Review Article

Follicular Unit Extraction [FUE] – One Procedure, Many Uses

Abstract

Follicular unit extraction [FUE] is a minimally invasive hair restoration surgery popularly known for its utility in androgenetic alopecia (AGA). In FUE, individual follicular grafts are extracted from donor area and implanted in the recipient area. Advantages of FUE are that it is comparatively 'scarless', has faster healing time, has less downtime and requires less technical staff. This article is aimed to highlight upon the multi-faceted utility of FUE technique in various dermatological indications like androgenetic alopecia, alopecia areata, facial hair restoration, tractional alopecia, scarring alopecia, body hair transplant, vitiligo as well as hirsutism.

Keywords: *FUE, hair transplant, multiple uses*

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Introduction

Follicular unit extraction (FUE) was originally discovered by William Rassman *et al*. in 2002 as a minimally invasive hair restoration surgery for androgenetic alopecia.[1] The New York dermatologist Dr. Norman Orentreich is called as the "*father of modern hair transplantation."*[2] The phenomenon of "*donor dominance"* was also coined by Dr. N. Orentreich.[2] Donor dominance is explained as the hair transplanted from the donor area of the scalp (occiput) will continue to grow in the recipient area as if it is in its original site.

In FUE, the grafts are extracted as individual follicular units from the donor area in a two-step or three-step technique and are implanted in the recipient area. It has several advantages like it is comparatively "scarless", has faster healing time, has less downtime, and requires less technical staff.

FUE is popular for its utility in androgenetic alopecia. In this article, the authors aim to highlight not only the conventional indications of follicular unit extraction but also to elicit the multifaceted and "out-of-the-box" utility of FUE in dermatological indications like facial hair restoration, body hair transplant, stable vitiligo, scarring alopecia, traction alopecia, alopecia areata, and hirsutism.

The role of FUE in the above list of indications is discussed in detail as below [Table 1]:

FUE in Androgenetic Alopecia

FUE is an established technique for androgenetic alopecia (AGA) in males as well as females. According to standard guidelines of care, hair transplantation can be done in any person with pattern hair loss, with a good donor area, who is in good general health and has reasonable expectations. However, one should exercise caution in the following cases:

- Young patients with early, evolving alopecia.[3]
- Patients with Norwood grade VI or VII with poor hair density.[3]

The expert panel opined that counselling is very important in patients undergoing hair transplantation.Criteria to be considered for patients who require hair transplantation include[3]:

- Grade 3 Norwood classification
- Stable hair loss that is not rapidly progressive
- Failure of adequate medical treatment
- If age <25, the transplant should be done only in cases of extensive baldness; if age >25 years with grade 3 Norwood's classification, transplant may be considered
- Bitemporal hair loss or frontal hairline baldness

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Table 1: Uses of follicular unit extraction in dermatology

Non cicatricial dermatoses	Cicatricial dermatoses	Miscellaneous
Androgenetic alopecia	Burn scar (chemical/thermal burns)	Madarosis (erythroderma, leprosy, hypothyroidism)
Alopecia areata	Traumatic scars	Focal stable vitiligo (over hairy areas)
Facial hair restoration in beard shapping, transgenders	Surgical scars (cleft lip/palate surgery, post-craniotomy scar)	Follicle cell suspension for stable vitiligo
Traction alopecia	Primary cicatricial alopecia with primary inflammatory dermatoses (e.g., Lichen plano-pilaris)	Body hair transplant
Trichotillomania		Hirsutism (white hair)

- In female patients, transplantation may be considered only after adequate trial of medical treatment, with proper investigations to identify the cause.

FUE and follicular unit transplant (FUT) by strip method are two commonly used procedures for hair transplant in androgenetic alopecia nowadays. Patients with predominant vertex hair loss in the early stages of AGA respond to the medical line of management better as compared to those with bitemporal recession.[4]

Among the two, FUE has gained tremendous popularity in the recent past. Both techniques have their own merits and demerits. Thus, a treating physician needs to have a better clinical judgment to choose between the two procedures on a case-to-case basis. However, a combination of both can prove to be good for some patients.

Figure 1a and b shows pre-procedure and post-procedure images of FUE in androgenetic alopecia.

FUE in Alopecia Areata (AA)

Alopecia areata (AA) is a non-scarring autoimmune type of alopecia. AA is a cell-mediated autoimmune disease, in which autoreactive cytotoxic T cells recognize melanocyte-associated proteins such as tyrosinase. Hair follicle is a unique "miniorgan" with its own immune and hormonal microenvironment. The immunosuppressive milieu of the anagen hair bulb modulated by immunosuppressive factors is known as "hair follicle immune privilege." The collapse of the hair follicle immune privilege leads to autoimmune reactions against hair follicle autoantigens. IFN-γ is one of the key factors that leads to the collapse of immune privilege.[5]

It usually responds moderately to medical management and is renowned for its recurrence. Hair transplantation in active/unstable forms of alopecia areata is not the treatment of choice as the implanted follicular grafts might be destroyed due to underlying autoimmune pathology; in rare cases, it might cause disease exacerbation.

There is a vast literature that focuses on the disease halting process which chiefly comprises of medical management in the form of intralesional steroids, oral and topical immunosuppresants, contact sensitizers, etc. But there is very less data upon hair transplantation in alopecia areata. In 2005, Barankin *et al.*, reported a case of successful hair transplantation over alopecia areata of eyebrow.[6] In their report, they specified a partial recurrence of the disease during the initial 8 months of follow-up, which was responsive to intralesional steroids (ILS). Ultimately, they achieved 80% hair growth at the end of 24 months. The patch which was earlier unresponsive to ILS was responding well to ILS after the hair transplant. Unger *et al.*, in 2008, also reported a case of successful FUT in alopecia areata over the scalp and eyebrow.[7]

In their case, the authors did not use any concomitant medical immunosuppressive therapy along with FUT in contrast to the case report by Barankin *et al.* Unger reported that not only the transplanted grafts grew well, but in addition, new hair grew peripheral to the grafts. Civas E *et al.*, in 2010, reported HT in alopecia areata of eyebrow. They did not give any other oral or topical immunosuppressants to their patient post-FUE.[8]

These successful results in the above case reports might be attributed to the following reasons-

- Phenomenon of "donor dominance" by the extracted hair follicles from occiput displaying their inherent growth characteristics and immunity to autoimmune activity onto the recipient area over beard.
- Addition of triamcinolone acetonide in tumescence solution, if any, might be a factor that can prevent recurrence.
- Improved angiogenesis in recipient area post-surgery; trauma and irritation over patch may lead to hair growth in a similar fashion like other sensitization methods; or due to possible repopulation of area with transplanted cells.
- Inactive disease status in the patch as proven by histopathology and dermoscopy.

Histopathology from an inactive alopecia areata patch is composed of absence of inflammatory infiltrates with empty follicular tracts which are replaced by fibrosis and lined by condensed elastic fibers. Dermoscopy reveals the absence of follicular openings or exclamation mark hair or vellus hair which are signs of disease activity.

Assessment of disease activity by histopathology and dermoscopy form the crux of patient selection in such

situations. FUE, though not routinely performed in alopecia areata, can lead to promising cosmetic outcome if the disease is inactive in long-standing cases. Figure 2b demonstrates an optimal and sustained hair growth in a case of longstanding alopecia areata over beard in a 22-year-old male in whom FUE was performed by authors. [Figure 2a and b] This patient was not supplemented with any oral immunosuppresants or intralesional steroids post-procedure. He has completed a follow-up period of 2 years without recurrence of signs and symptoms.

FUE in Traction Alopecia

Traction alopecia is a cause of scarring hair loss in women, especially Black and Caucasian women, worldwide, and the Sikh population in India.[9,10] Traction alopecia is caused by persistent pulling forces on the hair follicles from traction inducing hairstyles. Traction induces inflammation and follicular damage. In initial phases, it is reversible but later can lead to scarring alopecia. Dermoscopy in traction alopecia is reported as traction folliculitis, the fringe sign, hair casts (pseudonits), broken hair, black dots, sparse hair follicles, and reduced follicular ostia. In advanced cases, there is complete loss of follicular openings. Histopathological appearance of traction alopecia reveals preserved sebaceous glands, increase vellus hair, and paucity of inflammation in contrast to histopathology of other causes of scarring hair loss. Reports on medical management in initial stages are anecdotal. Prompt diagnosis and identification of causative hairstyle comprises the mainstay of management. But advanced cases require surgical management options like minipunch grafting and FUE.[11]

FUE has superseded minipunch grafting due to the fact that FUE leads to a more natural look with a seamless hairline and that the technique is minimally invasive with faster healing. For patches of alopecia on the face, a punch size of 0.7 to 0.8 mm should be used and nape of neck or post auricular hair grafts can be selected as their follicular units comprise of single hair follicles. For FUE on patches of scalp, a punch size of 0.9 mm can be taken, occiput being the donor area. Figure 3b elicits a successful case of FUE in traction alopecia in an Indian Sikh male.[Figure 3a and 3b].

Facial Hair Transplant

Facial hair transplant includes restoration of hair onto eyelashes, eyebrows, beard, and moustache. FUE remains the mainstay of surgical management in facial hair restoration as there is less scarring, and faster healing; donor areas being occiput or postauricular areas. Common indications include scars, tractional hair loss, congenital hypotrichia/atrichia, post-folliculitis scarring, and rarely long-standing alopecia areata.

In females, properly shaped eyebrows and in males, moustache, and beard are of aesthetic importance. FUE

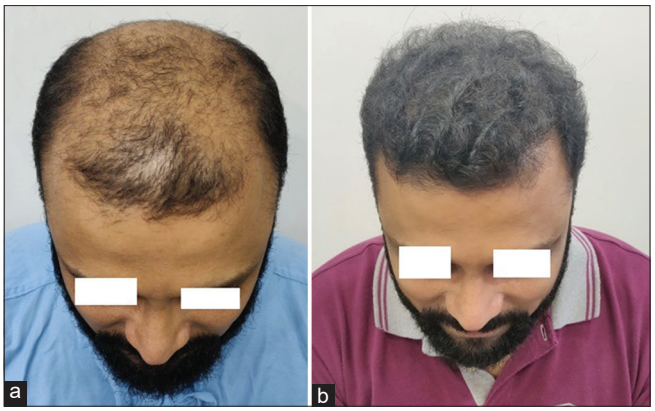

Figure 1: (a) FUE in androgenetic alopecia (before FUE). (b) FUE in androgenetic alopecia (after FUE)

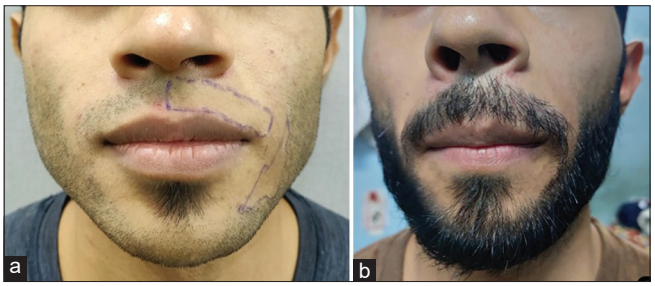

Figure 2: (a) FUE in long-standing case of alopecia areata (before FUE). (b)FUE in longstanding case of alopecia areata (after FUE)

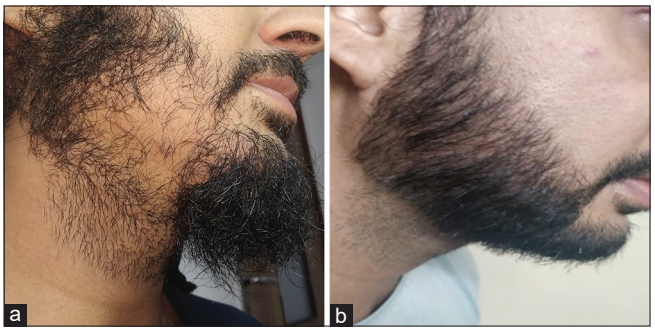

Figure 3: (a) FUE in traction alopecia in Indian Sikh male (before FUE). (b) FUE in traction alopecia in Indian Sikh male (after FUE)

serves as a "scarless" technique to restore or shape facial hair. Indications for eyebrow hair restoration surgeries include loss of eyebrows due to voluntary plucking, disease processes like leprosy, erythroderma, alopecia areata, trichotillomania, hypothyroidism or for the purpose of cosmesis.[12] FUE can benefit patients with hair loss over the eyebrow region in erythroderma or trichotillomania in advanced cases, provided the alopecia is in a quiescent stage.[12] It should be inactive on histopathology as well as on clinical examination with no evidence of active inflammation.[13], However, their first line of management is always medical therapy including treatment of the underlying condition.

Most male patients seeking facial hair restoration are men with a genetic paucity of facial hair. Facial hair

growth in men can occur between 15 years and 25 years of age, although it can vary on individual basis. So, hair transplantation can be delayed until 25 years of age and patients can be treated with medical management till the age of 25 years.[14] FUE can be considered as a treatment option after 25 years of age when men achieve complete beard hair growth.

Another small group is female to male transgender patients seeking a more masculine appearance.[14] In facial hair restoration, punch size ranges from 0.7mm to 0.8mm and the donor area commonly used is the nape of the neck or retro-auricular area consisting of follicular units with 1–2 hair follicles per unit. Prior to performing facial hair restoration, patients should be counselled that the number of grafts taken from the donor area will no longer be available for future hair transplant surgery in case the patient develops androgenetic alopecia. Facial hair restoration especially; over beard and eyebrow areas; is effective and has a very high satisfaction rate amongst patients.

Figure 4a and b illustrates a case of beard hair restoration and beard shaping in a young Indian male.

FUE in Scarring Alopecia

a. **Scarring alopecia secondary to inflammatory skin disease-** Scarring alopecia or cicatricial alopecia implies permanent destruction of hair follicles as a result of irreversible damage to hair follicle stem cells due to disease pathology or trauma. Trauma could be chemical, physical, or thermal. Dermoscopic assessment of these lesions helps in differentiating them from scarring and non-scarring alopecias. Age of scar, vascularity, presence of atrophy or hypertrophy, healthy nature of underlying tissue, any underlying pathological disease process, skin texture, area involved, and availability of donor area are the factors that decide graft survival and optimum hair growth following FUE in scarring alopecia.[15] In case of cicatricial alopecias secondary to inflammatory dermatological diseases, FUE can be considered as an option only when the disease activity is quiescent, and when the underlying dermatoses are adequately treated with anti-inflammatory agents and immunosuppresants. If the disease is unstable with plenty of inflammatory infiltrate, the implanted follicular grafts might get destroyed with the same mechanism of the underlying disease pathology. Also, in conditions like lichen plano-pilaris, there are chances of koebnerization if the underlying disease activity still persists[15,16]

b. **FUE in thermal burn scar-** Burn injuries; whether thermal or chemical; can lead to complete destruction of hair follicles along with severe scarring of tissue. Dermoscopy and histopathological assessment aids in judging the prognosis of FUE in burn scars. Dermoscopic features like reduced blood supply and thick underlying tissue with increased collagen make hair transplant challenging in such cases. Figure 5a and b demonstrates fair improvement in burn-induced scarring alopecia in a young female. The authors confirmed the cicatricial alopecia prior to FUE by dermoscopy and histopathology. FUE was done using a punch size of 0.9mm; occiput being the donor area. Similar cases of FUE in burn scar have been reported in the literature with a successful outcome[17,18]

c. **FUE in traumatic scar/surgical scar-** Scarring alopecia due to trauma or surgery is best treated by follicular unit extraction.[19] Figures 6a, 6b, 7a, 7b demonstrate the effective utility of FUE in improving the appearance of traumatic scars or surgical scars e.g., scars due to cleft lip/palate surgery [Figure 6b], post craniotomy scars [Figure 7b]. Thus, FUE does not heal the scar per se but helps camouflage it by growing new hair over bald areas on hair-bearing sites of the face and scalp

d. **FUE in FUT scar (strip method)-** FUT is a method of hair restoration that uses a strip from the back of the scalp as a source of follicular grafts. After healing, it might lead to a visible ugly scar over occiput which is inconvenient for adults who prefer to keep their hair short. This FUT induced scar can be corrected in a similar fashion as any other scar on hear bearing areas by follicular unit extraction and implantation. The only condition for doing FUE in such cases is that there should be availability of donor grafts from safe zones of

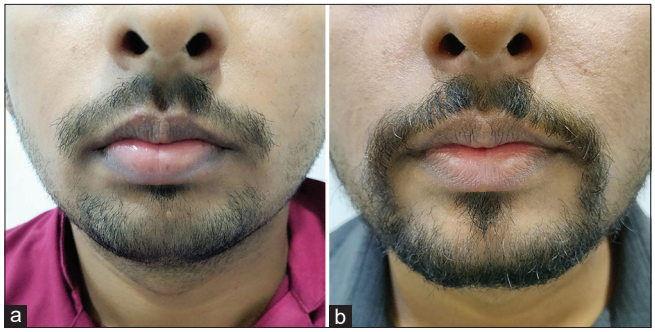

Figure 4: (a) Beard shaping by FUE (before FUE). (b) Beard shaping by FUE (after FUE)

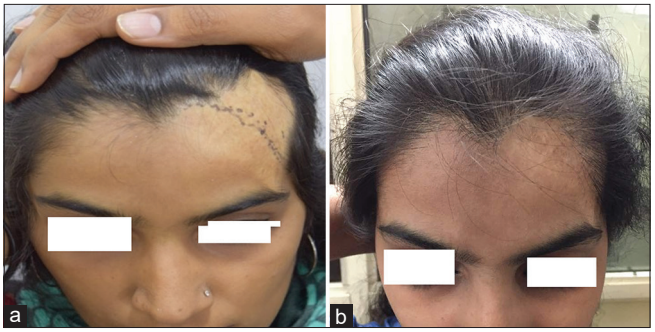

Figure 5: (a) 5a-FUE in Burn scar over scalp in a young female (before FUE)). (b) FUE in Burn scar over scalp in a young female (after FUE)

the scalp. Otherwise, body hair can be used to cover the defect. FUE serves as one of the options for correction of such surgical scars; other modalities include scalp micropigmentation, intralesional steroids (for hypertrohied scars) or simply keeping the hair long to camouflage the defect

FUE in Stable Focal Vitiligo

Vitiligo is a biosocial disease with prevalence of 2–5% in the Indian population.[20] The rationale behind using follicular units to repigment vitiliginous skin is that the outer hair root sheath of hair follicles has stem cells and a larger number of melanocytes as compared to normally pigmented glabrous skin which is used for skin grafting procedures. It is proposed that the stem cells and perifollicular melanocytes migrate onto the perifollicular skin and produce melanin, giving pigment to the vitiliginous patches.[21]

FUE and implantation was first introduced to repigment vitiligo patches in 1998 by Na G *et al*.[22]

According to a study conducted on 63 vitiligo patients by Sacchidanand *et al.*, excellent color match in vitiligo patches was reported in 72.1% of patients while good color match was reported in 26.2% patients.[21] Ample literature is available demonstrating the effectiveness of FUE as a dermatosurgical procedure for treating stable focal vitiligo.[20-23] FUE is particularly useful on hairy areas of body affected by vitiligo associated with leucotrichia.

Figure 8a and b demonstrates successful outcome in a few of our cases of localized vitiligo with coexisting leucotrichia in whom we used FUE as a surgical treatment modality. As these patches were located on hairy areas, FUE managed to recolor and avoid procedure-related scarring, hypo/hyper-pigmentation, and cobble-stonning in these patches and helped good matching with the surrounding skin. Dermoscopy of patch and surrounding area helped us calculate the approximate number of grafts required in these patients.

Follicle Cell Suspension for Vitiligo

Using follicular unit grafts instead of skin grafts while doing melanocyte cell suspension is another modification of the technique which has proven to be successful in stable vitiligo patches. Hair follicle outer root sheath is a rich source of DOPA negative inactive melanocytes (stem cells). These melanocyte stem cells have the capacity to migrate and enter vacant niches in the epidermis to cause perifollicular re-pigmentation which later spread in a concentric pattern causing diffuse re-pigmentation. This principle was used by Sawatkar G U *et al.* in melanocyte cell suspension method in a localized case of vitiligo where follicular units were used instead of epidermal grafts as a source of melanin.[24]

Hair-follicle melanocytes have some unique properties. A follicular melanin unit is constituted by one melanocyte

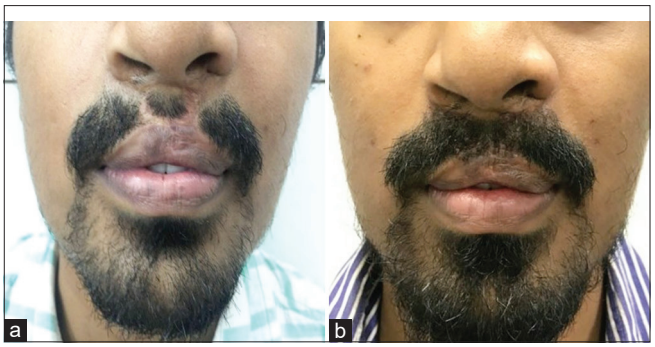

Figure 6: (a) FUE in a case of scar due to Cleft lip/cleft palate surgery (Before FUE). (b) FUE in a case of scar due to Cleft lip/cleft palate surgery (after FUE)

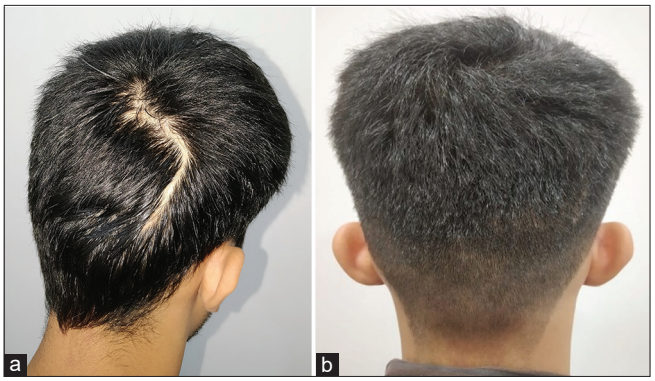

Figure 7: (a) FUE in a craniotomy scar over scalp (before FUE). (b) FUE in a craniotomy scar over scalp (after FUE)

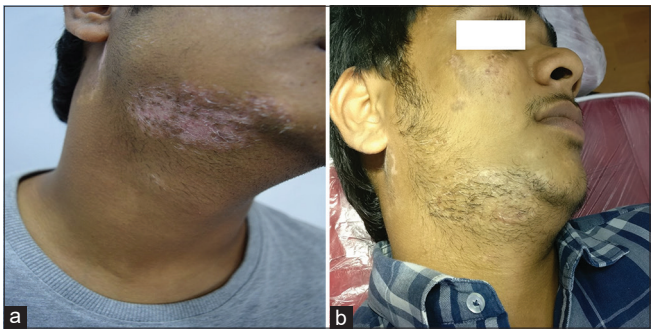

Figure 8: (a) Role of FUE in stable vitiligo associated with leucotrichia (before FUE). (b) Role of FUE in stable vitiligo associated with leucotrichia (after FUE)

for every five keratinocytes in the hair bulb, which is much higher than epidermal melanin unit, which has one melanocyte for every 36 keratinocytes. Furthermore, hair melanocytes have remarkable synthetic capacity, and a relatively small number of melanocytes can potentially produce sufficient melanin to pigment up to 1.5 m of the hair shaft. Hair-follicle is a rich source of three different types of stem cells, and it appears that all of them are important in hair growth. These stem cells include Melanocyte stem cells, keratinocyte stem cells, and mesenchymal stem cells. With all these properties, the hair appears to be a more attractive source of melanocytes than epidermis for cell-based therapies in vitiligo.

Also, with follicular unit cell suspension, wound creation is smaller as compared to epidermal shave grafts. Hence, the healing period is faster with a smaller wound size. In comparison with the conventional NCECS, the technique of preparation of FCS is simpler, as it does not require separation of the epidermis from dermis and manual breaking of epidermal samples into small pieces. Figure 9a and b elicits a repigmentation in stable vitiligo patches achieved by follicle cell suspension technique

FUE in Hirsutism Associated with White Hair

Hirsutism associated with white or gray hair may not respond to laser hair reduction as the chromophore "melanin" is missing. Because of the absence of any chromophore, photoepilation is not effective in this kind of hair. Many light- and heat-based therapies have been tried for white hair removal such as the use of radiofrequency, laser after coloring, or use of melanin-encapsulated liposomes before laser therapy.[25-27]However, none of them have proven to be an effective therapy with results varying between 17–54%. According to literature, electropilation or electrolysis is a suitable option to get rid of white hair along with the treatment of underlying hormonal disturbance if any.[28]Electrolysis can sometimes take multiple sessions to get rid of white hair completely as there are chances of regrowth from the hair bulge. Also, there are chances of folliculitis, recurrence and hyperpigmentation. FUE serves as a unique substitute for such a tedious process like electrolysis and can prove beneficial by removing the hair bulb as a whole including its bulge region thus minimizing the chances of recurrence and repeat sessions.

A 0.7mm serrated punch is used to minimize post-procedure scarring for the removal of white facial hair in hirsutism. After completion of a healing period of 3–4 weeks, there may be fine invisible scars. Transection rate should be less than 5% while using FUE as a method for removing white hair.[29]

Figure 10 a and b shows the removal of all hirsute hair over the chin by the FUE method.

Body Hair Transplant

In advanced grades of AGA, when limited grafts are available from the safe zone of the scalp; body hair can be used for hair restoration. Areas of body like beard (submental region), chest, axillae, pubis, arms, legs serve as judicious donor sites for FUE in such advanced cases. FUE is the only option to extract hair from these cosmetically important sites as FUT can lead to unsightly scars. Body hair transplantation can be successfully used either alone or in combination with scalp hair in advanced grades of baldness, for improving the cosmetic appearance of hairlines, and in scarring alopecia when there is paucity of donor scalp hair. Harvesting of body hairs opens up a new viable donor source, especially in cases of advanced Norwood grades five and above in androgenetic alopecia.[30][Figure 11]

Conclusion

FUE is a versatile technique and its effective utility in various indications is proven. A good clinical knowledge helps the appropriate selection of patients and a good surgical skill helps achieve optimum results.

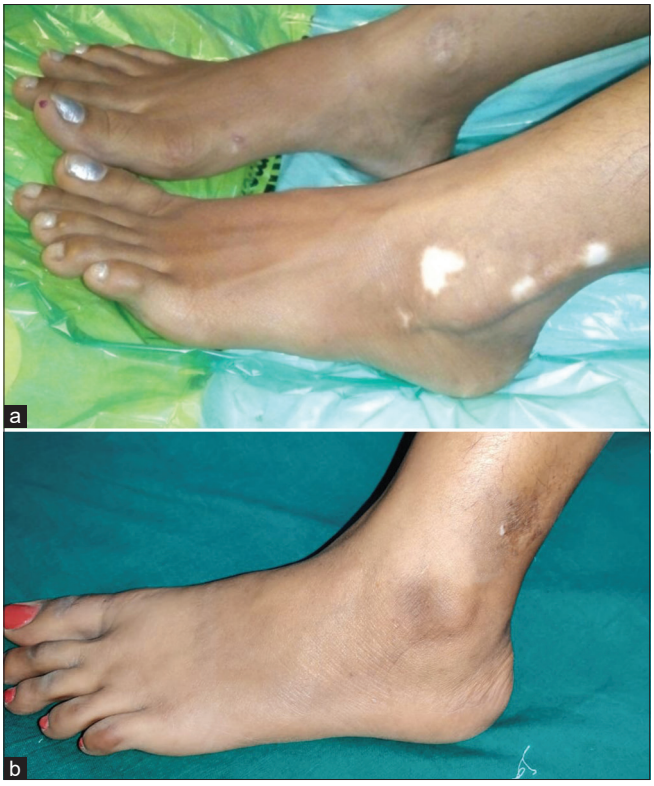

Figure 9: (a) Follicle cell suspension in a case of stable vitiligo (before FUE). (b) Follicle cell suspension in a case of stable vitiligo (after FUE)

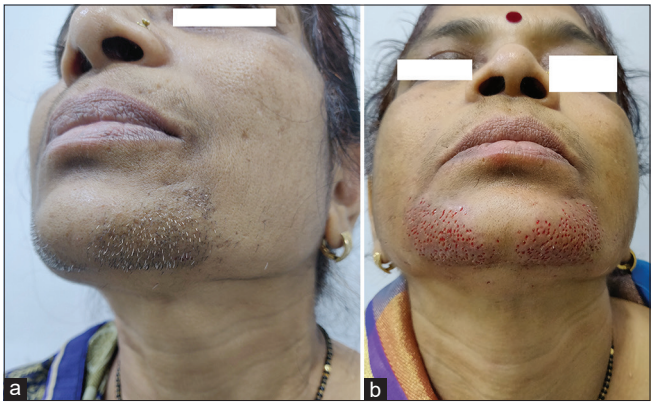

Figure 10: (a) FUE in a case of hirsutism (before FUE). (b) FUE in a case of hirsutism (after FUE)

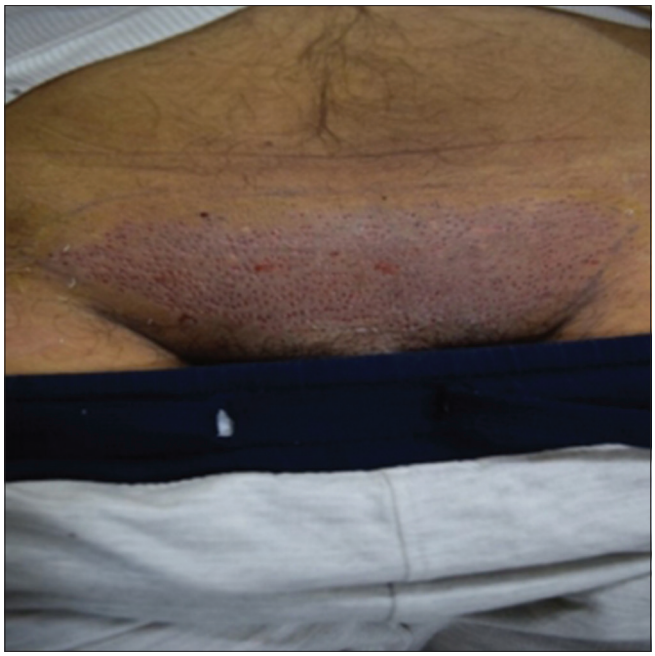

Figure 11: Body hair transplant (FUE from pubic area)

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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