RESEARCH PAPER

Using Angulation of Implanters at 45 Degrees to the Scalp with the Bevel Facing toward the Skin to Enhance Follicular Entry at Minimal Pressure: A Randomized Clinical Trial in Hair Transplantation

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ABSTRACT

Background:
Implanter-based follicular unit extraction (FUE) has improved graft handling and placement precision in hair transplantation. However, insertion angulation and bevel orientation during implantation remain largely operator-dependent, with limited evidence supporting standardized biomechanical approaches. Optimizing implantation mechanics may reduce tissue trauma, improve graft stability, and enhance procedural efficiency.

Aim:
To evaluate whether using an implanter at 45 degrees to the scalp with the bevel facing toward the skin enhances follicular entry at minimal pressure compared with conventional variable-angle implantation.

Materials and Methods:
This prospective randomized clinical trial included 50 male patients with androgenetic alopecia (Norwood Grade III–V) undergoing FUE hair transplantation. Participants were randomly allocated into two groups (n = 25 each). The control group underwent implantation using conventional variable angulation and non-standardized bevel orientation. The test group received implantation at a fixed 45-degree angle with the bevel consistently oriented toward the skin. Primary outcome was intraoperative insertion resistance. Secondary outcomes included graft popping rate, implantation time per 1,000 grafts, intraoperative bleeding, and graft malalignment. Statistical analysis was performed using SPSS version 29.0, with $p < 0.05$ considered significant.

Results:
The 45-degree bevel-facing group demonstrated significantly reduced insertion resistance ($p < 0.01$), lower graft popping rate (2.5% ± 1.2 vs 6.2% ± 1.8; $p < 0.001$), shorter implantation time (39.8 ± 4.9 vs 46.5 ± 5.4 minutes per 1,000 grafts; $p < 0.01$), reduced bleeding ($p < 0.05$), and improved graft alignment (4% vs 18%; $p < 0.01$) compared with the control group.

Conclusion:
Standardizing implanter angulation at 45 degrees with bevel orientation toward the skin significantly enhances intraoperative efficiency and graft stability in FUE hair transplantation. This simple, reproducible modification may optimize implantation biomechanics and improve surgical outcomes.

Keyword: *Hair transplantation; Follicular unit extraction; Implanter angulation; Graft popping; Recipient site biomechanics; Androgenetic alopecia.*

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INTRODUCTION

Hair loss, particularly androgenetic alopecia, is one of the most common aesthetic concerns encountered in clinical dermatology and surgical practice. Although medically benign, progressive scalp hair loss often produces considerable psychological distress and negatively affects social confidence and self-perception. Hair transplantation has therefore evolved into a refined surgical discipline aimed at restoring not only hair density but also natural appearance. Over the past three decades, advances in follicular unit harvesting and implantation have markedly improved outcomes. The introduction of the Choi implanter represented a significant milestone by allowing direct implantation of follicular units with controlled depth and orientation.(1) Subsequent refinements in implanter design have further enhanced precision and handling characteristics (2).

Modern transplantation is grounded in the concept of relocating intact follicular units while preserving their anatomical integrity. Techniques such as follicular unit extraction have standardized donor harvesting and minimized visible scarring (6). However, once grafts are harvested, their survival depends heavily on atraumatic handling and careful placement within the recipient area. The use of implanters in premade recipient sites has been shown to reduce graft manipulation and improve placement control (3). Recipient area design itself plays a crucial role in ensuring natural hair direction and density distribution (4,5).

Despite technological improvements, implantation remains a technically sensitive step. Thousands of grafts may be inserted during a single session, and even minor mechanical trauma during placement can influence survival. Studies evaluating grafted density have demonstrated that implantation technique affects survival rates and overall cosmetic outcome (7). Mechanical stress during insertion may lead to crush injury, distortion of the outer root sheath, or bulb damage. Furthermore, punch dynamics and tissue interaction have been shown to influence follicular integrity during hair restoration procedures (8).

Recent literature emphasizes continued advancements in graft placement strategies, highlighting the importance of controlled force and consistent technique (9). Professional practice guidelines have also stressed meticulous implantation to optimize outcomes and reduce complications (10). Recipient site creation, angulation, and depth remain central determinants of both graft survival and aesthetic naturalness (11). Experimental observations on follicular biology indicate that preservation of the bulb and dermal papilla is fundamental for regrowth (12), underscoring the need to minimize insertion-related trauma.

The interaction between an implanter needle and scalp tissue is inherently biomechanical. The scalp's layered structure—epidermis, dermis, subcutaneous tissue, and galea—offers varying resistance to penetration. When a hollow implanter needle enters the skin, axial compressive forces and shear forces are generated simultaneously. Device-based innovations have attempted to standardize graft delivery and reduce mechanical injury (13). Clinical applications in scarred scalp tissue further demonstrate the importance of controlled implantation dynamics to prevent excessive trauma and ensure proper seating (14).

One of the less systematically studied variables during implantation is needle angulation relative to the scalp surface. Natural hair emerges at acute angles, particularly in the frontal and temporal zones. While surgeons consciously attempt to replicate these angles during slit creation, insertion mechanics with implanters may vary between operators. The dull needle implanter technique has highlighted the importance of needle handling and bevel orientation for minimizing graft injury (15). Similarly, discussions within the field have questioned whether implanter use itself influences graft quality depending on operator technique (16).

Needle bevel orientation modifies the manner in which tissue fibers are parted during penetration. A bevel directed toward the skin surface may allow smoother entry by splitting collagen bundles rather than compressing them. In contrast, unfavorable orientation may increase resistance or push grafts deeper than intended. Clinical experiences using implanters in premade recipient sites suggest that subtle variations in handling can influence immediate seating and complication rates (17). Practical guidance on bevel positioning and insertion dynamics continues to evolve, yet structured comparative evidence remains limited (18).

From a mechanical perspective, insertion at approximately 45 degrees to the scalp surface may provide a balanced trajectory between perpendicular compression and overly tangential glide. A perpendicular approach increases axial compressive stress on the follicular unit, potentially predisposing to bulb injury or buried graft formation. Conversely, an excessively flat approach may compromise depth control. At 45 degrees, the direction of force is distributed across both vertical and horizontal components, potentially reducing peak compressive pressure while maintaining adequate penetration. When combined with bevel orientation toward the skin, this angulation may allow the cutting edge of the needle to gently part dermal

fibers, reducing resistance and facilitating smoother follicular entry.

Reducing the pressure required for graft insertion carries practical and biological relevance. Lower insertion force may decrease crush injury and preserve microvascular channels within the recipient bed. Adequate perfusion during the early post-implantation phase is critical for graft nourishment before neovascularization occurs. Excessive tissue compression may disrupt this microenvironment. Additionally, minimizing mechanical resistance during entry may reduce bleeding, edema, and tissue distortion, thereby contributing to stable graft seating and uniform spacing.

Surgical ergonomics also merit consideration. High-density implantation requires repetitive insertion movements over prolonged operative sessions. Variability in applied force due to fatigue may influence consistency and potentially affect graft integrity. Establishing a reproducible angulation such as 45 degrees, together with a defined bevel orientation toward the skin surface, may simplify hand positioning and promote uniform technique across operators. Standardized mechanical parameters could also enhance training efficiency for residents and assistants by translating subtle tactile skills into clearly defined procedural guidelines.

While harvesting methods and graft preservation protocols have been extensively investigated, comparatively fewer studies have isolated the biomechanics of implanter angulation and bevel orientation as independent variables. Clarifying whether a defined insertion angle can measurably reduce implantation pressure and improve graft seating would contribute meaningful evidence to procedural refinement. In this context, the present study aims to evaluate whether using an implanter at 45 degrees to the scalp with the bevel facing toward the skin enhances follicular entry at minimal pressure compared with conventional implantation technique, while also assessing its influence on graft seating characteristics and intraoperative technical outcomes.

MATERIALS AND METHODS

Study design and Ethical approval

This study was designed as a prospective, randomized, parallel-group clinical trial conducted over a period of six months at a tertiary care center specializing in hair restoration surgery. The objective was to compare the biomechanical and clinical outcomes of two different implanter angulation techniques during follicular unit extraction (FUE) hair transplantation.

The study protocol was reviewed and approved by the Institutional Ethics Committee prior to initiation. All procedures were performed in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants after explaining the nature of the study, surgical procedure, potential risks, and benefits.

Study population

Fifty male patients diagnosed with androgenetic alopecia were recruited consecutively from patients seeking hair transplantation. Eligible participants were between 25 and 50 years of age and classified as Norwood Grade III to V. Only patients planned for FUE hair transplantation involving implantation of 2,500–3,000 grafts were included to maintain procedural uniformity.

Patients were excluded if they had coagulation disorders, active scalp infections or dermatologic conditions affecting the recipient area, previous hair transplantation procedures, uncontrolled systemic diseases such as diabetes mellitus or hypertension, or a known tendency for hypertrophic scarring or keloid formation.

Randomisation and Allocation

Participants were randomly assigned in a 1:1 ratio into two groups (n = 25 each) using a computer-generated randomization sequence. Allocation concealment was ensured through the use of sequentially numbered opaque sealed envelopes opened immediately prior to the implantation phase. Due to the nature of the intervention, surgeon blinding was not feasible. However, postoperative outcome assessment was performed by an independent evaluator who was unaware of group allocation to minimize observer bias.

Surgical Procedure

All procedures were performed under local anesthesia using 2% lignocaine with adrenaline (1:200,000 dilution). Standard preoperative scalp preparation was carried out, including trimming of the donor area and antiseptic skin preparation.

Follicular units were harvested from the occipital donor region using a motorized punch system under magnification loupes. Care was taken to minimize transection during extraction. Harvested grafts were preserved in chilled normal saline solution until implantation. To eliminate operator-related variability, all implantation procedures in both groups were performed by the same experienced surgeon using the same model of implanter device and identical needle gauge.

Intervention Protocol

Control group (Group A)

In the control group, implantation was performed using conventional implanter technique. The angulation of insertion varied between approximately 30° and 60° relative to the scalp surface depending on anatomical location and surgeon discretion. Bevel orientation was not standardized and was adjusted subjectively during the procedure. Insertion force was applied manually based on tactile feedback without adherence to a fixed angulation protocol.

Test Group (Group B)

In the test group, implantation was performed using a standardized protocol. The implanter was consistently held at a fixed 45-degree angle relative to the scalp surface during insertion. Additionally, the bevel of the implanter needle was oriented toward the skin surface throughout graft placement.

The needle was advanced with controlled, minimal axial pressure, allowing the bevel edge to gently separate epidermal and dermal fibers. The plunger mechanism was activated only after the needle was fully seated at the intended depth.

This standardized angulation and bevel orientation were maintained throughout implantation of all grafts in this group. Except for angulation and bevel positioning, all other surgical parameters—including graft handling, implantation density, needle size, and recipient site planning—were kept identical between groups.

Outcome Measures

The primary outcome measure was insertion force during follicular entry. This was assessed subjectively by the operating surgeon based on tactile resistance encountered during implantation and categorized into four levels: minimal, mild, moderate, or high resistance. The assessment was recorded intraoperatively for each patient.

Postoperative Care and Follow-up

All patients received standardized postoperative instructions. Oral antibiotics were prescribed for five days, along with analgesics as required. Patients were instructed to avoid trauma to the recipient area and to use saline spray to maintain hydration.

Follow-up visits were scheduled on postoperative day 1, at one week, one month, and three months. Standardized clinical photographs were taken at each visit under consistent lighting and positioning conditions.

Statistical Analysis

Data were entered into Microsoft Excel and subsequently analyzed using IBM Statistical Package for the Social Sciences (SPSS) software, version 29.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all study variables. Continuous variables, including implantation time, were expressed as mean ± standard deviation (SD) after assessment of normality using the Shapiro–Wilk test. Categorical variables, such as graft popping rate, bleeding severity, graft malalignment, and insertion resistance categories, were presented as frequencies and percentages.

Intergroup comparisons for continuous variables were performed using the independent samples *t*-test for normally distributed data. For categorical variables, the chi-square test was used to assess differences between groups. Fisher's exact test was applied when expected cell counts were less than five. All statistical tests were two-tailed. A *p*-value of < 0.05 was considered statistically significant.

RESULTS

A total of 50 male patients with androgenetic alopecia were enrolled and randomized equally into two groups (n = 25 per group). All participants completed the procedure and follow-up assessments included in the study period. There were no intraoperative exclusions or protocol deviations. Baseline characteristics, including age distribution, Norwood grade classification, scalp characteristics, and average number of grafts implanted (2,500–3,000 units per patient), were comparable between the two groups, with no statistically significant differences observed.

Insertion Force

The primary outcome measure, intraoperative insertion force, demonstrated a statistically significant difference between the two groups. In the control group, insertion resistance was predominantly categorized as moderate to high during graft placement. Surgeons frequently encountered increased tactile resistance while advancing the implanter needle through the recipient scalp, requiring greater axial pressure.

In contrast, the 45-degree bevel-facing group demonstrated predominantly minimal to moderate resistance during follicular entry. The controlled angulation combined with bevel orientation toward the skin appeared to facilitate smoother penetration of epidermal and dermal layers. Statistical comparison revealed a significant reduction in insertion force in the test group compared with the control group ($p < 0.01$). This finding suggests that standardized angulation at 45 degrees effectively reduces mechanical resistance encountered during implantation.

Graft Popping Rate

A marked reduction in graft popping rate was observed in the test group. The control group demonstrated a mean graft popping rate of 6.2% ± 1.8, whereas the 45-degree bevel-facing group showed a significantly lower rate of 2.5% ± 1.2. The difference between groups was highly statistically significant ($p < 0.001$).

Clinically, graft popping was more frequently noted in the control group during placement of adjacent follicular units, particularly in high-density zones. In the test group, improved stability of previously placed grafts was observed, likely attributable to reduced insertion pressure and better directional control. The lower popping rate in the 45-degree group indicates enhanced graft seating stability and reduced disruption of surrounding implanted units.

Implantation Time

A statistically significant reduction in implantation time was noted in the test group. The control group required a mean duration of 46.5 ± 5.4 minutes per 1,000 grafts, whereas the 45-degree bevel-facing group required 39.8 ± 4.9 minutes per 1,000 grafts ($p < 0.01$).

This reduction in operative time may be attributed to smoother follicular entry, decreased resistance, and reduced need for repeated adjustments during placement. Additionally, the lower incidence of graft popping likely minimized time spent repositioning displaced grafts. The findings indicate that standardization of angulation not only improves mechanical efficiency but also enhances procedural workflow.

Bleeding at Implantation Site

Intraoperative bleeding was clinically assessed and categorized based on observed severity and need for hemostatic control. Moderate bleeding was more

commonly observed in the control group, whereas bleeding in the 45-degree bevel-facing group was predominantly mild. The intergroup difference was statistically significant ($p < 0.05$).

Reduced bleeding in the test group may reflect decreased tissue trauma and lower compressive stress during needle insertion. The smoother penetration achieved with bevel orientation toward the skin may have minimized disruption of superficial vascular structures within the dermis.

Graft Malalignment

Graft malalignment was observed in 18% of cases in the control group compared to 4% in the test group, demonstrating a statistically significant difference ($p < 0.01$). Malalignment included improper depth placement or deviation from intended hair direction immediately following implantation.

The improved alignment observed in the 45-degree group suggests enhanced directional control when a consistent angulation protocol is maintained. By aligning the implanter trajectory more closely with natural hair exit angles, the technique appears to facilitate more predictable orientation and depth control.

Collectively, the findings indicate that implantation using a standardized 45-degree angulation with bevel facing toward the skin significantly improves intraoperative efficiency and mechanical performance. The technique was associated with reduced insertion resistance, lower graft displacement, shorter procedural time, decreased bleeding, and improved alignment when compared with conventional variable-angle implanter use.

DISCUSSION

Hair transplantation has evolved substantially over the past three decades, with refinements in donor harvesting, graft preservation, and recipient site planning significantly improving aesthetic predictability. However, implantation technique remains one of the least standardized yet most technically sensitive phases of the procedure. The present randomized clinical study evaluated whether maintaining a fixed 45-degree implanter angulation with the bevel facing toward the skin could improve intraoperative performance compared with conventional variable-angle implantation. The findings demonstrated statistically significant reductions in insertion resistance, graft popping rate, implantation time, intraoperative bleeding, and graft malalignment in the standardized technique group, suggesting that subtle modifications in implantation mechanics may translate into measurable surgical advantages.

The biomechanics of graft insertion play a critical role in determining tissue trauma and follicular integrity. During implantation, the implanter needle must traverse the epidermis and dermis while carrying a delicate follicular unit. Excessive axial pressure may compress the bulb and outer root sheath, potentially compromising graft viability. Earlier descriptions of the Choi implanter emphasized the importance of controlled delivery and minimal manipulation to preserve follicular structure. Subsequent refinements in implanter design aimed to reduce crush injury and allow more precise depth control. Despite these technological advances, insertion angle and bevel orientation have largely remained dependent on operator preference rather than standardized evidence.(20)

In the present study, surgeons reported significantly lower insertion resistance when the implanter was held at 45 degrees with the bevel facing toward the skin. This observation is consistent with mechanical principles of tissue penetration. A bevel oriented toward the skin surface facilitates a slicing rather than compressive entry through dermal collagen bundles, thereby reducing resistance. Procedural literature describing sharp implanter methods similarly underscores the importance of controlled needle trajectory to reduce tissue drag and maintain graft integrity. Although these descriptions have been largely experiential, the current findings provide quantitative support for the concept that optimized angulation reduces mechanical resistance during follicular entry.(21)

Graft popping represents another important intraoperative challenge, particularly during dense packing. Displacement of previously placed grafts not only prolongs operative time but may also increase manipulation-related trauma. In this study, the 45-degree bevel-facing group demonstrated a markedly lower graft popping rate compared with controls. Use of implanters in premade recipient sites has been shown to reduce handling and improve placement stability. However, even within implanter-based techniques, variability in angulation can influence local tissue pressure and graft seating(26). The reduced popping observed in the standardized group may reflect decreased compression of adjacent tissue columns, allowing the recipient bed to accommodate new grafts without displacing earlier ones. This mechanical stability becomes particularly relevant in high-density implantation strategies, where tissue expansion is limited(22).

Efficiency of implantation is an increasingly relevant metric in modern hair restoration practice. Prolonged operative time contributes to surgeon fatigue and may increase ischemic exposure of grafts. In this trial, implantation time per 1,000 grafts was significantly lower in the standardized group. Reduced insertion resistance and fewer displaced grafts likely contributed to smoother workflow(23). Practice guidelines for hair transplantation emphasize procedural consistency and efficiency but acknowledge the lack of robust comparative data regarding specific implantation techniques. By demonstrating a measurable time advantage, this study suggests that angulation standardization may enhance productivity without compromising placement quality.

Intraoperative bleeding was also reduced in the 45-degree bevel-facing group. Recipient site creation and implantation inevitably disrupt superficial vascular networks. However, excessive axial compression and repeated needle adjustments can exacerbate vascular trauma. Literature addressing recipient site design emphasizes minimizing unnecessary tissue injury to

preserve perfusion. Although bleeding severity in this study was assessed clinically rather than quantitatively, the significant difference between groups supports the hypothesis that smoother needle entry decreases microvascular disruption. Preservation of recipient bed perfusion is particularly important during the immediate post-implantation phase, when graft survival depends on plasmatic imbibition before revascularization.

Proper graft alignment is central to aesthetic success. Natural hair exits the scalp at acute angles, especially in frontal and temporal regions. If implantation is performed too vertically or at inconsistent depths, the resulting hair direction may appear unnatural. Recipient site angulation has long been recognized as a determinant of cosmetic outcome.(11) However, the relationship between implanter insertion mechanics and final graft orientation has received limited attention. The significantly lower rate of graft malalignment observed in the standardized group suggests that maintaining a consistent 45-degree trajectory may improve directional predictability. This angulation approximates natural hair emergence patterns in many scalp regions, thereby facilitating alignment with existing follicles.

From a biological perspective, minimizing mechanical trauma during implantation may also support graft survival. Experimental studies have demonstrated that preservation of the dermal papilla and bulb is essential for follicular regeneration. Excessive compression or distortion during insertion could theoretically impair these structures. While the current study did not directly measure long-term survival beyond early assessment, reduced insertion resistance and improved seating stability may indirectly favor follicular viability. Further longitudinal follow-up would be valuable in confirming sustained survival advantages.

The broader literature on implanter use supports the principle that technique influences outcome. Reports on dull needle and sharp needle implanter methods emphasize that subtle variations in needle handling affect graft integrity and recipient site trauma. However, many such publications are descriptive or experience-based. Similarly, overviews of follicular extraction and implantation describe procedural nuances but rarely provide randomized comparisons.(23) The present study contributes higher-level evidence by isolating angulation and bevel orientation as modifiable variables and demonstrating statistically significant improvements across multiple intraoperative parameters.

It is noteworthy that all other surgical variables were standardized in this trial, including graft handling, needle gauge, anesthesia protocol, and surgeon experience. This methodological consistency strengthens the inference that the observed differences were attributable primarily to angulation and bevel orientation rather than confounding factors.(24) As hair transplantation continues to mature as a subspecialty, incremental technical refinements supported by evidence are essential for advancing standards of care.

The findings of this study have practical implications for surgical training and procedural standardization. Hair transplantation often involves multiple assistants participating in graft loading and placement. Establishing a clearly defined insertion angle and bevel orientation may reduce inter-operator variability and shorten the learning curve. In high-volume centers, even modest reductions in implantation time and complication rates can translate into meaningful efficiency gains(25,27).

Certain limitations must be acknowledged. Insertion force was assessed subjectively rather than with objective force-measuring instruments. While subjective tactile feedback reflects real-world surgical perception, future studies incorporating digital force sensors could provide more precise biomechanical data. Additionally, long-term graft survival and patient-reported aesthetic satisfaction were not extensively evaluated within the present timeframe. Extended follow-up would strengthen the clinical relevance of the findings.

Despite these limitations, the consistent superiority of the 45-degree bevel-facing technique across multiple intraoperative metrics suggests that implantation mechanics represent an underexplored yet impactful aspect of hair restoration surgery(28). As existing practice guidelines highlight the need for continued refinement and evidence generation[10], this study provides clinically actionable data supporting a simple and reproducible modification in implanter handling. By aligning mechanical principles with surgical execution, standardization of angulation may enhance both efficiency and graft stability without introducing additional cost or equipment.

Future research should integrate objective biomechanical assessment tools, larger multicenter cohorts, and long-term growth analysis to validate and extend these findings. Nevertheless, the present data support the premise that controlled 45-degree implanter angulation with bevel orientation toward the skin reduces insertion resistance, improves graft seating stability, decreases tissue trauma, and enhances procedural efficiency compared with conventional variable-angle implantation.

CONCLUSION

Standardizing implanter angulation at 45 degrees with the bevel oriented toward the skin significantly improved intraoperative performance in FUE hair transplantation. This technique was associated with reduced insertion resistance, lower graft popping rates, shorter implantation time, decreased bleeding, and improved graft alignment compared with conventional variable-angle implantation. The findings highlight the importance of implantation biomechanics in optimizing surgical efficiency and graft stability. As a simple and reproducible modification that does not require additional equipment, the 45-degree bevel-facing approach may enhance procedural consistency and clinical outcomes. Further long-term studies are recommended to evaluate its impact on sustained graft survival and aesthetic results.

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