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**Paper Accepted\***

**ISSN Online 2406-0895**

**Original Article / Оригинални рад**

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**Hair transplant – initial experience with semiautomated extraction and  
preservation in follicular unit extraction**

Трансплантација косе – почетно искуство са полиаутоматизованом екстракцијом  
и очувањем у фоликуларној јединици екстракције

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**Received: October 29, 2024**

**Revised: December 5, 2024**

**Accepted: December 12, 2024**

**Online First: December 16, 2024**

**DOI: <https://doi.org/10.2298/SARH241029094Y>**

\***Accepted papers** are articles in press that have gone through due peer review process and have been accepted for publication by the Editorial Board of the *Serbian Archives of Medicine*. They have not yet been copy-edited and/or formatted in the publication house style, and the text may be changed before the final publication.

Although accepted papers do not yet have all the accompanying bibliographic details available, they can already be cited using the year of online publication and the DOI, as follows: the author's last name and initial of the first name, article title, journal title, online first publication month and year, and the DOI; e.g.: Petrović P, Jovanović J. The title of the article. *Srp Arh Celok Lek*. Online First, February 2017.

When the final article is assigned to volumes/issues of the journal, the Article in Press version will be removed and the final version will appear in the associated published volumes/issues of the journal. The date the article was made available online first will be carried over.

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## Hair transplant – initial experience with semiautomated extraction and preservation in follicular unit extraction

Трансплантација косе – почетно искуство са полиаутоматизованом екстракцијом и очувањем у фоликуларној јединици екстракције

### SUMMARY

**Introduction /Objective** The most modern technique for follicular extraction in hair transplantation is the Follicular Unit Extraction (FUE) method, first described by Rassman et al. in 2002. With this method, individual intact follicular units are extracted "without visible scarring" and then implanted into the balding areas. A challenge with FUE is the lack of a single device that can adequately meet the requirements of different donor areas. The purpose of the present study is to share our initial experience with a new vacuum-automated FUE device with the ability to sterilely store follicles in an optimal environment in terms of temperature and humidity and to evaluate its capabilities to serve as a universal follicular unit extractor.

**Methods** Over a period of two years (2018–2020), 60 transplants were performed, of which 57 patients were male and three females, using this device for follicle extraction. Patients were divided into two groups: the first group with FUE vacuum-assisted extraction at 26.7% (n = 16), and the second group with forceps extraction at 73.3% (n = 44).

**Results** The mean graft numbers transplanted at the point of study were  $2015.0 \pm 507.2$ , and the mean graft numbers after 12 months were  $1915.6 \pm 480.6$  ( $t = 10.33$ ;  $p = 0.000$ ). In both groups (at the point of the study and after 12 months), there was a statistically significant difference between the graft numbers transplanted and the age distribution, surgical technique, and donor area ( $p < 0.05$ ). The younger group generally requires fewer grafts to be transplanted and has better skin quality, leading to a greater success rate.

**Conclusion** Our initial experience shows that with such a device, it becomes possible to achieve more than a thousand grafts in one day when working in different donor areas, which is minimally invasive for the patient and maximally ergonomic for the surgeon. Sterile storage of the follicles in an optimal environment is a prerequisite for increasing the viability of the transplanted follicles and achieving much better cosmetic results.

**Keywords:** FUE; automated extraction; hair transplantation

### САЖЕТАК

**Увод /Циљ** Најсавременија техника за екстракцију фоликула у трансплантацији косе је *FUE* (*Follicular Unit Extraction*), метода коју су први описали Расман и сарадници. Овом методом појединачне, нетакнуте фоликуларне јединице се екстрахују „без видљивих ожиљака“, а затим се имплантирају у жељена подручја. Изазов са *FUE* техником је недостатак једног уређаја који може адекватно да испуни захтеве различитих донаторских зона. Сврха ове студије је да поделимо наше почетно искуство са новим вакум-аутоматизованим *FUE* уређајем који омогућава стерилно складиштење фоликула у оптималном окружењу у смислу температуре и влажности, и да процени његов потенцијал за употребу као универзални уређај за екстракцију фоликула.

**Метод** Током двогодишњег периода (2018–2020) урађено је 60 трансплантација, од чега 57 мушких и три женске, овим апаратом за екстракцију фоликула. Пацијенти су подељени у две групе: прва са екстракцијом помоћу вакуума ФУЕ са 26,7% (n = 16), и друга са екстракцијом форцепсом са 73,3% (n = 44).

**Резултати** Средњи број графтова трансплантираних у тачки студије био је  $2015,0 \pm 507,2$ , а средњи број графтова након 12 месеци био је  $1915,6 \pm 480,6$  ( $t = 10,33$ ;  $p = 0,000$ ). У обе групе (након 12 месеци) постојала је статистички значајна разлика између броја трансплантираних графтова и старосне дистрибуције, хируршке технике и површине донора ( $p < 0,05$ ). Млађа група генерално захтева мање трансплантата за трансплантацију и има бољи квалитет коже, што доводи до веће стопе успеха.

**Закључак** Наше почетно искуство показује да је са овим апаратом могуће урадити више од хиљаду графтова у једном дану у раду са различитим донорским зонама, што је минимално инвазивно за пацијента и максимално ергономско за хирурга. Стерилно складиштење фоликула у оптималним условима је предуслов за повећање виталности трансплантираних фоликула и постизање много бољих естетских резултата.

**Кључне речи:** *FUE*; аутоматизована екстракција; трансплантација косе

## INTRODUCTION

Hair in every individual is associated with youth and vitality, and different hair styles shape our faces and unique personalities. Hair loss affects both men and women and it may impact psychosocial health and lead to emotional distress [1]. Androgenic alopecia (AA) is characterized by progressive androgen-related hair thinning and is the most common reason for seeking treatment. Nowadays, medical and surgical treatment options are available for stopping initial hair loss, and in advanced cases, new hair transplantation techniques are being developed [2]. In the early 1930s, the first autologous hair transplantation was performed in Japan by Okuda using punch grafts to harvest donor follicles and place them in the recipient area in openings made with smaller punches, but this technique received little attention worldwide. The hair transplantation technique became popular and received scientific success in the 1950s when Dr. Orentreich introduced large punch grafts 2-4 mm in size with 15 to 30 follicular units in each graft. He obtained the grafts from the posterior and lateral scalp in patients with androgenic alopecia and introduced the term "donor dominance," which refers to the fact that grafts maintain their original characteristics after they are placed in the recipient area [3]. Hair transplantation took an impressive leap in the early 1990s with the development of the Follicular Unit Transplantation (FUT) technique, which involves excising a linear strip of skin from the mid-occipital scalp. After that, each follicular unit is excised. This procedure leaves a long, thin scar, which is not appropriate for patients who like to have short hair [4]. Nowadays, the most commonly used technique is the Follicular unit extraction method (FUE), which was developed in the early 2000s. The technique is based on micropunches 0.8–1.0 mm in size to directly dissect individual follicular units from the donor site, leaving a particularly small scar defect [5]. FUE provides incredible versatility in terms of graft placement and design, as well as consistent and natural cosmetic results [6].

## METHODS

We performed a cross-sectional study in an independent clinic in Sofia, Bulgaria, between 2018 and 2021. It included sixty patients, of whom eight did not complete the final visit 12 months after surgery. All patients who were eligible for a hair transplant were included.

Before the procedure, patients undergo a primary evaluation for compatibility with the FUE method, including Norwood grade (refer to Figure 1), autoimmune diseases (Hashimoto's disease, anemia, syphilis, HIV, Hepatitis a/b/c), and testosterone levels.

Preoperative conservative treatment using platelet-rich plasma (PRP) every month for 3 months and a combination of topical and oral vitamin supplements was applied to almost all patients.

The procedure was performed under local anesthesia using Ropivacaine and 2% lidocaine diluted with 0.9 saline. Trichoscopy with photo documentation is performed preoperatively in every patient. We start excising grafts from single or multiple donor areas (occipital scalp, beard, and body hair) with micropunches. In the case of thicker skin on the scalp or if the follicles are longer or the hair is curly, the vacuum may not be sufficient to extract the grafts without additional force, and we move to manual extraction using ophthalmic forceps. The hair follicles are stored in the device and kept moist and chilled to 4 °C. Once all the necessary grafts are taken, we move to the implantation phase. After repositioning the patient, the openings for the excised grafts are created using a 19- or 20-gauge needle. Follicles with one hair are divided from multiple ones when a hair line is needed. The PRP procedure is then performed, and the graft placement begins by using ophthalmic forceps. Once all the grafts are in place, the surface is cleaned with iodinated povidone 7.5/100 ml, and both the donor and recipient areas are sprayed with neomycin cutaneous spray. The donor area is then covered

with a sterile bandage. The procedure time varies from 3 to 12 hours, depending on the number of harvested grafts. (refer to Figure 2 A,B,C)

After the surgery, the patient is told not to touch the implanted hair by no means. Every day for the next 10 days, the patient is asked to wash his hair by only placing foam from a bactericidal shampoo on it, leaving it for about 2 minutes, and washing it with a light force shower. After the initial 10 days, the post-op medication is stated as follows: 6 months of Finasteride 1mg, topical Minoxidil 5%, oral vitamin supplements, hair regrowth shampoos depending on the patient's tolerance, and a PRP procedure once a month from the second to 6th month after surgery, followed by twice a year after that.

Patient follow-up is performed between 8 and 12 months after surgery for review by trichoscopy, and the hair count is compared to the pre-op photo documentation.

Our device is one of the most efficient harvesting systems available today, utilizing a light-weight handpiece with a cold illumination design, a bio-dome collection and storage system with a chiller, and a touch-screen computer to control its functions. This FUE Technology minimizes procedure time, minimizes trauma to the grafts, and minimizes the amount of support staff needed. We believe that this device causes less trauma to the grafts from overhandling, It has a two-piece platform for easy transportation to be used in multiple locations, and has a greater viability of the grafts with its biodome technology that keeps the grafts cool and moist during the entire procedure until they are ready to be implanted. Keeping the grafts in these optimal conditions leads to a better overall survival rate and better results. With this semiautomated device we can control every aspect of the procedure, from temperature to graft count, illumination for better visibility, real-time graft extraction, and increased speed. Another advantage are the proprietary punches. The difference is that the punches we are using are 50% shorter and have a 26% smaller outside diameter, leaving a

smaller footprint. They are available in both inner and outer bevels. It allows us to pull out grafts directly, which saves time and is less traumatic for the patient. The device allows for a reduction of 33% in procedure time over manual technique, which equates to less fatigue for the operator and less fatigue for the patient.

All statistical results were processed using SPSS (Statistical Package for the Social Sciences) Statistics v26 (IBM, Armonk, NY, USA) and their graphic presentation using Microsoft 365 (Microsoft, Redmond, Washington, USA). All numeric variables were tested for normal distribution using the Kolmogorov-Smirnov test. Descriptive statistics, nonparametric tests, the t-test, the correlation test, the one-way analysis of variance (ANOVA), and the Bonferroni post-hoc test were used during statistical analyses. A p-value 0.05 was adopted for all tests to determine statistical significance.

**Ethics:** All procedures strictly adhered to the ethical standards set forth by the institutional and national research committee, in line with the 1964 Helsinki Declaration and its subsequent revisions or equivalent ethical standards.

## RESULTS

A total of 60 patients took part in the study. They were separated into two groups: the first group was performed with FUE vacuum-assisted extraction at 26.7% (n = 16), and the second group was performed using forceps for extraction at 73.3% (n = 44). Patients' median age was  $42.3 \pm 9.9$ . They were separated into two age groups (under 40 and between 41 and 80 years). 35% of patients had preoperative treatment with PRP and Minoxidil, but there was no significant statistical difference in their final results ( $P > 0.05$ ). Only 1.7% of patients did not receive postoperative conservative treatment due to a lack of compliance. 13.3% did not

complete the final visit 12 months after surgery. The only postoperative complication was folliculitis in 4 patients (6.7%). Patient demographic characteristics are presented in Table 1.

The average intraoperative time was  $413.6 \pm 127.2$ . There was a strong positive correlation ( $r = 0.95$ ;  $p = 0.000$ ) between the number of grafts transplanted and intraoperative time. Due to a more advanced stage of AA in the elder group, larger graft numbers were needed, leading to increased intraoperative time. There was a bigger time investment when harvesting follicles from different body areas, as it required further sedation and positioning of the patient. Using vacuum-assisted harvesting shortens the extraction time compared to the manual method. (refer to Table 2)

The mean graft numbers transplanted at the point of study were  $2015.0 \pm 507.2$ , and the mean graft numbers after 12 months were  $1915.6 \pm 480.6$  ( $t = 10.33$ ;  $p = 0.000$ ). In both groups (at the point of the study and after 12 months), there was a statistically significant difference between the graft numbers transplanted and the age distribution, surgical technique, and donor area ( $p < 0.05$ ). The younger group generally requires fewer grafts to be transplanted and has better skin quality, leading to a greater success rate. (refer to Figure 3 A,B,C) Hair follicles from the body and beard have a higher difficulty of extraction, leading to a greater transection rate. The vacuum-assisted technique, although being the faster method, is less precise, leads to a greater transection rate, and is preferable for younger patients with a rich and healthy occipital donor area. 86.7% of patients were followed up for a period of 8–12 months after surgery. Most of the time, grafts enter the telogen phase for the first 3 months following transplantation before entering the anagen phase; this is why we cannot evaluate the results prior to at least the 6th and preferably after the 12th (refer to Table 3).

## DISCUSSION

Androgenic alopecia is a progressive condition and the most common cause of hair transplantation. The severity of AA can be graded with the Hamilton-Norwood classification [7]. Nearly all of the patients benefit both from pharmacologic treatment and hair transplantation procedures, which ensure the best long-term results. The transplantation does not involve a net increase in new hair but rather the relocation of existing hair from the donor areas. Screening the patients is crucial in hair restoration surgeries, as the procedure is a long and taxing one with the need of a good post-surgery care from the patient, this is why a detailed pre-surgery interview is performed [8]. Some of the best conservative treatment options are: Oral finasteride and topical minoxidil are the first-line treatment options for AA that have been approved by the United States Food and Drug Administration (FDA) [9]. Finasteride can decrease the hair loss process in most men and can lead to partial regrowth in 66% of patients. For best results, finasteride needs to be used for at least six months. Topical minoxidil is used in both male and female patients; its direct mechanism of action is not yet understood, but its angiogenic and vasodilatory properties are suspected to have a positive influence. Its biggest side effect is unwanted hair growth on other hair bearing areas (face, hands, etc.). Dutasteride can be used off-label for patients who do not respond to finasteride. There are potential side effects that the patients should be notified about, including decreased libido, alterations to sperm, and erectile dysfunction. Topical finasteride is an option for patients who experience side effects from the oral drug or are reluctant to take it. The combination of oral finasteride and 5% topical minoxidil seems to achieve better results than monotherapy [10]. Other therapeutic options are platelet-rich plasma (PRP) injections and low-level laser therapy (LLLT). There are clinical trials with PRP showing positive results; procedures are most commonly performed every 3–4 weeks, but more research is needed to determine the optimal regimen. In our study, we performed PRP preoperatively in 35% of our patients and



postoperatively in 68.3%, with satisfying results and without any reported side effects. Other studies show that LLLT, based on the use of red light (wavelengths from 635 to 678 nm), can improve hair density with little to no side effects. LLLT can be delivered with different devices like a helmet, cap, band, or comb. The protocols range from 10–30 minutes per session and 2–7 sessions per week. Combining different medical therapies from the ones listed above can have a synergistic effect, but more studies are needed to confirm the efficacy of the different treatment combinations. The use of at least two of the conservative treatment modalities before and after the hair transplantation is recommended. In our study, we considered the combination of PRP, minoxidil, and Finasteride to be the best option for our patients because of its minimal side effects and excellent long-term results.

Nowadays, two types of hair transplantation techniques are used worldwide: harvesting donor grafts by elliptical excision of a horizontal strip (FUT) and removal of individual follicular groupings from the posterior scalp with a 0.75- to 1.2-mm punch device (FUE). Both techniques are associated with similar long-term results but with different intra- and post-operative complications. With FUT, there is a smaller risk of follicular transection, a shorter harvest time, the hair doesn't have to be trimmed, and the scar can be well hidden if the occipital hair is longer. The disadvantages of this method are a large visible scar when the hair is trimmed short, more work to prepare the grafts, the fact that body hair cannot be used, and a higher chance of nerve damage and bleeding. With the FUE technique, there is minimal graft preparation, body hair can be used, automated devices can be used to shorten the process, it is minimally invasive, and it is suitable for patients with thick scalps. On the other side, this technique is associated with a greater risk of transection of the follicle, a longer harvest time and learning curve, a wider donor area, and the hair being preferably trimmed short [11].

FUE can be used for a variety of different indications, like body hair transplantation, camouflage of scars, and the treatment of secondary scarring alopecia caused by burns, skin tumors or other type of trauma. FUE is the most versatile procedure in regards to cicatricial alopecia, as it can restore the natural anatomic structure [12]. By excising individual follicular units, surgeons have the option to repair hair defects on eyebrows and beards. The follicular survival rate is considerably high (above 75%), but the survival rates tend to vary in areas with significant scarring. The FUE procedure usually takes the surgical team between 3 and 10 hours, depending on the number of harvested grafts, ranging from 800 to 3600. In preparing for the procedure, standardization of photography of the hair and hairline is strongly recommended, with consistent lighting, patient positioning, and background. FUE allows the surgeon to obtain a large number of grafts with little to no visible scarring using a 0.75- to 1.2-mm punch device. FUE can be performed manually, with device assistance, or with a fully automated robotic device. FUE involves a longer learning curve compared to FUT because of the higher risk of transection of follicles and longer procedure times. Importantly, FUE also set the foundation for the incorporation of minimally invasive and automated technologies that lead to innovations on a regular basis [13].

Surgical complications from hair transplantation occur rarely, developing in approximately 2% to 3% of patients and often much less with experienced teams. Folliculitis and pustules occasionally develop and require treatment with topical or oral antibiotics. Neurosensory complications, including neuralgias, prolonged pain sensations, pruritus, or numbness, occur very rarely and generally resolve on their own in only a few days, almost always before the postoperative follow-up at 8 to 12 months. Very rarely, patients experience abnormal scarring or keloid formation in the donor or recipient sites, which is why a good history prior to the surgery is necessary. Some patients may experience a temporary effluvium throughout their scalp, including the donor area. Patient factors like adherence to postoperative

instructions, preoperative and postoperative medical management of hair loss, smoking history, presence of actinic damage, and vascularity play a crucial role in treatment success. The results of our study show that 6.7% develop folliculitis, mostly due to a lack of proper aftercare, but no other complications were observed. According to most studies, patient follow-up should be performed at least after the 6th month or preferably between the eighth and 12th month. This is because grafts enter the telogen phase for the first three months following transplantation before entering the anagen phase [14].

## CONCLUSION

AA is a progressive condition in both men and women and can seriously affect quality of life. Different conservative treatment options are available but none of them can achieve satisfactory long-term results. The hair transplantation techniques, including FUT and FUE, are the only chance for definitive treatment with long-lasting results. According to our study, semiautomated FUE using this system is the best hair transplant technique, which is associated with minimal invasiveness, shorter procedure times, greater comfort for the surgeon, and excellent cosmetic results.

Improving graft survivability before implantation is a major goal, and a variety of solutions have been proposed with almost no clinical results. The main limitation in meeting the patient's expectations is the amount of donor hair available, and thus, cloning of hair follicles will likely be the next leap in hair transplantation surgery over the next few decades. Many *in vitro* and animal model studies show the potential efficacy of the replication of hair follicles, but the challenges of translation into a useable *in vivo* model are vast, and the application of this technology is still a long way from its application in humans.

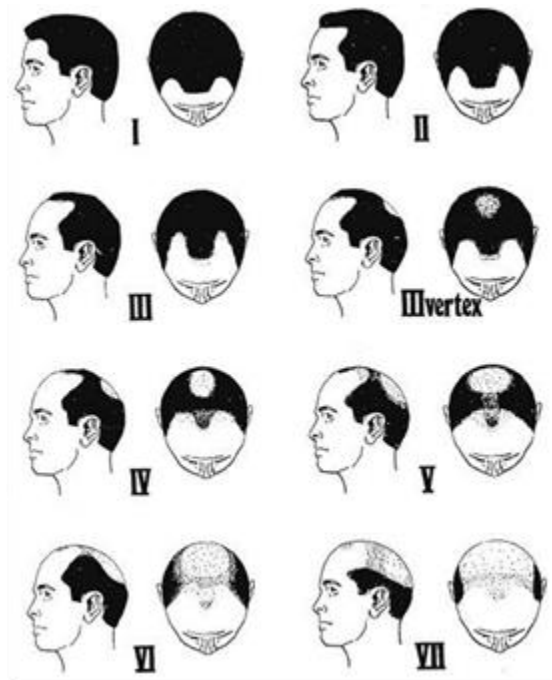
Despite this variety of conservative treatment options, an individual approach for every patient before and after transplantation is indicated for achieving the best long-term results.

**Conflict of interest:** None declared.

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**Figure 1.** Hamilton–Norwood scale for male pattern balding

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**Figure 2.** A – Follicle implantation; B – follicle extraction (occipital donor area); C – chest and abdomen after follicle extraction



**Figure 3.** A – transplantation of 2400 follicle units; B – transplantation of 2000 follicle units;  
C – transplantation of 1000 follicle units



**Table 1.** Patient demographic characteristics

Profile characteristics	Overall, % (n)
<b>Gender</b>	
Male, % (n)	95% (57)
Female, % (n)	5% (3)
Age, years $\pm$ SD	42.3 $\pm$ 9.9
<b>Age groups</b>	
$\leq$ 40 years, % (n)	45% (27)
$\geq$ 41 years, % (n)	55% (33)
<b>Comorbidity</b>	
without Hashimoto's disease, % (n)	83.3% (50)
with Hashimoto's disease, % (n)	16.7% (10)
<b>Previous procedures</b>	
with, % (n) without, % (n)	93.3% (56)
with, % (n)	6.7% (4)
<b>Donor Area</b>	
Occipital scalp, % (n)	86.7% (52)
Occipital scalp + beard, % (n)	8.3% (5)
Occipital scalp + beard + body hair, % (n)	5% (3)

**Table 2.** The mean intraoperative time compared to study variables

Variables		n	mean	SD	F	p
Age groups	under 40	27	368.1	83.5	6.91	0.011
	between 41 and 80	33	450.9	144.9		
Surgical technique	FUE: vacuum	16	332.3	113.7	10.32	0.002
	FUE: forceps	44	443.2	119.8		
Donor area	Occipital scalp	52	374.6	79.4	54.82	0.000
	Occipital scalp and beard	5	618.4	5.9		
	Occipital scalp, beard, and body hair	3	750.0	50.0		

SD – standard deviation; F – analysis of variance; FUE – follicular unit extraction

**Table 3.** Mean graft numbers transplanted after 12 months compared to study variables

Variables		n	mean	SD	F	p
Age groups	under 40	24	1774.6	382.2	4.07	0.049
	between 41 and 80	28	2036.4	528.3		
Surgical technique	FUE: vacuum	16	1511.3	545.9	15.83	0.000
	FUE: forceps	44	2050.4	376.0		
Donor area	Occipital scalp	52	1825.7	424.0	9.91	0.000
	Occipital scalp and beard	5	2485.3	114.7		
	Occipital scalp, beard, and body hair	3	2844.0	509.1		

SD – standard deviation; F – analysis of variance; FUE – follicular unit extraction