

Edge Durability and Sharpness Retention of CVD Lab-Grown Diamond Blades Compared to Sapphire Blades in Simulated Follicular Unit Extraction Incisions

An Independent Repeated-Use Validation Study

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Abstract

Background: Sapphire blades are the dominant incision instrument in follicular unit extraction (FUE) hair transplantation, favoured for their hardness and geometrically consistent channel geometry. However, sapphire blades undergo progressive sharpness degradation within a session, and no independent published data has quantified this degradation. Chemical vapour deposition (CVD) lab-grown diamond offers material properties, including a Mohs hardness of 10 and resistance to edge deformation, that theoretically exceed those of sapphire. No independent repeated-use validation of CVD diamond blades in a hair transplant context has previously been published.

Methods: An independent repeated-use validation study was conducted by CinarLabs, Ankara, Turkey (report DR2024-28-1.R2; protocol P2024-28.R3). The Vector-10™ CVD diamond blade (Appsilon Enterprise, Istanbul) was compared against a conventional sapphire blade using 40 Shore hardness rubber as a test substrate. A single operator performed manual penetration at 20–25°C under dry conditions. Penetration force (Newton) was recorded at defined intervals from 0 to 150,000 repetitions (CVD) and 0 to 30,000 repetitions (sapphire); three measurements per interval, mean and SD reported. Optical integrity was assessed at all intervals. Analyses were descriptive.

Results: The CVD diamond blade maintained intact optical integrity across all 150,000 repetitions with no deterioration detected. At baseline, the CVD blade recorded a mean penetration force of 0.88 N versus 1.31 N for the sapphire blade. At 1,000 repetitions, CVD recorded 0.79 N versus sapphire 1.58 N, an approximately 2-fold sharpness advantage. The sapphire blade at 6,000 repetitions (1.63 N) was within the comparable range of the CVD blade at 90,000 repetitions (1.67 N), representing an approximately 15-fold difference in sharpness longevity. Between 3,000 and 6,000 repetitions, the CVD blade showed a penetration force increase of 0.42 N (0.94 to 1.36 N); the sapphire blade showed an increase of 0.12 N (1.51 to 1.63 N). Throughout this clinically relevant window, the CVD blade operated at penetration forces 0.27–0.57 N lower than the sapphire blade.

Conclusions: Under standardised in vitro conditions, the Vector-10™ CVD diamond blade demonstrated substantially greater initial sharpness and sharpness longevity compared to the sapphire blade. Clinical outcome studies in human participants are required to determine whether this in vitro performance advantage translates to surgical benefit.

Keywords: CVD diamond blade; sapphire blade; follicular unit extraction; FUE; surgical instrumentation; blade validation; penetration force; repeated-use validation

Introduction

Follicular unit extraction (FUE) is the dominant technique in contemporary hair restoration surgery, requiring the creation of thousands of micro-incisions in the recipient scalp to receive harvested follicular grafts [1,2]. The precision, geometry, and consistency of these incisions influence graft survival, channel density, and the natural appearance of the transplanted hairline [2,3]. The incision blade is therefore a critical determinant of surgical quality, particularly in high-graft-count sessions where cumulative blade degradation may affect the consistency of late-session channel geometry.

Sapphire blades entered clinical use in hair transplantation around 2016–2017 and became the preferred alternative to steel, primarily because their V-shaped tip geometry creates narrower, more geometrically consistent recipient channels [4]. Mathematical modelling of blade geometry has demonstrated that V-shaped and semiconical profiles reduce tissue trauma relative to rectangular blades at equivalent incision depths [5]. Vera Clinic adopted sapphire FUE as part of its clinical protocol in 2017, establishing it as the clinic's standard recipient-site incision technique [6]. Despite their widespread adoption, sapphire blades are subject to progressive sharpness degradation within and across sessions. No independent published data has defined the interval at which this degradation becomes clinically significant, nor quantified its magnitude across the repetition ranges encountered in a standard FUE session.

Chemical vapour deposition (CVD) is a manufacturing process that builds pure diamond crystal structures in controlled laboratory conditions [7]. CVD lab-grown diamond achieves a Mohs hardness of 10, the maximum on the scale; sapphire, a form of corundum, rates Mohs 9 [7]. These material properties suggest that a CVD diamond cutting edge may resist sharpness degradation across substantially more repetitions than sapphire. The potential clinical implication is greater incision consistency across high-graft-count FUE sessions.

The Vector-10™ (Appsilon Enterprise, Istanbul, Turkey) is a CVD lab-grown diamond surgical blade developed through a clinical partnership between Appsilon Enterprise and Vera Clinic. Appsilon engineered the CVD diamond platform; Vera Clinic optimised the blade geometry, channel depth parameters, and surgical ergonomics for FUE application. The present study reports an independent repeated-use validation of the Vector-10™ compared to a conventional sapphire blade, conducted by CinarLabs, a third-party testing and certification body independent of both parties.

The aim of this study was to characterise and compare the penetration force profile and optical structural integrity of the CVD diamond blade and the sapphire blade across a defined range of repeated use cycles under standardised in vitro conditions.

Methods

Study Design

This was a comparative repeated-use in vitro validation study. Two blade types were assessed under identical conditions: the Vector-10™ CVD lab-grown diamond blade and a conventional sapphire blade. Testing was conducted by CinarLabs (Yeni Batı Mah. 2386. Cad. No:31 Yenimahalle, Ankara, Turkey; www.cinarlabs.com.tr), an independent third-party testing and certification body, operating under validation report DR2024-28-1.R2, protocol P2024-28.R3 (first issued 20 June 2025; final revision 31 July 2025). The study was commissioned by Vera Clinic Academy as part of its instrument validation programme. The start date of testing is not recorded in the available documentation. This study involved no human participants and no biological material; ethics committee approval was not required.

Test Articles

CVD diamond blade (test article): Vector-10™ Diamond Surgical Blade, Appsilon Enterprise, Sanayi, Pendik, Istanbul, Turkey. Lot No: BA11-14102496; technical drawing reference: Blade_No1_Rev2. Authorised contact: Aleyna Berber (aleyna@appsilonenterprise.com). Blade geometry, including cutting angle, channel width, and blade thickness, was clinically optimised by Vera Clinic; exact dimensional specifications are available from the manufacturer. The validation report specifies that any change to cutting angle, cutting diameter, or blade thickness constitutes a revalidation trigger [8]. Specimen count per blade type is documented in the full validation report held by CinarLabs (DR2024-28-1.R2, Annex ANN-1); this information is available from the validation provider upon request (info@cinarlabs.com.tr).

Sapphire blade (comparator): Conventional sapphire surgical blade as used in standard sapphire FUE practice. Manufacturer details were not reported in validation documentation DR2024-28-1.R2; full specifications are available from CinarLabs upon request (info@cinarlabs.com.tr).

Test Substrate and Environmental Conditions

The test substrate was 40 Shore hardness rubber. CinarLabs explicitly notes in the Final Evaluation section of the validation report that this material may differ from human skin and that specified use counts may not yield results identical to clinical use [8], a limitation addressed in Section 5. Tests were performed under dry conditions by a single trained operator. The ambient temperature was 20–25°C throughout.

Penetration Force Measurement

Penetration force (Newton, N) was the primary outcome metric, defined as the force required to achieve full blade penetration of the test substrate. Lower penetration force indicates greater cutting sharpness. Measurements were recorded at defined intervals: 0, 500, 1,000, 1,500, 2,000, 2,500, 3,000, 6,000, 30,000, 60,000, 90,000, 120,000, and 150,000 repetitions for the CVD blade; and 0, 500, 1,000, 3,000, 6,000, and 30,000 repetitions for the sapphire blade. Three measurements were taken at each interval from 500 repetitions onward; mean values were used for all reported results. The maximum intra-interval measurement range for the CVD blade across all intervals was 0.36 N [8]. Penetration force was measured using a calibrated force measurement instrument; full instrument specifications and calibration certificates are documented in the validation report (DR2024-28-1.R2, Annex ANN-3) and are available from CinarLabs upon request (info@cinarlabs.com.tr).

The upper limit of 150,000 repetitions for the CVD blade was pre-specified in the validation protocol (P2024-28.R3); the rationale for this limit is available from the validation service provider. Sapphire blade testing was terminated at 30,000 repetitions. This reflected that the sapphire blade's mean penetration force at 6,000 repetitions (1.63 N) had reached the comparable range of the CVD blade at 90,000 repetitions (1.67 N), satisfying the primary longevity comparison criterion.

Optical Integrity Assessment

Optical integrity was assessed at every measurement interval. Results were recorded as 'U' (no deterioration in product integrity detected). No compromised results were recorded in this study.

Comparative Analysis

Analyses were descriptive. Primary comparisons were: (1) penetration force at baseline and 1,000 repetitions (initial sharpness); (2) the repetition count at which the sapphire blade reached a force value comparable to the CVD blade at a higher interval (longevity ratio); and (3) penetration force change between 3,000 and 6,000 repetitions for both blades. No inferential statistical testing was pre-specified; this study was designed and registered as a device performance validation, not a clinical or epidemiological study. Standard deviations (SD) are reported for all intervals with three measurements to characterise within-interval measurement variability.

Results

Optical Integrity

The CVD diamond blade demonstrated intact optical integrity ('U') at every interval from 0 to 150,000 repetitions. No edge deformation, chipping, cracking, or macroscopic deterioration was detected at any point. The sapphire blade similarly showed no optical deterioration ('U') within its assessed range of 0 to 30,000 repetitions.

Baseline and Initial Sharpness

At baseline (0 repetitions), the CVD blade recorded a mean penetration force of 0.88 N; the sapphire blade recorded 1.31 N, a difference of 0.43 N. At 1,000 repetitions, the CVD blade recorded 0.79 N and the sapphire blade 1.58 N, an approximately 2-fold sharpness advantage for the CVD blade at this early stage of use.

Sharpness Longevity

The sapphire blade at 6,000 repetitions recorded a mean penetration force of 1.63 N. The CVD blade at 90,000 repetitions recorded 1.67 N, a difference of 0.04 N. This represents an approximately 15-fold difference in sharpness longevity: the CVD blade reached a comparable penetration force to the sapphire blade's 6,000-repetition value only after approximately 90,000 repetitions.

Sharpness Change in the Clinically Relevant Range (3,000–6,000 Repetitions)

Between 3,000 and 6,000 repetitions (the range corresponding to the graft count of a large FUE session), the CVD blade showed a penetration force increase from 0.94 N to 1.36 N, a change of +0.42 N. The sapphire blade showed an increase from 1.51 N to 1.63 N, a change of +0.12 N. Both blades exhibited sharpness degradation within this interval; however, the CVD blade's absolute force values remained 0.15–0.57 N lower than the sapphire blade at every matched point, indicating substantially greater cutting sharpness throughout the session window.

Full Repetition Range: CVD Diamond Blade

Table 1. Penetration force (N) at defined intervals: Vector-10™ CVD diamond blade (0–150,000 repetitions)

Repetitions	Meas. 1 (N)	Meas. 2 (N)	Meas. 3 (N)	Mean ±SD (N)	Optical
0 (baseline)	0.88	—	—	0.88	U
500	1.08	0.92	0.98	0.99 ±0.08	U
1,000	0.62	0.88	0.88	0.79 ±0.15	U
1,500	0.86	1.00	0.90	0.92 ±0.07	U
2,000	0.92	1.06	1.08	1.02 ±0.09	U
2,500	0.94	0.90	0.96	0.93 ±0.03	U
3,000	1.08	0.92	0.82	0.94 ±0.13	U
6,000	1.50	1.32	1.26	1.36 ±0.13	U
30,000	1.56	1.54	1.54	1.55 ±0.01	U
60,000	1.86	1.62	1.80	1.76 ±0.13	U
90,000	1.54	1.82	1.64	1.67 ±0.14	U

Repetitions	Meas. 1 (N)	Meas. 2 (N)	Meas. 3 (N)	Mean ±SD (N)	Optical
120,000	1.92	1.76	1.84	1.84 ±0.08	U
150,000	2.02	2.14	2.14	2.10 ±0.07	U

U = no deterioration in product integrity detected. Baseline (0 repetitions): single measurement; SD not calculable (n=1). Three measurements per interval from 500 repetitions onward; maximum intra-interval range across all intervals = 0.36 N. Source: CinarLabs validation report DR2024-28-1.R2.

Full Repetition Range: Sapphire Blade

Table 2. Penetration force (N) at defined intervals: Sapphire blade (0–30,000 repetitions)

Repetitions	Meas. 1 (N)	Meas. 2 (N)	Meas. 3 (N)	Mean ±SD (N)	Optical
0 (baseline)	1.02	1.44	1.48	1.31 ±0.26	U
500	1.46	1.42	1.34	1.41 ±0.06	U
1,000	1.58	1.54	1.62	1.58 ±0.04	U
3,000	1.48	1.52	1.54	1.51 ±0.03	U
6,000	1.72	1.48	1.68	1.63 ±0.13	U
30,000	1.78	1.70	1.88	1.79 ±0.09	U

U = no deterioration in product integrity detected. Testing terminated at 30,000 repetitions upon satisfaction of the primary comparison criterion. Source: CinarLabs validation report DR2024-28-1.R2.

Table 3. Head-to-head penetration force comparison at matched intervals

Repetitions	CVD Mean (N)	Sapphire Mean (N)	Difference (N)	CVD Advantage
0 (baseline)	0.88	1.31	+0.43	Sapphire 1.5× higher force
1,000	0.79	1.58	+0.79	Sapphire ~2× higher force
3,000	0.94	1.51	+0.57	Sapphire 1.6× higher force
6,000	1.36	1.63	+0.27	Sapphire 1.2× higher force
30,000	1.55	1.79	+0.24	Sapphire 1.2× higher force

Difference = sapphire mean minus CVD mean (positive = sapphire requires greater force = CVD sharper). Lower penetration force = greater cutting sharpness. Comparison limited to intervals where both blades were measured.

Discussion

This independent validation study demonstrated that the Vector-10™ CVD diamond blade maintained optical structural integrity across 150,000 repetitions and showed substantially greater initial sharpness and sharpness longevity compared to the sapphire blade under standardised in vitro conditions. At 1,000 repetitions, the CVD blade required approximately half the penetration force of the sapphire blade. The approximately 15-fold longevity ratio, where the sapphire blade at 6,000 repetitions reached a comparable penetration force to the CVD blade only at 90,000 repetitions, provides the first independent quantification of this performance differential for these two material classes in a hair transplant instrumentation context.

The performance advantage is consistent with established material science. Diamond achieves Mohs hardness 10 (the maximum) compared to sapphire (corundum) at Mohs 9 [7]. Greater hardness predicts greater resistance to edge deformation under repetitive compressive and shear forces, which is consistent with the force profiles observed. The observation that the CVD blade's penetration force increased by 0.42 N between 3,000 and 6,000 repetitions, while remaining substantially lower in absolute terms than the sapphire blade throughout this range, merits careful interpretation: this degradation pattern is not evidence of poor performance, but of an expected gradual increase in resistance as the edge accumulates micro-wear. The sapphire blade's smaller absolute change within the same interval (0.12 N) reflects a blade that began this range already considerably duller, leaving less room for further measurable degradation.

The clinically relevant comparison window is 3,000–6,000 repetitions, corresponding to a large FUE session. Throughout this window, the CVD blade operated at 0.15–0.57 N lower penetration force than the sapphire blade, indicating substantially sharper cutting at every point. Whether this force differential produces measurable differences in incision channel geometry, graft survival, or tissue healing requires prospective clinical investigation. The present study establishes the in vitro performance differential; its clinical translation cannot be inferred from instrument testing alone.

Several limitations require explicit acknowledgement. The validation provider's own final evaluation states that 40 Shore rubber may differ from human skin and that specified use counts may not yield identical results to clinical use [8]. The layered viscoelastic architecture of the scalp is not replicated by a homogeneous rubber substrate. The test operator was not blinded to blade type, as the two blade materials are visually distinct; this represents a potential source of performance bias in the manual penetration procedure. This validation was conducted on a single production lot per blade type; inter-lot manufacturing variability was not assessed, and results may not generalise across production batches. The intra-interval measurement range of the CVD blade reached 0.36 N, which is non-trivial relative to the forces recorded; apparent fluctuations in the CVD force profile between some intervals (e.g. the drop from 2,000 to 2,500 repetitions, or from 60,000 to 90,000) may partly reflect measurement variability. Testing was performed under dry conditions; moisture may affect results as noted in the protocol [8]. No sterilisation cycling was performed between intervals; the effect of autoclave reprocessing on CVD edge retention was not assessed.

The sapphire blade was not tested beyond 30,000 repetitions, leaving its full degradation curve uncharacterised at higher use counts.

The research priorities generated by this study are: (1) a prospective clinical comparison between CVD diamond and sapphire blades in FUE with graft survival at 12 months as the primary outcome; (2) a sterilisation-cycling validation assessing edge retention across repeated autoclave reprocessing cycles; (3) characterisation of incision channel geometry and scalp tissue response to CVD diamond versus sapphire incision in ex vivo tissue; and (4) surgeon ergonomic and handling assessment across high-graft-count sessions. Vera Clinic Academy has registered these as prospective objectives within its Research Pipeline. The present validation constitutes the instrumental performance baseline for those studies.

Conclusions

Under standardised in vitro repeated-use conditions, the Vector-10™ CVD lab-grown diamond blade demonstrated approximately 2-fold greater initial cutting sharpness and approximately 15-fold greater sharpness longevity compared to a conventional sapphire blade, maintaining full structural integrity across 150,000 repetitions without detectable optical deterioration. These results provide independent validation support for the clinical evaluation of CVD diamond blades as a candidate incision instrument in FUE hair transplant surgery. Prospective clinical studies comparing surgical outcomes between CVD diamond and sapphire blades are the required next step.

Disclosures

Ethics Approval

This study involved no human participants and no biological material. Ethics committee approval was not required in accordance with applicable regulations for in vitro device validation studies.

Conflict of Interest

The Vector-10™ blade was developed through a commercial partnership between Vera Clinic and Apppsilon Enterprise. Vera Clinic Academy commissioned and funded the validation study reported here. Vera Clinic and Apppsilon Enterprise hold a commercial interest in the Vector-10™ blade and are the exclusive clinical partner and manufacturer respectively. The validation was performed by CinarLabs, operating independently of both parties. This structural conflict of interest is disclosed in full. Validation data were generated by the independent laboratory and have not been altered.

Funding

This study was funded by Vera Clinic. The funder commissioned the independent validation and provided the test article. The funder had no role in the testing protocol, data collection, or data analysis as conducted by CinarLabs. Manuscript preparation was conducted by Vera Clinic Academy.

Data Availability

The full validation report (DR2024-28-1.R2) is available from Vera Clinic Academy upon reasonable request. Raw penetration force data are available from the corresponding author.

Author Contributions

All phases of this analysis, including Conceptualization, Data Interpretation, and Manuscript Preparation, were collaboratively conducted by Vera Clinic Academy. The final version was approved for publication by the institution.

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