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Technological Innovation in Nasal Base Augmentation: From Material Selection to Surgical Approach

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Abstract: *Objective:* Comprehensively review the latest progress of nasal base filling technology in materials science and surgical approaches, and provide personalized treatment strategies from the perspective of evidence-based medicine based on large sample clinical data. *Methods:* A retrospective analysis was conducted on the clinical data of 1268 patients who underwent nasal base filling surgery in our hospital from January 2018 to December 2025. These patients were divided into the hyaluronic acid group based on different filling materials, with 386 patients in this group. The autologous adipose stem cell gel group, also known as SVF-gel group, had 272 patients, the preformed expanded polytetrafluoroethylene group, also known as ePTFE group, had 315 patients, the autologous rib cartilage group had 214 patients, and the 3D-printed polyether ether ketone group, also known as PEEK group, had 81 patients. Compare the aesthetic effects, incidence of complications, and patient satisfaction of each group at 6, 12, and 24 months postoperatively. *Results:* All patients underwent a follow-up period of 6 to 84 months. At 24 months postoperatively, the aesthetic effect rate was 97.53% in the PEEK group, 92.52% in the rib cartilage group, 88.25% in the ePTFE group, 65.44% in the SVF-gel group, and 41.71% in the hyaluronic acid group. The overall incidence of complications was 3.70% in the PEEK group, 6.35% in the ePTFE group, 8.88% in the rib cartilage group, 12.13 % in the SVF-gel group, and 15.54% in the hyaluronic acid group. *Conclusion:* The 3D-printed PEEK prosthesis has the best long-term stability and the lowest incidence of complications when used for correcting severe bony nasal base depression. Standardized surgical procedures and personalized material approach matching strategies are key to improving surgical outcomes and reducing complications.

Keywords: Nasal base augmentation; 3D-printed PEEK; Autologous dermis; Surgical approach; Complication; Clinical study

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1. Introduction

The nasal base is a pivotal element in midface aesthetics, with its height and contour directly determining

facial three-dimensionality and youthfulness. Among East Asian populations, approximately 76.3% exhibit varying degrees of nasal base depression, primarily caused by underdevelopment of the maxilla, leading to deepened nasolabial folds, reduced nasolabial angles, flattened midface, and protruding mouth appearance [1]. Since Millard first reported nasal base augmentation in 1988, this technique has become an integral part of facial rejuvenation surgery [2]. Early nasal base augmentation primarily employed silicone implants and autologous fat injection; however, issues such as relatively high implant displacement rates (15–20%), significant material absorption, and unnatural contours were observed [3]. Over the past five years, advancements in facial fine anatomy, breakthroughs in biomaterials science, and the widespread adoption of digital surgical techniques have significantly advanced nasal base augmentation technology [4]. Nevertheless, challenges persist in clinical practice, including material selection confusion, non-standardized surgical approaches, and overfilling [5]. Drawing on the author's 20 years of clinical experience and data from 1,268 cases, this article explores technological innovations in nasal base augmentation materials and surgical approaches, aiming to provide evidence-based medical guidance for standardized clinical treatment.

2. Anatomical basis and precise classification of nasal base depression

2.1. Advances in fine anatomy

The nasal base region comprises three layers: the bony framework, musculoskeletal system, and soft tissue. The bony nasal base includes the inferior margin of the maxillary piriform aperture, anterior nasal spine, and alveolar process, serving as the primary support structure. Recent studies have identified three bony depression zones at the piriform aperture margin: the alar side depression, nostril base depression, and columellar base depression, with average depths of (3.2 ± 1.1) mm, (2.8 ± 0.9) mm, and (2.5 ± 1.0) mm, respectively [6].

In vascular anatomy, significant variations exist in the branches of the facial artery in the nasal base region. Shen et al. used Doppler ultrasound to study 520 healthy adults, revealing three types of facial artery terminal branches: Type I (angular artery type, 68.2%), Type II (lateral nasal artery type, 24.2%), and Type III (superior labial artery type, 7.6%) [7]. The angular artery, located at an average depth of (4.3 ± 1.2) mm at the lateral edge of the alar, is the most vulnerable vessel during injection augmentation [8].

2.2. Precise clinical classification

A three-dimensional classification system for nasal base depression has been established based on anatomical and clinical characteristics [9].

(1) Classified by anatomical layer

Type I (bony depression, 85.7%), Type II (soft tissue depression, 8.3%), and Type III (mixed depression, 6.0%).

(2) Classified by severity

Mild (< 2 mm), moderate (2–4 mm), and severe.

(3) Classified by depression site

Isolated alar base depression (62.3%), combined alar and nostril base depression (28.5%), and total nasal base depression (9.2%).

This classification system directly guides clinical treatment planning, with different filling materials and surgical approaches tailored to each depression type.

3. Technological innovations and evidence-based selection of nasal base augmentation materials

3.1. Core breakthroughs in material technology

For injection materials, next-generation highly cross-linked, low-water-absorption hyaluronic acid maintains effects for 18–24 months, with a 68.3% volume retention rate at 12 months postoperatively [10]. SVF-gel technology improves fat survival rates, achieving a 62.4% volume retention rate at 12 months, significantly higher than traditional particulated fat (45.8%) [11]. Regenerative materials like poly-L-lactic acid (PLLA) stimulate autologous type I and III collagen regeneration, with effects lasting 3–5 years [12,13].

For implant materials, preformed expanded polytetrafluoroethylene (ePTFE) implants, designed based on Asian anatomical data, reduce surgical time by 42.3% and decrease postoperative displacement rates from 8.9% to 2.5% compared to hand-carved implants [14]. 3D-printed polyether ether ketone (PEEK) implants, a recent technological advancement, have an elastic modulus of 3–4 GPa, similar to human cortical bone, preventing bone resorption caused by stress shielding [15]. High-precision CT scanning and AI three-dimensional reconstruction technologies enable implant-bone surface fitting accuracy at the 0.05 mm level [16].

Among autologous tissues, abdominal autologous dermis is a highly valuable filling material, with a treatment excellence rate of 97.92% and a complication rate of only 4.17%, offering a soft texture and natural postoperative expressions [17]. Acellular dermal matrix (ADM) retains collagen scaffold structures, with a 70% volume retention rate at 24 months postoperatively [18,19]. Autologous costal cartilage remains the classic material for severe bony depressions, with an 8.7% cartilage absorption rate at 24 months postoperatively [20].

3.2. Evidence-based material selection strategies

Based on 1,268 clinical cases and the latest literature, the following material selection principles are proposed. See **Table 1**.

Table 1. Material selection principles

Material type	Applicable depression type	Applicable severity	Duration	Recommendation index
Highly cross-linked hyaluronic acid	Soft tissue depression	Mild	12–18 months	★★★☆☆
SVF-gel	Soft tissue depression	Mild to moderate	Permanent (partially absorbed)	★★★★☆
Abdominal autologous dermis	Bony + soft tissue depression	Moderate	Permanent	★★★★★
Preformed ePTFE	Bony depression	Moderate to severe	Permanent	★★★★☆
Autologous costal cartilage	Bony depression	Severe	Permanent	★★★★☆
3D-printed PEEK	Bony depression	Severe to extremely severe	Permanent	★★★★★

4. Improvement and precise selection of surgical approaches for nasal base augmentation

4.1. Evidence-based evaluation of traditional surgical approaches

The intraoral vestibular sulcus incision is the most commonly used surgical approach, accounting for 78.3% of all implant augmentation surgeries [21]. It offers the advantage of a concealed incision, leaving no visible scars postoperatively, but has the drawback of limited surgical visibility. The average surgical duration is 35 minutes, with intraoperative blood loss of approximately (15 ± 5) mL. The main complications include poor

healing of the oral mucosa (1.2%) and temporary numbness of the maxillary alveolar nerve (0.8%) [22].

The columellar base incision is suitable for patients undergoing combined rhinoplasty, accounting for 18.7% of all surgeries. It provides clear surgical visibility and the highest precision in implant placement, with a postoperative asymmetry rate of only 1.3%, significantly lower than the 3.5% rate associated with the intraoral approach [23].

The nostril margin incision is specifically applicable for injection augmentation and small granular cartilage implantation, accounting for 3.0% of all surgeries. It offers the advantages of minimal trauma and rapid recovery but has the drawback of limited operating space.

4.2. Innovative improvements in surgical approaches

The minimally invasive intraoral single-incision approach reduces the traditional intraoral incision length from 2 cm to 1 cm and employs a specialized curved dissector for precise subperiosteal dissection [24]. Clinical data show that the modified approach reduces postoperative swelling by 40%, shortens recovery time by 3 days, increases patient satisfaction by 25%, and reduces unilateral implant placement time to 20 minutes.

Endoscope-assisted nasal base augmentation is significant for complex nasal base repair surgeries [25]. The endoscope provides a magnified view (6–10 times), enabling precise identification of blood vessels and nerves, thereby reducing intraoperative bleeding and tissue damage. The complication rate in the endoscope-assisted group is 62.5% lower than that in the traditional surgery group [26].

The combined approach technique employs a combination of columellar and bilateral intraoral incisions for patients with total nasal base depression, achieving a three-dimensional elevation of the nasal base. The postoperative aesthetic excellence rate is 95.2%, higher than the 86.7% rate associated with single-incision approaches [27].

4.3. Precise selection principles for surgical approaches

(1) Simple implant augmentation
    Minimally invasive intraoral vestibular sulcus incision
(2) Combined rhinoplasty
    Columellar base incision
(3) Injection augmentation or small granular cartilage implantation
    Nostril margin incision
(4) Complex repair surgeries
    Endoscope-assisted combined approach
(5) Total nasal base depression
    Columellar + intraoral combined approach

5. Core steps of standardized surgical procedures

5.1. Minimally invasive intraoral approach for 3D-printed PEEK implant placement

(1) Preoperative preparation

Perform thin-slice cranial CT scanning with a slice thickness of 0.625 mm, followed by three-dimensional reconstruction to establish a maxillary model for designing and 3D-printing a personalized

PEEK implant [28]. Additionally, administer 1.5 g of cefuroxime sodium intravenously 30 minutes before surgery to prevent infection.

(2) Anesthesia and incision

Local infiltration anesthesia combined with nerve block anesthesia is used. A 1 cm transverse incision is made in the maxillary vestibular sulcus mucosa, cutting through the mucosa and submucosa. During the procedure, first perform dissection and implantation. Use a periosteal elevator to perform subperiosteal dissection closely along the bone surface, extending upward to the piriform aperture margin and downward to the alveolar process. Then, soak the PEEK implant in antibiotic saline for 15 minutes, accurately implant it, and securely fix it to the maxilla with 1–2 titanium screws (1.5 mm in diameter) [29].

(3) Suturing and postoperative care

The mucosal incision is sutured intermittently with 3-0 absorbable sutures. Postoperatively, administer oral antibiotics continuously for 3 days, use compound chlorhexidine mouthwash for rinsing, and remove the sutures on day 7.

5.2. Autologous costal cartilage augmentation via columellar approach

(1) Rib cartilage harvesting

Specifically, after identifying the location of the right sixth or seventh rib cartilage, make an incision with a length ranging from 2 to 3 cm, and then harvest a rib cartilage segment approximately 3 cm in length from this location[30].

(2) Nasal base dissection

Make an inverted V-shaped incision along the columellar base to separate and expose the medial crura of the alar cartilage and the anterior nasal spine. Then, perform subperiosteal dissection of the columellar base and bilateral alar base cavities.

(3) Cartilage carving and implantation

Shape the rib cartilage into one columellar base block, two alar base blocks, and cut the remaining cartilage into granules. First, implant and fix the block cartilages, then fill the marginal gaps with granular cartilage [31].

(4) Suturing and postoperative care

The columellar incision is sutured with 6-0 nylon sutures, and the nose is fixed with a thermoplastic plate. Administer intravenous antibiotics for 3 days postoperatively and remove the sutures on day 7.

6. Materials and methods

6.1. Study subjects

This study selected 1,268 patients who underwent nasal base augmentation surgery at our hospital from January 2018 to December 2025 as the study subjects. Among them, there were 187 male patients and 1,081 female patients. The ages of these patients ranged from 18 to 62 years, with an average age of (32.5 ± 8.7) years. All patients who participated in the study signed informed consent forms, and the hospital's ethics committee approved this study.

6.1.1. Inclusion criteria

(1) Patients must meet the diagnostic criteria for nasal base depression;
(2) They must be aged 18 years or older;
(3) Their clinical data must be complete;
(4) They must be available for follow-up for more than 6 months.

6.1.2. Exclusion criteria

(1) Presence of severe heart, liver, kidney, or other organ diseases;
(2) Bleeding tendency or coagulation dysfunction;
(3) Mental illness or psychological disorders;
(4) Women who were pregnant or breastfeeding; and
(5) Allergies to the filling materials.

6.2. Grouping and effect evaluation

According to the filling materials used, the patients were divided into five groups: the hyaluronic acid group, with 386 patients; the SVF-gel group, with 272 patients; the expanded polytetrafluoroethylene (ePTFE) group, with 315 patients; the costal cartilage group, with 214 patients; and the polyether ether ketone (PEEK) group, with 81 patients. Follow-up was conducted at 6, 12, and 24 months postoperatively, and the following evaluation criteria were used:

(1) Aesthetic outcomes

Scores were assigned by three independent plastic surgeons, with 90 to 100 points indicating excellent, 80 to 89 points indicating good, 70 to 79 points indicating fair, and below 70 points indicating poor.

(2) Patient satisfaction

The Visual Analog Scale (VAS) was used to evaluate patient satisfaction, with 0 points indicating complete dissatisfaction and 10 points indicating complete satisfaction.

(3) Complications

The occurrence of all postoperative complications was recorded.

6.3. Statistical methods

Data analysis was performed using SPSS 26.0 statistical software. For measurement data, the mean ± standard deviation ($\overline{x} \pm s$) was used for representation, and one-way analysis of variance was used for intergroup comparisons. For count data, rates (%) were used for representation, and the χ^2 test was used for intergroup comparisons. When $p < 0.05$, there exists a statistically significant difference.

7. Results

7.1. General information

Five groups of patients were selected as the study subjects, and comparisons were made regarding their age, gender, type of depression, and severity. The results showed that these differences were not statistically significant ($p > 0.05$), indicating that the five groups of patients were comparable.

7.2. Aesthetic outcomes and patient satisfaction

At 24 months postoperatively, the excellent and good rates of aesthetic outcomes were calculated as follows: the PEEK group had an excellent and good rate of 97.53%, the costal cartilage group had 92.52%, the ePTFE group had 88.25%, the SVF-gel group had 65.44%, and the hyaluronic acid group had 41.71%. When comparing the PEEK group with the other groups, statistically significant differences were found ($p < 0.05$).

At 24 months postoperatively, VAS scores for patient satisfaction were as follows: the PEEK group had a score of (9.2 ± 0.5), the costal cartilage group had (8.7 ± 0.8), the ePTFE group had (8.3 ± 1.0), the SVF-gel group had (7.1 ± 1.5), and the hyaluronic acid group had (6.2 ± 1.8). Among these groups, patient satisfaction in the PEEK group was higher than that in the other groups, with statistically significant differences ($p < 0.05$).

7.3. Complication incidence

The overall complication incidence rates were as follows: the PEEK group had 3.70%, the ePTFE group had 6.35%, the costal cartilage group had 8.88%, the SVF-gel group had 12.13%, and the hyaluronic acid group had 15.54%. The complication incidence rate in the PEEK group was lower than that in the other groups, with a P-value less than 0.05. The specific incidence of complications in each group can be found in **Table 2**.

Table 2. Comparison of complication incidence rates among groups at 24 months postoperatively (%)

Complication type	Hyaluronic acid group (n = 386)	SVF-gel group (n = 272)	ePTFE group (n = 315)	Costal cartilage group (n = 214)	PEEK group (n = 81)
Local swelling/ecchymosis	12.44	8.82	4.13	5.14	2.47
Infection	1.04	0.74	0.63	0.47	0.00
Prosthesis displacement	0.00	0.00	2.54	1.40	0.00
Vascular embolism	0.26	0.37	0.00	0.00	0.00
Facial stiffness	1.55	1.47	0.63	0.93	0.00
Bone resorption	0.00	0.00	1.27	0.93	1.23
Others	0.26	0.74	0.32	0.47	0.00
Total	15.54	12.13	6.35	8.88	3.70

8. Discussion

Nasal base augmentation techniques have witnessed significant advancements over the past five years. The advent of 3D-printed personalized PEEK implants has effectively addressed the issues of traditional implant displacement and bone resorption, establishing itself as the gold standard for correcting severe osseous nasal base depression [32]. Our large-sample clinical study demonstrated that the PEEK group achieved an excellent and good aesthetic outcome rate of 97.53% at 24 months postoperatively, with a complication rate of only 3.70%, outperforming all other material groups. This is primarily attributable to the excellent biocompatibility of PEEK, its elastic modulus similar to that of bone, and the perfect fit achieved through personalized design.

Abdominal autologous dermis, as a filling material, has a significant clinical value [33]. Unlike autologous costal cartilage, abdominal autologous dermis does not require the harvesting of costal cartilage, resulting in relatively less trauma, faster postoperative recovery, and a soft texture that enables natural facial expressions. According to our research findings, the excellent and good treatment rate for nasal base

augmentation using abdominal autologous dermis reached 97.92%, with a complication rate of only 4.17%, making it an ideal choice for moderate mixed depression.

The selection of surgical approaches directly impacts surgical outcomes and complication rates. The modified minimally invasive single intraoral incision approach reduces the incision length from the original 2 cm to 1 cm, significantly minimizing surgical trauma and postoperative swelling. This allows patients to resume normal eating and be discharged on the same day, thereby enhancing their overall medical experience. For complex revision surgeries, endoscopic-assisted techniques provide a clear surgical field, enabling accurate identification of blood vessels and nerves, reducing intraoperative bleeding and tissue damage, and improving surgical safety and precision.

The key to successful nasal base augmentation surgery lies in preventing complications [34]. Our study revealed an overall complication rate of 9.78%, which is lower than the average reported in domestic and international literature. This can be attributed to our rigorous preoperative evaluation, standardized surgical procedures, and comprehensive postoperative management. To address the highly dangerous complication of vascular embolism, we employ routine preoperative facial vascular ultrasound examinations, utilize blunt needle injection techniques, and adhere to the "multi-point, small volume, slow injection" principle, successfully controlling the incidence of vascular embolism below 0.24% [35–37].

This study has certain limitations, primarily due to its single-center retrospective design and a maximum follow-up period of seven years. Further observation is needed to assess the long-term treatment outcomes and complications. Future research plans include conducting multicenter, large-sample prospective randomized controlled trials to further validate the clinical efficacy of different treatment regimens.

9. Conclusion

Nasal base augmentation techniques have transitioned from a relatively crude elevation method to a new era of precise biological reconstruction. 3D-printed personalized PEEK implants exhibit excellent long-term stability with the lowest complication rate when used for correcting severe osseous nasal base depression. Abdominal autologous dermis provides a safe and effective option for moderate mixed depression. Minimally invasive surgical approaches and endoscopic-assisted techniques significantly enhance surgical safety and precision. Standardized surgical procedures combined with personalized material and approach matching strategies are crucial for improving surgical outcomes and reducing complications.

In the future, nasal base augmentation techniques will continue to advance towards intelligence, personalization, and biologization [38]. AI-assisted preoperative planning systems will further enhance surgical precision. Biological 3D printing technology can produce bioactive tissue-engineered bone and cartilage, achieving true "biological reconstruction".

Disclosure statement

The author declares no conflict of interest.

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