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Potential use of bioresorbable poly-D-L-lactic acid (PDLLA) plates in rhinoseptoplasty

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ABSTRACT

Objective: Bioresorbable poly-D-L-lactic acid (PDLLA) plates are increasingly used in rhinoseptoplasty due to their biocompatibility, adequate initial mechanical strength, and complete resorption over time. These properties may offer advantages over permanent implants, particularly in complex cases involving post-traumatic nasal deformity. To evaluate the clinical efficacy and safety of PDLLA plates in achieving functional and aesthetic outcomes in primary and reconstructive rhinoseptoplasty.

Material and Methods: A retrospective cohort study was conducted on 37 consecutive patients [23 men, 14 women; median age 37 years, interquartile range (IQR) 30-44] who underwent rhinoseptoplasty between January 2022 and December 2024. The minimum follow-up was 3 months. Primary endpoints included septal stability, complication profile (e.g., infection, extrusion, resorption issues), and patient-reported outcomes. Subjective nasal appearance and symptom burden were assessed using the validated Standardized Cosmesis and Health Nasal Outcomes Survey (SCHNOS). In select cases requiring revision, histopathological evaluation of implantation sites was performed at 12 and 24 months.

Results: He use of pure PDLLA plates provided reliable septal stabilization and facilitated precise dorsal alignment, eliminating the need for autologous graft harvesting in 83.8% of cases. No plate-related infections, extrusions, or delayed resorption events were observed. Patient-reported symptom burden, as measured by the SCHNOS score, improved markedly from a median of 21 (IQR: 15-26) preoperatively to 1 (IQR: 0-1) postoperatively. Histology confirmed complete material resorption by 24 months, with mature collagenous remodeling and an absence of chronic inflammatory infiltrate.

Conclusion: In carefully selected patients, PDLLA plates appear to be a biocompatible and technically feasible adjunct in rhinoseptoplasty, facilitating septal reconstruction, eliminating donor-site morbidity, and yielding improvements in both patient-reported nasal function and aesthetic outcomes. These preliminary findings support further investigation in larger, controlled studies.

Keywords: Rhinoseptoplasty, bioresorbable implant, poly-D-L-lactic acid (PDLLA), septal deviation, Standardized Cosmesis and Health Nasal Outcomes Survey (SCHNOS)

INTRODUCTION

Nasal septal deviation is a highly prevalent condition, affecting up to 86.6% of adults. It is a leading cause of both functional impairments, such as nasal obstruction, and external deformities (1).

Nasal deviation is a common pathology that requires anatomically-based treatment. Septal correction requires a systematic approach to achieve a straight nasal profile. Modern rhinoseptoplasty techniques aim to achieve two objectives simultaneously: Restoring laminar airflow and creating a harmonious nasal contour (2). Moreover, septal deviation and turbinate hypertrophy are associated with impaired olfaction in the obstructed nostril. Surgical correction of these anatomical abnormalities has been shown to improve olfactory function (3). In severe cases, extracorporeal septoplasty may be required. Although this method has demonstrated efficacy in reconstructing severely deviated septa, there is a risk of destabilizing critical anatomical areas, such as the dorsal nasal lines and the keystone area (3). Thus, nasal septal deformity leads to aesthetic and functional consequences, such as impaired breathing and olfaction.

In 2024, plastic surgeons and otolaryngologists preferred rhinoseptoplasty, followed by facelift and blepharoplasty, to correct nasal deviation and restore its normal function. Notably, approximately 80% of surgeons affiliated with the American Academy of Facial Plastic and Reconstructive Surgery report that over 10% of their rhinoplasty patients seek revision procedures (4).

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The correction of nasal deformities requires establishing an anatomically straight septum to provide stable support for the nasal dorsum. While submucous resection is commonly employed, its application is restricted to cases in which the L-strut is not affected by the septal deviation (5). The use of poly-D-L-lactic acid (PDLLA) plates is the most appropriate solution when temporary stabilization is required. The plates maintain structural integrity for 12 weeks, a period that coincides with the critical phase of cartilage remodeling; after this period, the plates undergo complete hydrolytic degradation to CO_2 and H_2O. As a result, there is no need to remove the implant.

Anatomical accuracy is increased by excising the deformed septal cartilage and reconstructing it *ex vivo*. Preliminary studies indicate excellent biocompatibility and minimal chronic inflammatory response (6). This study systematically evaluates clinical, radiologic, functional, and histological outcomes associated with PDLLA-assisted septal reconstruction.

However, this procedure may cause complications, such as instability of the quadrangular cartilage–nasal bone junction, potentially altering the dorsal contour (7).

Technical challenges may arise in cases of a hypoplastic (less than 3 mm in height) or an absent anterior nasal spine (8). Rib cartilage is typically used in primary cases when septal cartilage is insufficient and in revision cases where it has been previously harvested (9). During integration of the cartilage graft, bioresorbable plates provide the necessary structural fixation and stability for 12 weeks due to their perforated design; they also reduce the duration of the surgical intervention and sometimes eliminate the need for additional implant harvesting, which is a major advantage of PDLLA plates (10). The implication is that PDLLA plates are a safe, reliable, and resorbable option for septal reconstruction (10). Macroscopic examination reveals complete resorption of the plates within three months post-insertion, when they cease to provide structural support. Histologically, PDLLA vacuoles become undetectable by 24 months post-implantation, with the areas previously occupied by polymer-containing vacuoles being completely replaced by mature connective tissue without signs of inflammation (11). Due to the ability of the PDLLA plates to be completely resorbed within three months after implantation, possible risks and complications, such as inflammation, allergic reactions, or incomplete resorption of the material, can be minimized.

This study aimed to evaluate the clinical efficacy and safety of bioresorbable PDLLA plates used in primary rhinoseptoplasty to correct deviated nasal septa.

MATERIAL and METHODS

Study Design and Ethics

This single-center retrospective analysis was approved by the Local Ethics Committee at the St. Petersburg State Pediatric Medical University (approval no: 32/06, dated: 08.11.2023) and was conducted in accordance with the Declaration of Helsinki (12).

Patients Selection

Inclusion criteria: Congenital, post-traumatic, or iatrogenic septal deformity amenable to open, combined or closed rhinoseptoplasty. The indications for PDLLA implantation include limited availability of autologous cartilage and bone grafts and post-traumatic, congenital, or iatrogenic deformities requiring additional structural support. In primary cases without cartilage or bone deficiency, only autologous grafts were used. The resorbable plate was primarily employed as a substitute for the perforated cribriform plate, which is commonly used to straighten and reinforce the nasal septum.

Exclusion criteria: Prior structural rhinoseptoplasty, active sinonasal infection, chronic rhinosinusitis.

In all cases, data on sex, age, surgical technique, patient-reported outcomes, and standardized photographs were collected. Patients attended follow-up visits at 14 days and at 1, 3, 6, and 12 months postoperatively.

Histological analyses of tissue samples from the surgical site were performed at 1- and 2-years post-implantation.

Biopsy Procedure

Biopsy specimens were obtained during scheduled minor revision procedures under local anesthesia at 12 and 24 months postoperatively. Biopsies were performed only when contour refinement was clinically indicated; no additional surgical interventions were carried out solely for research purposes. Through a semi-transfixion incision along the left anterior septal margin (≤0.5 cm in length), a small septal fragment (approximately 0.2 cm^2) was dissected supraperichondrially and excised with a scalpel.

Surgical Technique

Following transcolumellar-marginal or hemitransfixion approaches, complete subperichondrial and periosteal elevation was achieved. Deviated cartilaginous and bony elements were excised or reshaped *ex vivo*. A perforated 30×30×0.2-mm pure PDLLA plate (Resorb-X®, KLS Martin, Tuttlingen, Germany) was anchored to the anterior nasal spine or nasal bones via 18-gauge transosseous tunnels. Cartilaginous/bony grafts were sutured to the plate with 5-0 polydioxanone, reconstituting a minimum 25×20-mm neo-L strut. Detailed intraoperative footage is provided in the video (Supplementary content - Video 1) and in Figure 1.

Outcome Measures

Subjective: Pre- and postoperative Standardized Cosmesis and Health Nasal Outcomes Survey (SCHNOS) questionnaires.

Objective: Anterior rhinomanometry (150 Pa reference), computed tomography-based septal deviation angle, and standardized photographs (frontal, lateral, basal, oblique ×2, smiling frontal).

Histology: Haemotoxylin and eosin and Masson's trichrome staining of biopsies at 12 and 24 months.

Statistical Analysis

Data were processed with R 4.3. Potential outliers were identified and handled using interquartile range criteria to minimize measurement error; suspected measurement errors were imputed using variable-specific means. Normality was assessed using the Shapiro-Wilk test. Parametric or non-parametric tests (Student's t-test or Mann-Whitney U test) were applied as appropriate, with α=0.05.

RESULTS

Between January 2022 and December 2024, 37 rhinoseptoplasty procedures were performed using perforated PDLLA plates [23 men and 14 women; mean (standard deviation) age, 37±9 years; range, 19-75 years].

Table 1 presents the distribution of operative times and the difference between SGHNOS scores measured preoperatively and at three months postoperatively, by type of surgical approach. Figure 2 provides a graphical representation of changes in SCHNOS scores.

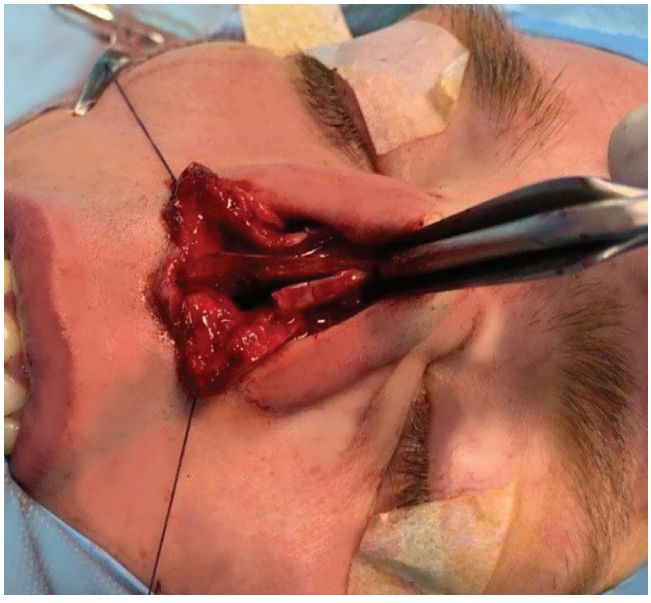


Figure 1. Implantation of a perforated PDLLA plate (30×30×0.2 mm) during rhinoseptoplasty. A perforated plate measuring 30×30×0.2 mm, made of 100% PDLLA, is fixed to the nasal bones and the anterior nasal spine with a monofilament soluble thread, PDS 4-0.

PDLLA: Poly-D-L-lactic acid

The operative time was significantly longer for open approaches, intermediate for combined techniques, and shortest for closed procedures ($p<0.05$). All groups demonstrated statistically significant improvements in SCHNOS scores at 3 months postoperatively, indicating both functional and aesthetic improvements.

No plate-related complications, such as infection, extrusion, or palpable irregularities, were observed during either early postoperative (≤30 days) or late postoperative (≤2 years) intervals.

Table 1. Total operative time and early patient-reported outcome measures ($p<0.05$*)

Surgical approach	Operative time, min [median (IQR***)]	ΔSCHNOS** [0-3 mo, median (IQR)]
Open	215 (182.5-270)	24.5 (18.5-26) → **0.5 (0-1)**
Combined	190 (180-210)	26 (15-27) → **1 (1-2)**
Closed	137.5 (117.5-150)	17 (15-21.5) → **0 (0-1)**

*: $p<0.05$ versus the other approaches (Mann-Whitney U test with Bonferroni correction);
**: ΔSCHNOS: Difference between pre-operative and 3-month Standardized Cosmesis & Health Nasal Outcomes Survey scores
***: IQR stands for interquartile range. IQR: Interquartile range, SCHNOS: Standardized Cosmesis and Health Nasal Outcomes Survey

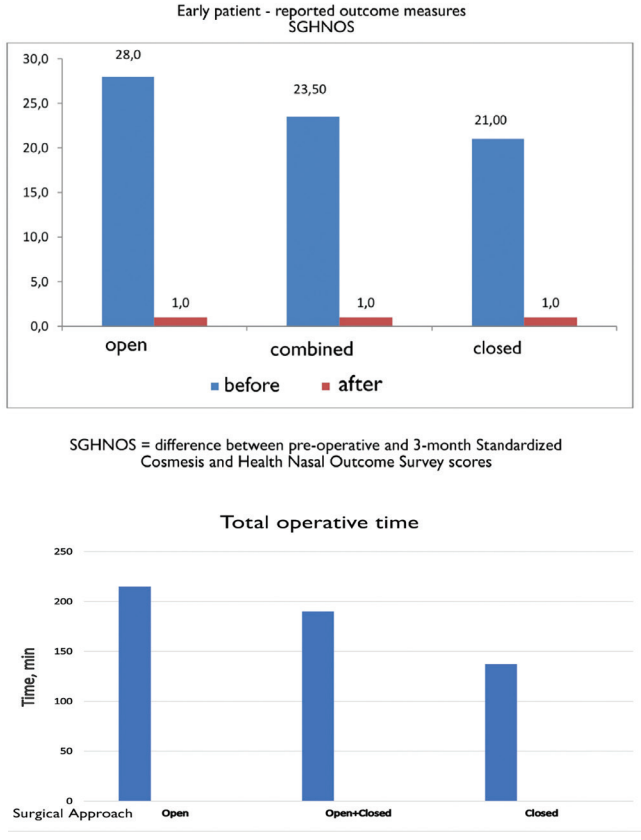


Figure 2. Graphical presentation of SCHNOS score changes.

SCHNOS: Standardized Cosmesis and Health Nasal Outcomes Survey

Comparison with a small subgroup of patients (n=6) who underwent reconstruction of a perforated cribriform plate using only autologous cartilage and bone grafts revealed comparable functional and aesthetic outcomes; however, operative times were longer in this group. The use of PDLLA eliminated donor-site morbidity, minimized the need for autologous graft harvesting, and reduced surgical duration.

Representative Clinical Cases

Case 1: Saddle-nose reconstruction (male, 28 years)

Primary open structural rhinoseptoplasty was performed for a severe post-traumatic L-strut collapse. The PDLLA matrix served as a rigid scaffold for septal reconstruction; no osteotomies were required. Two-year photographic follow-up confirmed restoration of dorsal height and mid-vault symmetry (Figure 3).

Case 2: Cleft-related revision deformity (male, 20 years)

Following two childhood rhinoplasties, the patient presented with caudal septal loss and cicatricial stenosis. A 4×1.5×0.2-cm costal cartilage graft was laminated onto the PDLLA plate to prevent warping. Both aesthetic and airway outcomes remained stable at 24-month follow-up (Figure 4).

Case 3: Post-traumatic septal buckle (female, 22 years)

A primary open procedure achieved septal realignment with PDLLA reinforcement. At 12 months, a minor contour refinement under local anesthesia was performed; excised tissue was submitted for histology (Figure 5).

Histopathology

Biopsies harvested at 12 and 24 months revealed:

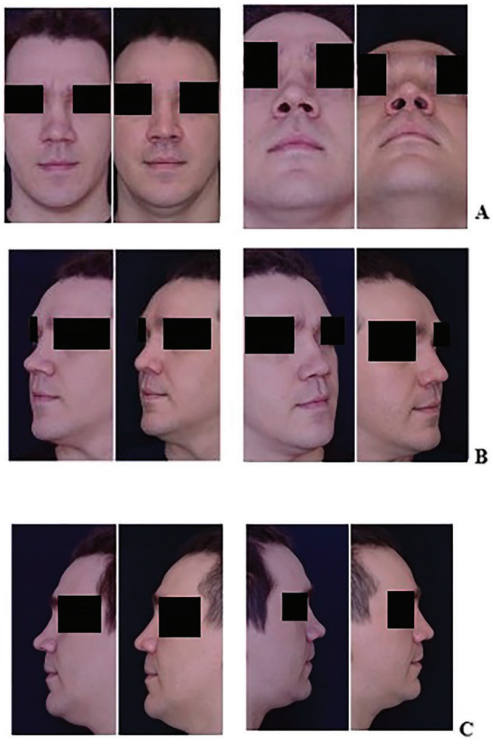
12 months: Intact plate silhouette demarcated by a thin fibrous capsule; sparse macrophages without foreign-body giant cells (Figure 6).

24 months: Complete material resorption; vacuolar footprints replaced by mature, collagenized connective tissue devoid of inflammatory infiltrate (Figure 7).

These findings corroborate the predictable two-phase degradation profile of PDLLA: initial structural retention (approximately 12 weeks), followed by gradual hydrolysis and uneventful incorporation.

DISCUSSION

The open rhinoplasty approach, while requiring extended operative time, demonstrates unparalleled efficacy in addressing complex post-traumatic corrections. In contrast, closed and combined techniques allow shorter operative times for less severe deformities (13-15). The consistent, statistically significant improvement in SCHNOS scores objectively validates the clinical utility of PDLLA reinforcement across different types of nasal surgery.



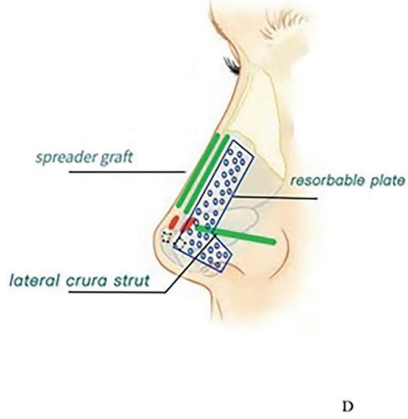


Figure 3. Preoperative and 2-year postoperative photographs of the patient: A – frontal view (at rest) and nasolabial angle view; B – three-quarter view (at rest); C – lateral view (at rest); D – a schematic illustration of the surgical technique.

The use of absorbable PDS foil facilitates this complex and technically demanding procedure. Septal cartilage fragments removed during surgery are sutured to an absorbable PDS foil, creating a stable free graft suitable for precise reimplantation into the nose. The foil stabilizes the cartilage fragments and provides essential structural support to the nasal dorsum during the initial healing phase while maintaining proper cartilaginous positioning. Subsequently, the foil is completely resorbed, thereby avoiding long-term complications associated with other synthetic implants. Numerous studies have confirmed the efficacy of polydioxanone in this application (16-20).

While polydioxanone foils have represented the historical standard for septal graft stabilization, market unavailability in the Russian Federation prompted clinicians to implement PDLLA as a functionally equivalent alternative, given its comparable

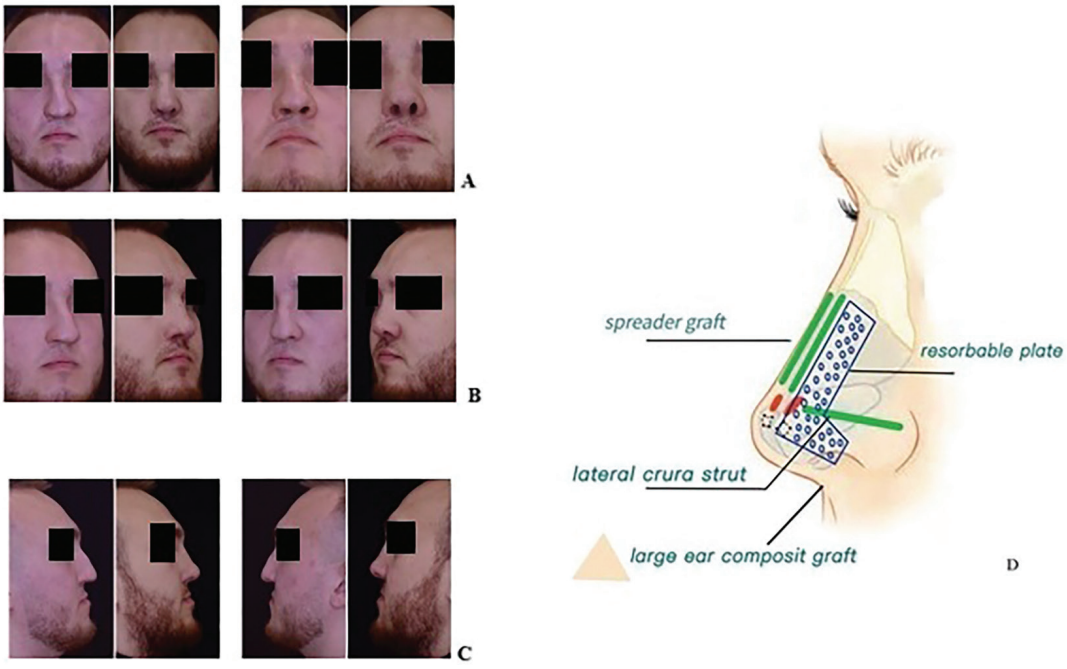


Figure 4. Preoperative and 2-year postoperative photographs of the patient: A – frontal view (at rest) and nasolabial angle view; B – three-quarter view (at rest); C – lateral view (at rest); D – a schematic illustration of the surgical technique.

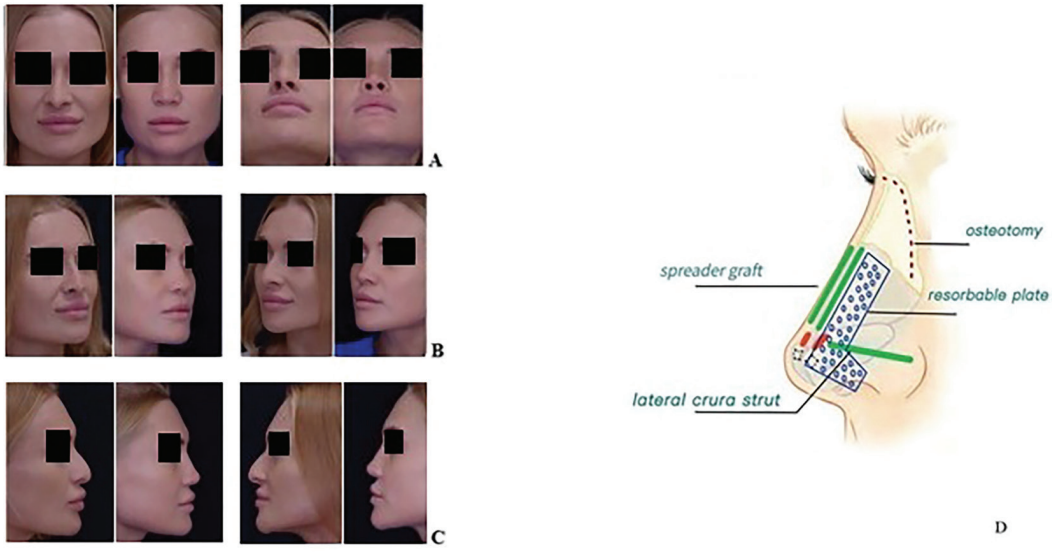


Figure 5. Preoperative and 2-year postoperative photographs of the patient: A – frontal view (at rest) and nasolabial angle view; B – three-quarter view (at rest); C – lateral view (at rest); D – a schematic illustration of the surgical technique.

biomechanical properties and a well-documented safety profile. *In vivo,* macrophage-mediated phagocytosis of degradation particles and subsequent collagen deposition ultimately result in the formation of a structurally competent fibrous neoseptum and the preservation of native cartilage integrity (21). The indications for PDLLA use included the limited availability of autologous cartilage and bone in cases of post-traumatic, congenital, or iatrogenic nasal deformities. In primary cases without cartilage deficiency, reconstruction was performed exclusively with autologous grafts. These selection criteria are described in detail to enhance the reproducibility of the study. Harvesting costal cartilage necessitates a second surgical site, entails donor-site morbidity, and prolongs operative time. The decision to use PDLLA was therefore guided by the aim of minimizing donor-site trauma, avoiding complications associated with rib cartilage harvest, and reducing overall surgical duration. PDLLA provides temporary structural rigidity sufficient to support tissue remodeling during the initial 12–24-week postoperative period and is subsequently fully resorbed.

The use of costal cartilage, while providing abundant graft material, necessitates a second surgical site, carries the risk of donor-site morbidity (e.g., pain, pneumothorax, contour deformities), and significantly prolongs operative time. In contrast, PDLLA offers temporary structural support during the critical early healing phase (approximately 12 weeks), after which it is fully resorbed without leaving a permanent implant. This approach eliminates donor-site complications and streamlines the surgical procedure, making it particularly advantageous for patients with adequate, albeit limited, septal or auricular cartilage.

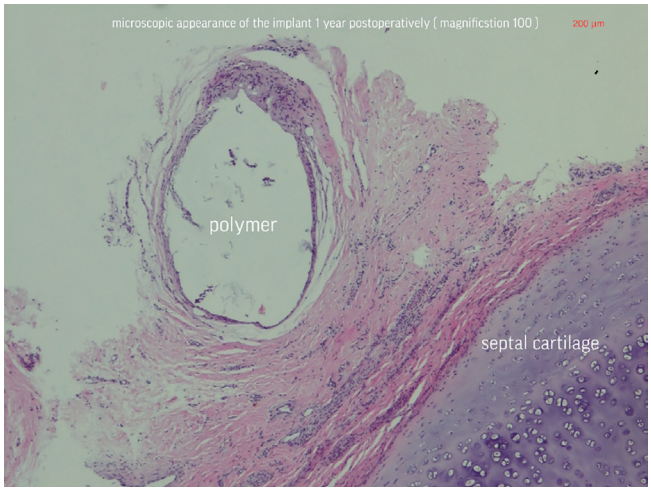


Figure 6. Microscopic appearance of the implant 1 year postoperatively (magnification ×100). Clear, round spaces correspond to the locations of implants. All implant sites are encapsulated. Inset (100x) shows a fibrous connective tissue capsule and mild inflammation (macrophages and a few multinucleated giant cells) within it. Scale bars, 200 µm.

This study introduces two principal innovations: 1) the pioneering use of PDLLA plates for correction of severe septal deviation in primary rhinoseptoplasty; and 2) the assessment of patients' satisfaction using a standardized questionnaire evaluating both functional and aesthetic outcomes, combined with systematic histological analyses performed at 12 and 24 months after polymer-augmented implantation. The study cohort included patients with various types of nasal deformities (congenital, traumatic, iatrogenic, and cleft-related). This heterogeneity in the patient population reflects real-world clinical practice; however, reduces sample homogeneity and may limit the precision of the analysis. Future studies should consider stratification by type of deformity and surgical approach.

Numerous studies have confirmed the biocompatibility of PDLLA-based polymers. Initially, these materials elicit only a minimal tissue response. As degradation progresses into the active phase, a controlled inflammatory response occurs, representing a normal physiological process whereby immune cells clear breakdown product. Macrophages are known to

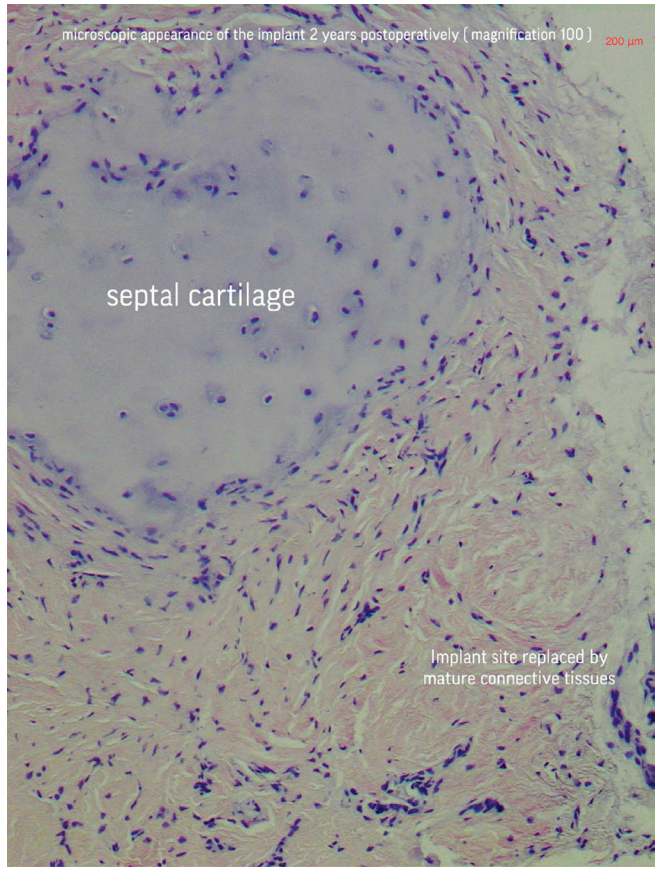


Figure 7. Microscopic appearance of the implant 2 years postoperatively (magnification ×100). A nodular solid site corresponds to the location of the implant. Scale bar: 200 µm. The implant site replaced by mature collagenized connective tissue devoid of inflammation and any evidence of degraded material (complete resolution of implant site).

play a significant role in phagocytosing polymer particles from the biodegradable implant. Concurrently with material resorption, progressive collagen deposition becomes evident at the implantation site. An ovine model study examining PDLLA copolymer implants along the nasal dorsum demonstrated: 1) excellent material tolerance, 2) ongoing volumetric reduction at 18 months, and 3) complete replacement by organized fibrous tissue by 24 months (11). Histopathological analysis revealed preserved cartilage architecture beneath the implant site, with only a defined layer of mature connective tissue forming at the cartilage-implant interface.

The research confirms that degradation byproducts of PDLLA polymers do not adversely affect cartilage or the human body.

Consequently, the integration of septal cartilage with a resorbable PDLLA polymer plate provides both technical advantages during surgery and postoperative benefits inherent to biodegradable materials.

Quantitative assessment of patient satisfaction demonstrates a statistically significant improvement in outcomes across all surgical techniques.

The follow-up period, with a median of twenty-four months, is sufficient to assess early and intermediate outcomes but does not reach the five-year threshold required to rule out late complications such as cartilage warping or contour relapse. Objective assessment was limited to single-pressure rhinomanometry, whereas more advanced techniques–computational fluid dynamics, formal olfactory testing, and blinded photographic analysis–were not carried out. Similarly, the SCHNOS instrument, although validated, is a subjective measure susceptible to respondent bias.

Heterogeneity in etiology and surgical approach was inevitable in routine clinical practice, as patients with congenital, traumatic, cleft-related, and iatrogenic deformities underwent open, closed, or combined approaches; however, such clinical diversity may obscure approach-specific nuances. Finally, the study evaluated only one PDLLA plate geometry from a single manufacturer, leaving open the question of whether alternative dimensions, molecular weights, or copolymer ratios would demonstrate comparable behavior *in vivo*.

Despite certain limitations, this study represents meaningful progress in rhinoseptoplasty. It advances biomaterials research by enabling translation from animal models to clinical application in humans. For the first time, it demonstrates that a PDLLA plate used in rhinoplasty degrades in two stages, is biocompatible, and provides sufficient mechanical strength for septal stabilization. By integrating this technique with the SCHNOS, the study establishes a correlation between material performance and patient satisfaction, thereby bridging materials science with current surgical methods.

The observed maintenance of septal alignment following polymer resorption suggests that stiffening it for twelve weeks is sufficient to support proper bone and cartilage remodeling. Serial biopsies at 12 and 24 months provide rare human evidence of complete polymer resorption and replacement with mature collagen, confirming hypotheses regarding PDLLA resorption in facial tissues.

These findings have direct clinical relevance. In the majority of cases, the PDLLA plate facilitated septal reconstruction; in selected cases, it reduced the need to harvest costal cartilage. This technique reduced donor-site morbidity and shortened the total operative time. The technique provides a valuable alternative in regions where polydioxanone foils remain unavailable, offering surgeons an additional tool for managing complex deformities. Since the fixation method is simple and reliable, use of the PDLLA plate in surgical practice can accelerate the learning process of young specialists and help them maintain consistent dorsal stability.

Preliminary calculations showed that the use of PDLLA plates in surgical practice will, on the one hand, reduce operative time and the need to harvest a transplant, and, on the other hand, decrease the need for revision procedures, making this surgical approach more cost-effective for the healthcare system.

Study Limitations

However, this retrospective study included results from only one hospital, had a limited sample of patients, and lacked a control group for comparison. Extensive studies in numerous health care facilities, with patient monitoring for at least 5 years and measurable airflow analysis, are required to demonstrate the advantages of this method over the conventional one using cartilage from the patient or polydioxanone foil. The sample size (37 patients) limits the ability to detect rare complications and establish statistically significant differences. Further multicenter trials with larger cohorts and long-term follow-up are required to confirm these findings. Additionally, the absence of a control group limits the ability to directly compare outcomes with those obtained using alternative techniques, such as autologous cartilage, PDS foil, or titanium mesh. This gap will be addressed in future randomized controlled trials that include control groups receiving autologous cartilage grafts.

This study employed only standard rhinomanometry at a fixed pressure. In subsequent research, we plan to incorporate additional objective assessment methods, including computational aerodynamics, airflow analysis, and validated olfactory testing.

CONCLUSION

This study provides the first clinical evidence that a perforated, fully bioresorbable PDLLA plate, when sutured to resected

septal cartilage fragments, can serve as a reliable and rigid-yet-temporary scaffold, providing mechanical stability for nasal dorsal aesthetic lines and maintaining physiologic nasal airflow during the critical early remodeling phase. In 37 consecutive patients, this method achieved the following:

- a median surgical duration of 137–215 minutes (depending on the surgical approach),

- a >90% reduction in SCHNOS scores at 3 months (median decrease from 24 (preoperatively) to 1 (postoperatively),

- no implant-related infections or extrusions over a median 24-month follow-up.

Serial histological analysis confirmed a predictable, two-stage hydrolytic degradation of the polymer: encapsulation at 12 months and complete replacement by collagenized connective tissue at 24 months, with no signs of chondrocyte damage or chronic inflammation. The results of the study demonstrated that 12 weeks of temporary support appear sufficient for intermediate-term stabilization; longer follow-up is warranted.

The clinical significance of this study consists of three points:

1. The first-in-human application of PDLLA plates for septal reconstruction,

2. Demonstration of a direct correlation between material performance and patient satisfaction (quantified via SCHNOS),

3. Histopathologic validation of tissue integration, corroborating prior preclinical data.

Future Research

Future research should progress beyond observational studies. A large, randomized, multicenter comparative trial with a 5-year follow-up evaluating PDLLA plates versus autologous cartilage, polydioxanone foils, and titanium meshes would demonstrate their efficacy, safety, and economic benefit. Further studies, such as high-resolution imaging and finite-element modeling, are clearly needed to elucidate the relationship between polymer degradation kinetics, dorsal contour preservation, and plate thickness optimization.

Future studies should focus on: (1) PDLLA materials that can release drugs or substances that promote bone or cartilage growth, (2) patient-specific 3D-printed plates for complicated cases of nasal septal perforation, (3) specialized hybrid copolymers for pediatric applications, and (4) cost-effectiveness analyses that incorporate quality-of-life metrics. These advancements would enhance material performance, expand surgical indications, and improve rhinoseptoplasty outcomes.

Additionally, focused research on revision rhinoplasty, cleft-related deformities, and ethnicity-specific nasal anatomy is needed to validate the efficacy of PDLLA plates across all septal reconstruction indications.

Video 1 Link: https://youtube.com/shorts/dZ4BWmwpU-w

Ethics

Ethics Committee Approval: This single-center retrospective analysis was approved by the Local Ethics Committee at the St. Petersburg State Pediatric Medical University (approval no: 32/06, dated: 08.11.2023).

Informed Consent: Retrospective study.

Footnotes

Author Contributions

Surgical and Medical Practices - A.M., N.K., P.P., M.D.; Concept - A.M., N.K., P.P.; Design - A.M., N.K., P.P.; Data Collection or Processing - A.M., M.D.; Analysis or Interpretation - A.M., N.K., P.P., M.D.; Literature Search - A.M., N.K., P.P., M.D.; Writing - A.M., N.K., P.P., M.D.

Conflict of Interest: No conflict of interest was declared by the authors.

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