased hair shaft diameter.

Increased proportion of miniaturized follicles.

Reduced visible scalp hair density.

The occipital scalp generally demonstrates relative resistance to androgen-mediated miniaturization. This biological characteristic forms the foundation of modern hair transplantation.

The principle of donor dominance, traditionally

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associated with Norman Orentreich, explains why transplanted follicles generally retain characteristics of their original donor location.

However, the progression of native hair loss may continue after transplantation. Therefore, long-term treatment planning should consider both transplanted and non-transplanted follicles.

4. EVOLUTION OF HAIR TRANSPLANTATION

Hair transplantation has undergone substantial technological and surgical development.

Early procedures relied on relatively large grafts containing multiple follicles. Although these procedures could restore hair coverage, they frequently produced an unnatural appearance.

The introduction of smaller grafts and follicular unit transplantation significantly improved aesthetic outcomes.

The development of FUE further changed surgical practice by allowing individual follicular units to be harvested without removing a linear strip of scalp tissue.

Subsequent innovations included motorized extraction instruments, improved punch designs, implanter devices, sapphire recipient-site blades, and robotic-assisted harvesting systems.

Modern hair transplantation is therefore based on the combination of anatomical knowledge, surgical precision, appropriate graft selection, and preservation of the donor area.

5.MODERN HAIR TRANSPLANTATION TECHNIQUES

5.1. Follicular Unit Transplantation (FUT)

FUT, commonly known as the strip technique, involves the surgical removal of a narrow elliptical strip of hair-bearing scalp from the donor region.

The harvested tissue is subsequently dissected under magnification into individual follicular units.

These units are prepared for implantation into the recipient area.

Advantages:

Allows harvesting of a substantial number of follicular units in selected patients.

Provides direct access to follicular units under stereomicroscopic dissection.

Can be appropriate when the donor scalp has suitable laxity.

May be useful in patients requiring multiple surgical sessions.

Limitations:

Produces a linear donor scar.

Requires surgical wound closure.

May cause postoperative discomfort or tension.

Scar width may increase in patients with unfavorable scalp laxity or healing characteristics.

FUT remains a valid surgical technique in appropriately selected patients. Figure 1.

5.2. Follicular Unit Extraction (FUE)

FUE is one of the most widely used contemporary hair transplantation techniques.

It involves the individual extraction of follicular units using small circular punches.

Unlike FUT, FUE does not require removal of a continuous strip of scalp tissue or linear wound closure.

Extracted grafts are subsequently prepared and implanted into the recipient area.

Advantages:

No continuous linear donor scar.

Small extraction wounds.

Relatively short recovery period.

Greater flexibility in donor-area selection in appropriately selected patients.

Compatibility with different implantation techniques.

Limitations:

Multiple small scars remain in the donor area.

Excessive harvesting may result in visible donor depletion.

Follicular transection may occur.

The procedure is technically demanding.

Graft quality depends on appropriate extraction and handling.

FUE is particularly useful for patients who prefer to avoid a linear donor scar, although the technique remains a surgical procedure and requires careful donor-area management. Figure 1.

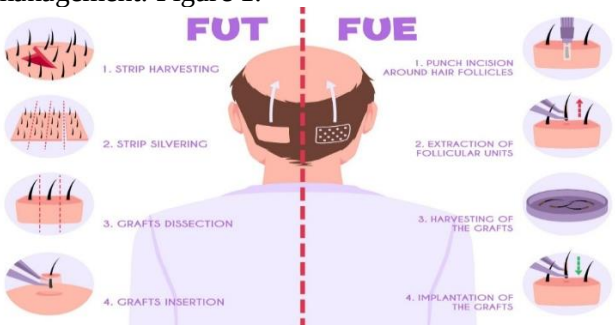


Figure 1. FUT versus FUE: donor-area harvesting

5.3. Direct Hair Implantation (DHI)

Direct Hair Implantation is an implantation approach that commonly uses specialized implanter pens.

After harvesting and preparation, follicular units are loaded into the implanter instrument and placed directly into the recipient scalp. The implanter allows the operator to control the placement of the graft, including depth, angle, and direction. DHI is frequently combined with FUE harvesting.It is important to distinguish between the harvesting method and the implantation method: DHI does not represent a separate biological source of grafts Figure 2.

Potential advantages:

Controlled placement of follicular units.

Integration of graft placement and recipient-site creation.

Potentially efficient handling of selected grafts.

Useful in carefully planned hairline reconstruction.

Limitations:

Requires specialized instruments and training.

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Graft handling remains technically demanding.
Implantation speed and density depend on the surgical team.
Comparative evidence demonstrating universal superiority over conventional implantation remains limited.

5.4. Sapphire FUE
Sapphire FUE combines conventional FUE harvesting with recipient-site creation using blades manufactured from sapphire.
The principal distinction is the material used for the recipient-site incision instrument.
Sapphire blades are used to create small recipient channels before graft implantation.
Potential advantages:
Precise recipient-site incision.
Availability of different blade configurations.
Potentially controlled incision geometry.
Compatibility with contemporary implantation protocols.
Limitations:
Requires surgical expertise.
Does not eliminate the risks associated with recipient-site creation.
Clinical superiority over conventional steel blades has not been conclusively established by high-quality comparative studies.
Sapphire FUE should therefore be considered an instrumental variation within modern FUE-based transplantation rather than an entirely separate harvesting technique Figure 2.

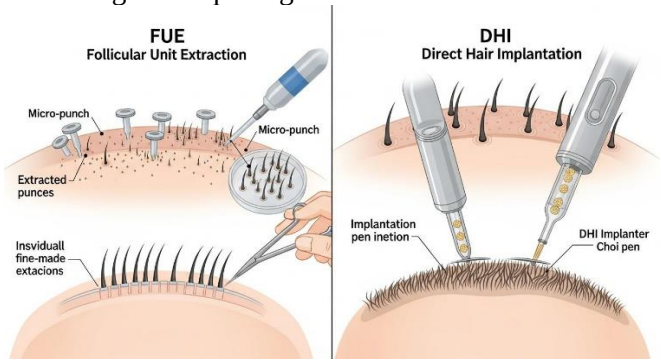


Figure 2. DHI versus Sapphire FUE: recipient-site implantation

5.5. Robotic-Assisted Hair Transplantation
Robotic-assisted systems, including ARTAS, have been developed to assist with selected stages of follicular unit extraction.
These systems use imaging, digital analysis, and robotic instruments to identify and extract selected follicular units.
The technology is intended to improve consistency and assist the surgeon during graft harvesting.
However, robotic systems do not eliminate the need for surgical judgment, appropriate patient selection, graft evaluation, recipient-site planning, and implantation expertise.

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A comparative clinical study published in 2024 evaluated robotic-assisted harvesting against conventional FUE in 13 male patients. The findings demonstrated differences in graft yield, discard rates, and transection rates, without establishing universal superiority of either approach.

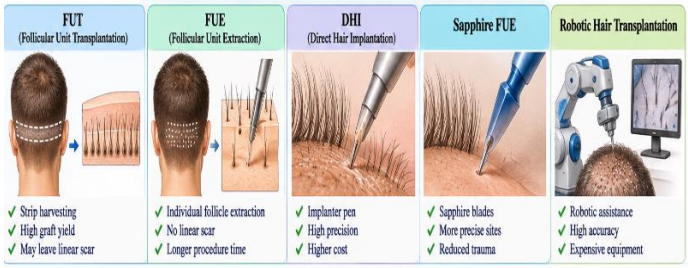


Figure 3. Classification of modern hair transplantation techniques

6. COMPARISON OF MODERN TECHNIQUES
Modern hair transplantation encompasses several surgical approaches that differ in follicular unit harvesting, graft preparation, recipient-site creation, and implantation procedures. The most commonly discussed techniques include follicular unit transplantation (FUT), follicular unit extraction (FUE), direct hair implantation (DHI), Sapphire FUE, and robotic-assisted FUE. Although these approaches share the common objective of restoring hair density and achieving natural-looking results, they differ considerably in their surgical principles, instrumentation, procedural requirements, and potential limitations. FUT and FUE primarily represent two distinct methods of harvesting follicular units from the donor area. FUT involves the excision of a strip of scalp followed by microscopic dissection into individual follicular units, whereas FUE involves the direct extraction of individual follicular units using specialized punches. In contrast, DHI primarily refers to an implantation technique in which prepared grafts are placed using a specialized implanter device. Sapphire FUE involves the use of sapphire blades for creating recipient-site incisions, while robotic-assisted FUE incorporates computer-guided technology to assist with selected stages of follicular extraction. A comparative overview of these techniques, including their principal characteristics, donor-site considerations, graft preparation procedures, recipient-site creation, equipment requirements, and major limitations, is presented in Table 1.

Table 1. Comparative characteristics of modern hair transplantation techniques

Comparative Characteristics of Hair Transplantation Techniques					
Parameter	**FUT**	**FUE**	**DHI**	**Sapphire FUE**	**Robotic FUE**
Harvesting Method	Strip	Follicular units	Implanter pen	FUE + sapphire blade	Robotic extraction
Scarring	Linear	Minimal	Minimal	Minimal	Minimal
Graft Yield	High	Moderate–High	Moderate–High	Moderate–High	High
Healing Time	7–14 days	3–7 days	3–7 days	3–7 days	3–7 days
Precision	Moderate	High	Very High	Very High	Very High
Cost	Lower	Moderate	Higher	Moderate–High	High
Ideal Indications	Extensive baldness	All cases	Hairline, small areas	Natural results	Large sessions

As demonstrated in Table 1, the techniques differ not only in their harvesting and implantation principles but also in the equipment required and the potential complications associated with each procedural stage. FUT remains characterized by strip harvesting and the possibility of linear donor-site scarring, whereas FUE avoids a continuous linear incision but may result in multiple small punctate scars. DHI provides an implanter-based approach to graft placement, while Sapphire FUE focuses on recipient-site incision using sapphire blades. Robotic-assisted FUE introduces technological support during selected extraction procedures but remains dependent on appropriate patient selection and surgical supervision.

Importantly, these techniques should not be considered entirely interchangeable or mutually exclusive. FUT and FUE describe follicular unit harvesting methods, whereas DHI primarily describes an implantation approach. Sapphire FUE refers to the instrumentation used for recipient-site creation, and robotic systems provide technological assistance during selected surgical stages. Therefore, the selection of an appropriate technique should be based on donor-area characteristics, the extent and pattern of hair loss, follicular unit requirements, patient expectations, available equipment, and the surgeon's experience.

7.PATIENT SELECTION AND PREOPERATIVE ASSESSMENT

Appropriate patient selection is one of the most important determinants of successful hair transplantation.

The preoperative assessment should include a detailed medical history, physical examination, evaluation of donor density, and assessment of the pattern and progression of hair loss Table 2.

7.1. Medical History

The following factors should be evaluated:

Duration and progression of hair loss.

Family history of androgenetic alopecia.

Previous hair restoration procedures.

Medical conditions.

Current medications.

History of smoking.

Allergies and previous surgical complications.

Patient expectations.

7.2. Clinical Examination

The examination should include:

Assessment of frontal hairline.

Evaluation of temporal recession.

Assessment of vertex involvement.

Donor-area density.

Hair shaft diameter.

Hair characteristics and curl.

Scalp condition.

Presence of inflammation or scarring.

7.3. Classification

The Norwood-Hamilton classification is commonly used to describe male pattern hair loss.

For women, the Ludwig classification and other appropriate clinical assessment systems may be used.

Trichoscopy can assist in identifying follicular miniaturization and differentiating androgenetic alopecia from other hair-loss disorders.

7.4. Contraindications and Caution

Hair transplantation should be postponed or avoided in selected patients with:

Active inflammatory scalp disease.

Uncontrolled systemic medical conditions.

Insufficient donor density.

Unstable or rapidly progressive hair loss without an appropriate treatment plan.

Active cicatricial alopecia.

Unrealistic expectations.

Careful assessment is particularly important in younger patients because future progression may significantly alter long-term aesthetic results.

Table 2. Comparison of preoperative and postoperative assessment parameters

Assessment domain	Preoperative evaluation	Postoperative evaluation
Hair density	Donor and recipient density	Visible hair density
Hairline	Design and symmetry	Naturalness and symmetry
Donor area	Follicular density and scalp laxity	Scarring and depletion
Graft characteristics	Hair number per follicular unit	Graft growth
Scalp condition	Inflammation and skin quality	Healing and complications
Patient satisfaction	Expectations and treatment goals	Patient-reported satisfaction
Clinical photography	Standardized baseline images	Standardized follow-up images

8. SURGICAL PLANNING AND GRAFT MANAGEMENT

The success of hair transplantation depends not only on the harvesting technique but also on the quality of graft preparation, storage, and implantation.

A follicular unit may contain one, two, three, or occasionally four terminal hairs.

Single-hair follicular units are commonly used in the frontal hairline to create a gradual and natural transition.

Multi-hair follicular units may be distributed behind the frontal hairline to improve visual density.

The surgeon should consider:

Hairline design.

Natural hair direction.

Recipient-site angulation.

Donor-area preservation.

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Graft distribution.
Existing native hair.
Future progression of alopecia.

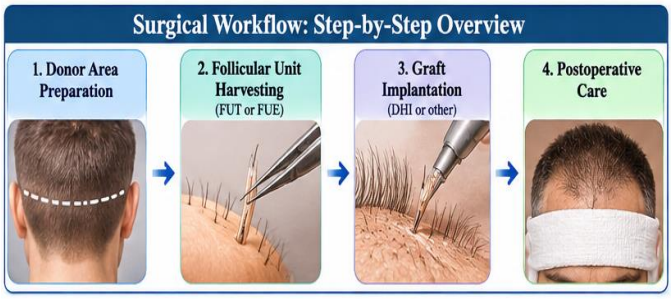


Figure 4. Surgical Workflow

Grafts should be handled carefully to minimize mechanical trauma, dehydration, and prolonged exposure outside the body.

The use of magnification and appropriate graft-storage conditions is important during the procedure.

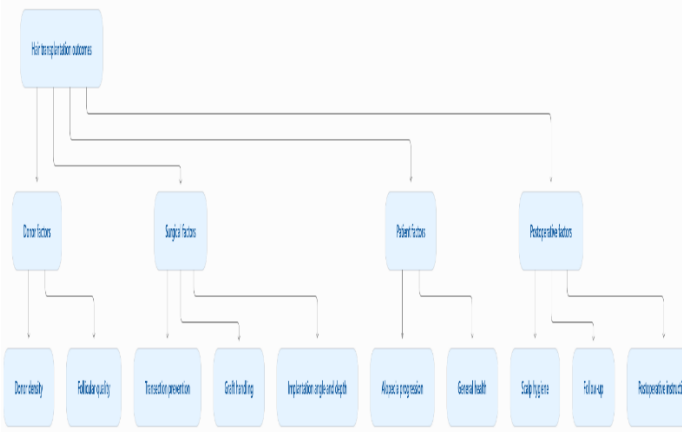


Figure 5. Factors influencing graft survival and aesthetic outcomes

9.COMPLICATIONS OF HAIR TRANSPLANTATION

Although hair transplantation is generally considered a relatively safe elective procedure in appropriately selected patients, complications may occur.

The literature describes both temporary postoperative complaints and more significant surgical complications.

9.1. Donor-Area Complications

Potential complications include:

Pain and discomfort.
Bleeding.
Infection.
Folliculitis.
Hypopigmented scars.
Hypertrophic scarring.
Donor-area depletion.
Persistent numbness.
Delayed wound healing.

FUE may produce diffuse punctate scarring, while FUT produces a linear donor scar.

9.2. Recipient-Area Complications

Potential complications include:

Postoperative edema.
Crusting.
Folliculitis.
Infection.
Temporary shock loss.
Poor graft growth.
Unnatural hairline.
Inadequate density.
Skin necrosis in rare cases.

9.3. Factors Influencing Complications

Important contributing factors include:

Inadequate preoperative assessment.
Excessive donor harvesting.
Poor graft handling.
Insufficient surgical experience.
Inappropriate recipient-site planning.
Inadequate aseptic conditions.
Failure to follow postoperative instructions.

A review of published complications emphasizes that donor-area depletion, scarring, infection, and recipient-site problems should be considered during surgical planning Table 3..

Table 3. Comparative complications associated with harvesting techniques

Complication	FUT	FUE	DHI / Sapphire
Linear scarring	Characteristic	Absent	Depends on harvesting
Punctate scarring	No	Possible	Possible
Donor depletion	Possible	Possible	Possible
Follicular transection	Possible	Possible	Depends on harvesting
Postoperative edema	Possible	Possible	Possible
Folliculitis	Possible	Possible	Possible
Recipient-site necrosis	Rare	Rare	Rare

Source: Complications described in the manuscript; comparative incidence is not established.

9.4. Prevention

Prevention includes careful patient selection, appropriate surgical planning, preservation of the donor area, meticulous graft handling, aseptic surgical conditions, and clear postoperative instructions.

Patients should be informed about expected postoperative changes and possible complications before undergoing surgery.

10. POSTOPERATIVE MANAGEMENT

Postoperative care is an important component of the overall treatment process.

Patients should receive written instructions regarding scalp hygiene, physical activity, wound care, and follow-up appointments.

Early Postoperative Period

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During the first postoperative days, mild edema, redness, tenderness, and crust formation may occur.
Patients should avoid unnecessary manipulation of the recipient area and follow the operating surgeon's washing instructions.
First Month
Temporary shedding of transplanted hair shafts may occur. This phenomenon is commonly referred to as postoperative shedding or shock loss.
Patients should be informed that shedding does not necessarily indicate graft failure.
Three to Six Months
Early visible hair growth generally becomes more apparent during this period, although individual variation is expected.
Six to Twelve Months
Hair density and cosmetic appearance can continue to improve.
A 12-month evaluation is commonly used as an important clinical follow-up point, although maturation may continue beyond this period.

11. CLINICAL CASE 1 ILLUSTRATION

Important: The following is a proposed illustrative clinical scenario for manuscript development. It is not a verified patient record. All clinical observations, operative details, and outcomes must be replaced with documented patient information before journal submission.

11.1. Patient Presentation

Hair Transplantation in the Frontotemporal Regions Following a Burn Injury

The patient presented with cicatricial alopecia in the frontotemporal regions following a burn injury. Hair transplantation was performed to restore hair coverage using the FUE (Follicular Unit Extraction) technique, involving the individual extraction and subsequent transplantation of follicular units.

To evaluate the surgical outcome and early postoperative course, clinical photographs were obtained at three time points: before surgery, immediately after surgery, and 10 days postoperatively.

11.2. Preoperative Assessment

The preoperative evaluation included assessment of:
Scalp condition.
Donor-area density.
Hair shaft characteristics.
Hairline configuration.
Frontal and temporal hair loss.
General medical history.
The occipital and parietal scalp regions were considered as potential donor areas.

11.3. Surgical Technique

Follicular Unit Extraction (FUE) was selected as the proposed harvesting technique.
The illustrative surgical plan included approximately 2,500 follicular unit grafts.
The harvested follicular units were intended for transplantation into the frontal and frontotemporal recipient regions.
The implantation plan emphasized natural hairline design, appropriate follicular orientation, and balanced graft distribution.

11.4. Postoperative Care

Postoperative management was planned according to standard hair transplantation principles.
The patient would receive instructions concerning scalp hygiene, protection of the recipient area, physical activity restrictions, and scheduled clinical follow-up.

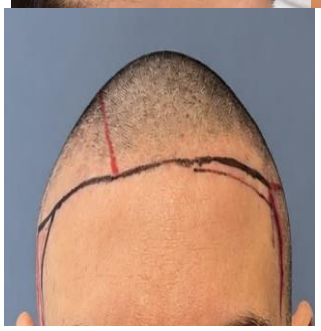
11.5. Follow-up Assessment

Clinical assessment was planned at:
1 month.
3 months.
6 months.
12 months.
The principal clinical outcome measures would include:
Hair growth in the recipient area.
Visual hair density.
Hairline naturalness.
Donor-area appearance.
Patient satisfaction.
Presence or absence of complications.

11.6. Clinical Documentation

Preoperative and postoperative clinical photographs should be obtained using standardized lighting, camera distance, positioning, and scalp orientation.
Photographs should document the frontal, vertex, temporal, and donor regions when relevant.
The actual clinical outcome must be reported only after examination and comparison of the patient's documented photographs.





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Figure 6. Preoperative clinical appearance of the frontotemporal regions showing post-burn cicatricial alopecia.



Figure 7. Immediate postoperative appearance following FUE hair transplantation in the frontotemporal regions.



Figure 8. Clinical appearance of the recipient areas 10 days after FUE hair transplantation.

12 CLINICAL CASE 2 ILLUSTRATION

12.1. Patient Presentation

Hair Transplantation in the Frontal Region Following Treatment of Folliculitis

Hair transplantation was performed in the frontal region following treatment of folliculitis. The preoperative photographs demonstrate residual skin changes remaining after treatment. Following dermatological assessment, the dermatologist confirmed that the inflammatory process had sufficiently resolved and approved proceeding with hair transplantation at this stage.The procedure was performed using the FUE (Follicular Unit Extraction) technique, involving the individual extraction and subsequent transplantation of follicular units. To evaluate the surgical outcome and early postoperative course, clinical photographs were obtained at three time points: before surgery, immediately after surgery, and 10 days postoperatively.

12.2. Preoperative Assessment

The preoperative evaluation included assessment of:

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Scalp condition.

Donor-area density.

Hair shaft characteristics.

Hairline configuration.

Frontal and temporal hair loss.

General medical history.

The occipital and parietal scalp regions were considered as potential donor areas.

12.3. Surgical Technique

Follicular Unit Extraction (FUE) was selected as the proposed harvesting technique. The illustrative surgical plan included approximately 2,500 follicular unit grafts.The harvested follicular units were intended for transplantation into the frontal and frontotemporal recipient regions.The implantation plan emphasized natural hairline design, appropriate follicular orientation, and balanced graft distribution.

13.4. Postoperative Care

Postoperative management was planned according to standard hair transplantation principles.

The patient would receive instructions concerning scalp hygiene, protection of the recipient area, physical activity restrictions, and scheduled clinical follow-up.

14.5. Follow-up Assessment

Clinical assessment was planned at:

1 month.

3 months.

6 months.

12 months.

The principal clinical outcome measures would include:

Hair growth in the recipient area.

Visual hair density.

Hairline naturalness.

Donor-area appearance.

Patient satisfaction.

Presence or absence of complications.

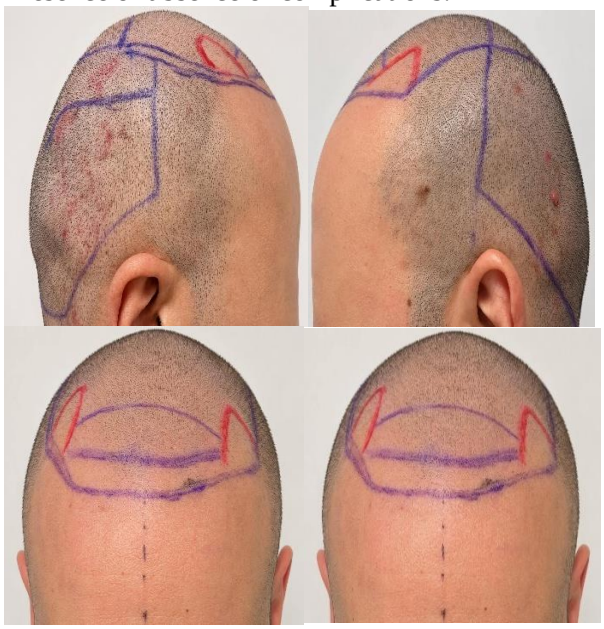


Figure 9. Preoperative clinical appearance of the frontotemporal regions showing post-burn cicatricial alopecia.



Figure 10. Clinical appearance of the recipient areas after FUE hair transplantation.

12.6. Clinical Documentation

Preoperative and postoperative clinical photographs should be obtained using standardized lighting, camera distance, positioning, and scalp orientation.

Photographs should document the frontal, vertex, temporal, and donor regions when relevant.

The actual clinical outcome must be reported only after examination and comparison of the patient's documented photographs.

12. DISCUSSION

Modern hair transplantation is based on the principle of transferring androgen-resistant follicular units from donor regions to areas affected by androgenetic alopecia.

The development of FUE has significantly expanded the possibilities of surgical hair restoration. Its popularity is associated with the absence of a continuous linear donor incision and the flexibility of individual follicular unit harvesting.

Nevertheless, FUE is not free from scarring or complications. Excessive extraction may lead to donor depletion, visible hypopigmentation, and reduced future harvesting capacity.

FUT remains an important alternative, particularly in selected patients requiring substantial graft numbers and possessing suitable scalp laxity.

The choice between FUT and FUE should be individualized rather than based solely on patient preference or marketing claims.

DHI and Sapphire FUE have introduced additional options for graft implantation and recipient-site creation. However, these approaches should be interpreted within the broader framework of surgical planning and follicular unit transplantation.

The available evidence does not establish that the use of an implanter pen or sapphire blade alone guarantees superior graft survival or greater hair density.

Robotic-assisted transplantation represents another technological development. Although robotic systems may improve consistency during selected stages, the surgeon remains responsible for planning, patient selection, donor management, and the final aesthetic result.

A particularly important aspect of contemporary hair transplantation is long-term donor management. The donor area represents a finite resource, and excessive harvesting may compromise the possibility of future procedures.

The literature also highlights the importance of transparent communication with patients regarding expected results, complications, and the progressive nature of androgenetic alopecia.

The clinical illustration presented in this manuscript demonstrates a proposed framework for reporting a standard FUE procedure. Its final scientific value will depend on the inclusion of verified clinical data and documented postoperative outcomes.

13. FUTURE PERSPECTIVES

Future developments in hair transplantation are likely to focus on improved follicular unit preservation, automated graft assessment, robotic assistance, advanced imaging, and more standardized outcome measurements.

Research into follicular regeneration, stem-cell-based approaches, and tissue engineering may eventually expand the therapeutic options available for patients with advanced hair loss.

However, these approaches require further clinical validation before they can be considered established alternatives to conventional transplantation.

Future comparative studies should use standardized definitions of graft survival, hair density, donor depletion, patient satisfaction, and adverse events.

14. CONCLUSION

Modern scalp hair transplantation has evolved into a sophisticated surgical discipline combining anatomical knowledge, follicular unit preservation, precise surgical planning, and advanced instrumentation.

FUE and FUT remain the principal harvesting techniques, while DHI and Sapphire FUE represent variations in graft implantation and recipient-site creation. Robotic-assisted systems provide additional technological support in selected procedures.

No technique can be considered universally superior for all patients. The choice should depend on individual donor characteristics, the extent of hair loss, patient expectations, surgical indications, and the experience of the operating surgeon.

Appropriate patient selection, careful donor-area management, standardized surgical protocols, and long-term follow-up remain essential for achieving safe and satisfactory clinical outcomes.

Further high-quality comparative research is required to establish the relative effectiveness and long-term outcomes of emerging hair transplantation technologies.

DECLARATION

Ethical Approval

Not applicable.

Informed Consent

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Written informed consent was obtained from all patients for the surgical procedures and the use of their clinical data for research purposes. In addition, written consent for publication of clinical photographs was obtained from the patients whose photographs are included in this article, where applicable.

CONFLICT OF INTEREST

The authors should disclose any financial, professional, or personal relationships that could influence the content of this manuscript.

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AUTHOR CONTRIBUTIONS

To be completed according to the actual contributions of each author.

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