



Review Article

EVOLUTIONARY ADVANCES IN HAIR RESTORATION TECHNIQUES: A REVIEW

Sheeraz Badal¹, Gopal Nagargoje², Minal Sonare^{*3}, Poonum Nagargoje⁴,
Paras Doshi⁵ and Shubham Bhele⁶

Department of Oral and Maxillofacial Surgery, in Maharashtra Institute of Dental Sciences and Research (Dental College),
Vishwanathpuram, latur 413512, Maharashtra, India

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ABSTRACT

Hair loss, or alopecia, is a concern for both men and women. It can be the result of heredity, hormonal changes, medical conditions, Trauma or medications. The loss of hair can have philosophical effects on one's self esteem and emotional well-being. Hair transplant surgery has become increasingly popular because of its remarkable results by providing a natural appearance in spite of challenges that prevent the achievement of optimal results. The objective of this article reviews advancement of hair restoration techniques that has been practiced till date. The electronic search was conducted to the English PubMed literature and specialty literature in hair restoration techniques. The electronic search was accompanied by a manual search of the reference lists. Data is extracted from the articles which focused on the advances of hair restoration methods both surgical, pharmacological and non-surgical. A further research and clinical investigations needed better understanding of hair restoration techniques.

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INTRODUCTION

The history of hair transplant started in 1822 when Dieffenbach tried with hair transplant in birds^[1]. The field of surgical hair restoration thereafter progressed in two different directions where one group started discovering role of autografts while other segment of surgeons endeavored several flaps and serial excisions. The use of autograft technique was conquered and implemented globally^[2, 3]. Early efforts were made by Japanese dermatologists Sasagawa^[4], Okuda^[5], Tamura^[6] and Fujita.^[7] They used small autografts containing hair follicles for the correction of scars and cicatricial alopecia, but they never stated the technique for androgenetic alopecia and their work went unacknowledged for years. Later, Dr. Norman Orentreich who is also considered as father of modern hair transplantation performed hair transplant with 4-mm punch for "punch grafting" technique and discussed the idea of donor and recipient site dominance.^[8, 9] While patients did grow hair, the grafted hair, done with large "plugs", gave an odd, plug-like appearance. Attempts to alleviate this esthetically displeasing result led to the use of smaller grafts, such as mini grafts, strip grafts, and single-hair micro grafts.^[10] Nordström^[11] and Marritt^[12] advanced follicular grafting with the introduction of single-hair transfers, or micrografts. Scalp rotational flaps have their origin in the management of cicatricial alopecia but became renowned as a means of aesthetic hair restoration with the contribution of Juri's eponymous, twice-delayed

temporoparietal-occipital flap.^[13-15] Scalp reduction was familiarized in 1977 by the Blanchards^[16] and has had a somewhat variable course of success partly due to two complications, stretch-back^[17] and slot deformity.^[18-21] The former problem, in which the reduced, bald scalp partially stretches back after reduction, was brilliantly answered by Frechet^[22] in 1993 with the use of an implanted extender. But it was not until 2002 when Rassman *et al.*^[23] defined the FUE technique in detail and discoursed various clinical and microscopic features of follicular grafts harvested from 1-mm punch. Since then, FUE technique which is also denoted or modified as FOX procedure, FUSE (follicular unit separation extraction) method, Wood's technique, follicular isolation technique (FIT), individual follicular group harvesting (IFGH)^[24, 25] is gaining relentless popularity among hair restoration surgeons and their patients^[3].

The modern hair replacement grew suitably to provide accurately natural results. Additionally, a better appreciation of hair line esthetics and amplified knowledge of the androgenetic hair loss progression over one's lifetime gave physicians the ability to generate extremely natural outcomes.^[26-28] Hair loss is a wide-reaching problem affecting both genders, males being more. Hamilton-Norwood classification system for male pattern baldness and the Ludwig system for females are utmost commonly used classification systems.^[29]

In past few years, several maxillofacial surgeons have extended their practice in cosmetic and hair restoration surgeries. Moreover, hair transplant techniques have been

*Corresponding author: Minal Sonare

Department of Oral and Maxillofacial Surgery, in Maharashtra Institute of Dental Sciences and Research (Dental college), Vishwanathpuram, latur 413512, Maharashtra, India.

successfully used in camouflage correction of cleft lip scars, face lift scars, post-burn or traumatic scars, reconstruction of eyebrows, eyelashes, beard, mustache, vitiligo and as an adjunct to various maxillofacial procedures.^[30-35] While the evolution of hair restoration surgery has afforded us the capability to generate brilliant results, we still face situations where patient expectations cannot be reached. Challenges like in the areas of donor surgery, graft preservation, optimization of growth, donor preservation and possible enhancement, improved graft survival, and possible regeneration of hairs in areas of bald scalp exist that limit our ability to produce results that rival hair in its natural state. Despite global interest, there is a general lack of the literature in maxillofacial journals on this topic. The aim of this paper is to discuss the various aspects of novel hair restoration technique in detail, graft holding solutions, recent advances and other key factors.

MATERIALS AND METHODS

We did the literature search in PubMed and Google Scholar. Publications with relevant information based on their abstracts and, or full text are included in this article. The electronic search was accompanied by a manual search of the reference lists. The articles which focused on the advances of hair restoration methods like surgical, non-surgical and pharmacological were included.

DISCUSSION

As the Japanese discoveries were not then known, Western surgeons used several available plastic surgery techniques to re-distribute the donor hair. There are three broad categories of surgical restoration procedures. These may be summarised as follows:

1. Scalp flaps (advancement flaps, rotation flaps and free flaps),
2. Surgical excision (alopecia reduction), and
3. Free autografts of hairy scalp from the well-haired to the bald area.

All three categories of operation are still performed, but the most generally accepted are the autograft techniques known as “micro-grafting”, “mini-grafting” and, in particular, “follicular unit transplantation”.

Scalp Flaps

Small pedicle flaps and even free strip grafts of donor scalp had been employed for decades for scar correction on the scalp and eyebrows and had a renaissance after 1975 chiefly due to the work of J. Juri in Buenos Aires.^[13] His long scalp flaps eliminated the curious tufted appearance of a punch graft hairline, but they were still not always popular with patients. This was because of their higher failure rate and even when successful, the frontal hair growth was frequently unnatural in density and direction. In the current practice, the routine use of scalp flaps remains restricted to the hands of a select few individuals such as the Juri brothers in Argentina, Patrick Frechet in France and Mayer and Fleming in the USA.

Alopecia Reduction Surgery

A fascinating and rational spin-off from scalp flap surgery was the development of the alopecia reduction operation around 1977.^[36] Alopecia reduction procedures could be hastily learnt and had a high safety factor. A wide number of

variations quickly became available and the procedure remained extremely popular for a decade or more. Conflicting camps arose between those who favoured lateral or central reductions.

Morrison, Norwood and Shiell issued a paper on “*The Complications of Scalp Reduction*” in 1984,^[37] but these warnings mostly overlooked for another decade. The major glitches with alopecia reductions were cosmetic. The shape of the residual bald area became gradually irregular and more difficult to conceal with each additional reduction procedure. In addition, the scalp had a surprising capacity to stretch and much of the initial baldness reduction was lost over subsequent months as the phenomenon titled “stretch-back” consumed up to 50% of the initial gain. Even when all the bald area was excised, one still had the problem of future expansion of the baldness which could expose the old scars.

Frechet introduced his “*Triple Flap* procedure” in 1989 in an attempt to correct the central slot.^[38] He also developed the *Frechet Extender*, a device which was implanted under the skin where it remained for 30 days producing continuous traction on the hair bearing scalp.^[22] This not only prevented stretch-back, but also produced additional tissue-creep enabling further tissue to be removed after 30 days. Gerald Seery of the USA advocated the attachment of the advanced scalp to the galea by sutures or a small galeal flap.^[21] He claimed that this significantly reduced stretch-back without the introduction of any internal foreign body requiring later removal.

However, these developments in flaps and scalp have lagged behind the advances in graft techniques and the era of alopecia reduction seems to have passed. It remains to be seen whether surgeons of the future, using improved techniques and better case selection will be able to stimulate a new era of alopecia reduction.

Advances in Autograft Technique

Punch grafting remained widespread throughout this entire period, but the use of the hand and motorized skin trephine diminished as surgeons swapped to square donor grafts cut from long donor strips prepared with multi-blade scalpels. This was not only much quicker, but also eradicated the risk posed by atomized blood particles that spun off the rapidly spinning mechanical punch. This was particularly a worry once the Acquired Immune-Deficiency Syndrome (AIDS) was shown to result from a blood-borne virus.

From the early 1980s, small grafts were produced by dissecting the traditional 4 mm plugs or squares into halves or quarters. These grafts still had up to eight hairs however and still appeared quite tufted when working with coarse black donor hair. Carlos Uebel in Brazil^[39] and the Moser Clinic in Vienna^[40] advocated large sessions of even smaller grafts containing 3-4 hairs, cut from a donor strip and inserted into slits made with a No 11 blade.

The accomplishment and acceptance of this mini/micrografting finally brought the passion for alopecia reduction and 4 mm punch grafting to a break. At last, we had a technique which was safe, relatively easy to learn and produced a result which was popular with patients and surgeons alike. There was a down side as the new technique was much more labour exhaustive, requiring many hours for

the dissection and implantation of 1000 small grafts. The surgeon spent only 1-2 h with the patient and most of the grueling monotonous work was performed by the specially trained surgical assistants. The labour factor increased again when Dr. William Rassman of Los Angeles pushed session sizes to over 3000 mini-grafts in some cases. This required a team of one surgeon and up to 10 assistants for a total work time of some 80 man-hours.^[41] To speed up the production of small grafts, multi-blade knives for the cutting of donor strips acquired up to 10 blades. These could be spaced as close as 1 mm apart but required considerable skill and strength to use successfully. Automatic dissection devices were also developed by Boudjema in France in 1992 and Dr. Tony Maugubat in the USA in 1996.^[42]

Microscope-Aided Dissection

Many surgeons were startled at the degree of follicular transection that was occurring with the “blind” cutting of multiple strips with multi-blade knives and the new dissection devices. It was estimated that up to 25% of follicles were traumatized in some cases and 10 % with the most skilled surgeons.^[43] In their defence, the multi-strip surgeons quoted the work of J.C. Kim of Korea who demonstrated experimentally that most transected follicles eventually regrew hair.^[44]

Strip dissection under stereoscopic microscopes had been introduced by Dr. Bob Limmer of Texas in 1987 and gave the operator an extraordinary view of the excised scalp tissue and the individual hair follicles.^[45] Microscopic dissection averaged only about 150-200 grafts per hour however and greatly increased the number of staff members required for each procedure. As a result, there was much initial resistance to the new microscopic methods and professionals were slow to take up this scrupulous technique. Later, David Seager of Toronto^[46] wrote expansively and eloquently about the technique and it was taken up further by doctors Bernstein and Rassman^[47] and many others. Dissection teams of 10 or more assistants became common and an additional 2-3 assistants were required for graft implantation.

There was a downside to this development too. It was no longer possible for a cosmetic surgeon with a casual interest in hair restoration to perform these new procedures at a high standard. Unless he had a regular flow of hair patients, it was not feasible for the surgeon to assemble, train and keep a large team of surgical assistants together and therefore technique became restricted to few dedicated teams.

Alternative Approaches

In Korea, an alternative approach for speeding up the process of transplantation was developed by Choi *et al.*^[48] The follicular units or bundles still had to be cautiously prepared by hand, but they were implanted with the aid of a mechanical implantation device. The Choi Implanter is the most resourceful device into which follicular bundle containing 1-4 hairs may be loaded. The needle is inserted into the scalp and the plunger pressed to implant the graft. With a three-person team of two loaders and one planter about 12 grafts per minute or around 700/h can be implanted. As an alternative regime, the fine slits can be pre-made by the surgeon and the assistants “fill the holes” with the aid of the implanter at some later time. This enables very close spacing of the grafts and the surgeon remains in full control of the spacing and direction of each

implant. Professor Jung Chul Kim, from South Korea, has developed his own version of the Choi implanter that has a different method of action and disposable needles. Surgeons outside of Asia are slowly showing interest in both these devices and they are now being used in Greece and other centres.

A Hair Implanter Pen was developed by Dr. Pascal Boudjema of France^[49] and mechanical implantation devices have been developed by Dr. Bill Rassman^[50] and Dr. Barry Markman of the USA.

Donor Scar

The switch from individual 4-mm donor plugs sites to strip excision of the donor site in the 1980s led to criticisms from patients and their hairstylists about residual linear scarring at the back and sides of the patient's scalp. Wound tension was a major factor in causing wide scar. However, wide scar often occurred even when there had been negligible tension during closure and it is possible therefore, that there are significant individual variations in healing characteristics of human skin of a genetic basis.

To overcome this problem of donor scar, there have been two developments:

1. A return to the removal of individual grafts, this time of 1.0 mm (or even less) follicular-unit dimensions. This is technically difficult and may result in damage to the follicle during extraction of the follicular unit. This has become known as “follicular unit extraction” or FUE.^[51]
2. A refined donor closure technique was developed as a spin-off from the frontal flap techniques of two decades earlier. This, known as the “trichophytic closure”, was designed to allow hairs to grow through the residual scar.^[52] This was accomplished by cutting a 1-mm ledge of epidermis off one edge of the donor site before the closure of the wound, so that the underlying hair will grow through the linear scar. This is usually very successful providing a resultant scar, which is no more than 2 mm wide.

Preserving Donor Hair and Regenerating Existing Miniaturizing Hair-Drug Therapy

An ongoing challenge in hair restoration is preventing hair loss in patients destined to have Androgenic alopecia. By limiting hair loss, we can hopefully reduce the need for increased numbers of grafts to be placed into an area of alopecia. A means to early diagnosis such as genetic mapping might be helpful in starting medical therapy early.^[53]

Finasteride and minoxidil are the only approved medical therapies for the treatment of scalp hair loss. A drug similar to finasteride is dutasteride.^[54] This drug blocks both of the alpha reductase pathways.^[55] A recent advance in terms of hair growth has occurred with the use of bimatoprost for eyelash hair growth. It is unclear how this interaction can promote eyelash hair growth. The drug has been used to try to promote eyebrow hair growth and it is being investigated for use in scalp hair loss. In a study published in 2012, a prostaglandin analog latanoprost, was used topically. The study lasted 24 weeks and the drug was shown to improve hair growth in male patients with AGA.^[56]

Laser Hair Transplantation

Low-level light lasers have been promoted to re-grow hair. The use of such laser is based on the work of Mester *et al.*,^[57] who reported on the effects of low energy laser light on hair growth in mice. There is a strong case to be made that lasers can affect hair growth and character of hair, but there are relatively few studies that document the effects with double-blind placebo-controlled investigation. A study in 2009^[58] looking at the LaserMax device, 655 nm showed an increase in terminal hairs as well as an increase in the caliber of hairs, and improved texture. Several recent studies using the comb device demonstrated an increase in terminal hairs and hair diameter.^[59-61] The devices are considered to be class II US Food and Drug Administration (FDA) devices, and while considered safe, a Section 510(k) is required for legal sale. Many devices are available, and these may be considered safe, but many do not have the necessary US FDA clearance.

Motorized Punching Techniques and Devices

Standardization of punches, forceps, motorized devices, holding solutions, etc., is the need of time. Dental micromotors and handpieces are serving the hair transplant industry in economical and efficient way, but several advancements in motorized punching techniques and devices have been introduced in market like surgically advanced follicular extraction (SAFE)^[62], FUExtractor system^[63], Cole Isolation Device, True Device, Alphagraft, Devroye, Feller, Neograft suction-assisted motorized device, etc.^[64].

Robotic Hair Transplantation

Robotic hair transplantation is the leading technological advancement in hair transplant surgery recently. The use of robotic devices makes grafts harvesting and preparation of recipient site more precise and fast as compared to manual hair transplant^[65]. The robot allows surgeons without trained surgical assistants to perform hair transplant surgery. Although the robot is a state-of-the-art instrument, it does not have the judgment and artistic ability of an experienced hair transplant surgeon. The robot cannot tell the surgeon where to place grafts and where not to place grafts for optimal long-term cosmetic results. Candidate selection, effective medical therapy, and planning a procedure for both potential short- and long-term future hair loss are performed by the physician not robot. Robotic hair transplantation allows rapid, accurate harvesting of follicular units from donor region with minimal scarring. Hair grows in natural 1- to 4-hair units on the scalp.^[66]

Piloscopy

Wesley has familiarized a technique termed "piloscopy," a below the surface graft harvesting approach, and has designed an advanced endoscopic device "piloscope." The technique offers several advantages over conventional FUE including less scarring and graft transaction^[67]. In vivo hair follicle multiplication, partial follicular extraction or techniques to divide single hair follicular unit into two has been stated in the literature. The technique may be suitable for cases with compromised donor area, but the primary results are mixed and long-term assessment and larger trials are needed^[68].

Platelet-Rich Plasma

Autologous plasma has been tried as extracellular holding media for hair follicles exhibited better results. Intraoperative and postoperative injections of platelet-rich plasma (PRP), extracellular matrix (ECM) and platelet-rich fibrin matrix which is the rich source of various growth factors have also shown beneficial and promising results^[69]. The preferred PRP injections usually 1–2 months after hair transplant on donor and recipient area and have observed better and early results. The role and correct time for the use of topical minoxidil, PRP, low-level laser therapy and other adjuvant therapies should be explored more to achieve early and better results^[70].

Stem Cells

According to a survey report by International Society for Hair Restoration Surgery (ISHRS), hair cloning or stem cell can be the next immense "technological leap" in the field of hair restoration followed by mechanization/FUE/robotic surgery/automation and therefore, bioengineering of hair follicle can prove penultimate solution to the hair gain therapy; till then, hair transplant offers predictable and long-term results to the balding population^[71]. Some physicians are combining stem cells with PRP, particularly when doing facial filler injections. Till date, no controlled studies in humans have been available demonstrating a positive outcome. It is unclear as to what volume should be injected, what concentration, what depth of injection, and what other stimuli are needed.

CONCLUSION

Hair transplant has seen several developments, but still is in its inception stage. With gaining interest worldwide and more and more doctors learning the techniques, the science and art of hair transplant surgery is expected to see major advancements in coming years. Hair transplant surgery has become an excellent means to treat many forms of hair loss, particularly male and female pattern hair loss. The techniques utilized today provide natural appearing results that are esthetically pleasing, but there is room for the results to be enhanced. The primary limitation has been accessed to sufficient quantities of donor hair. This lack of donor hair, coupled with the fact that hair loss is often progressive, has led us to encounter various challenges. The solutions to the problems we face lie in preserving donor hair, skillful surgical techniques, limiting hair loss, and developing the means to replenish hair. Hair transplant is proving to be more than just a cure for baldness, and the possible application of the technique in maxillofacial region is yet to be fully explored. A further detailed review of the published and unpublished cases should be done for a better understanding of advancements in hair restoration.

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Conflict of interest

There is no conflict of interest among the authors. All the author's have equally contributed in the article.

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