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ORIGINAL ARTICLE
Reconstructive

Nasal Alar and Tip Reconstruction Following Mohs Surgery Using Fresh Frozen Human Costal Cartilage Allograft: A Novel Approach

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Background: Skin cancer patients who undergo Mohs surgery may require subsequent reconstructive rhinoplasty for large nasal defects. Autologous cartilage is the primary source of supporting cartilage grafts, but carries the risk of potential donor-site complications. In this study, we demonstrate the safety and efficacy of nonterminally irradiated fresh frozen human costal cartilage allografts (CCAs) in reconstructive rhinoplasty after skin cancer removal.

Methods: A retrospective chart review of 25 patients who underwent reconstructive rhinoplasties using human CCA after basal cell carcinoma resection was conducted. Human CCA undergoes a process of sterilization without terminal irradiation and is stored frozen (−40°C to −80°C). Anthropometric measurements were taken on pre- and postoperative photographs to evaluate nasal tip projection. Adverse events were evaluated.

Results: There were 25 participants, with an average age of 71 years at the time of surgery (range: 42–90). The average follow-up duration was 12 months (range: 3–66 mo). Types of grafts used included alar batten graft (n = 17, 68%), nasal tip graft (n = 7, 28%), and alar batten graft with nasal tip graft (n = 1, 4%). Measurements on the 2-dimensional photographs of the patients showed no significant resorption or deviation at the 6- or 12-month follow-up. No significant complications related to the use of the cartilage were noted.

Conclusions: Our data highlight the low complication rate and aesthetically positive outcomes from using nonterminally irradiated human CCA for reconstructive rhinoplasties in post-Mohs surgery for older patients. This approach offers a reliable source of high-quality cartilage for reconstruction. *(Plast Reconstr Surg Glob Open 2025;13:e6790; doi: 10.1097/GOX.0000000000006790; Published online 12 May 2025.)*

INTRODUCTION

Skin cancer is the most common cancer globally.[1,2] One in 5 Americans will develop skin cancer in their lifetime with basal cell cancers having the highest incidence.[3] Death from basal cell carcinoma (BCC) is uncommon and decreasing,[4,5] which makes improving the quality of life and social confidence of these patients increasingly important. Approximately 80% of BCCs develop on the head and neck of a patient, regions with the most exposure to sunlight.[6] The nose, primarily the nasal tip and alae, is an extremely common anatomical location for the development of BCC.[7] Although BCCs have the tendency to grow and spread very slowly, these cancers are notorious for being able to deeply infiltrate surrounding tissues, thus leading to nasal cartilage invasion.

Mohs surgery is considered the most effective technique to treat nonmelanoma skin cancers.[8] Removal of cancerous cells by Mohs surgery has a high cure rate but often leaves resultant tissue defects on the face. Reconstructive rhinoplasty of full-thickness nasal defects

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Received for publication October 30, 2024; accepted March 24, 2025.

DOI: 10.1097/GOX.0000000000006790

Disclosure statements are at the end of this article, following the correspondence information.

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is essential to restore a functional nasal airway and achieve aesthetic outcomes for post-Mohs surgery patients.

Autologous cartilage grafts are widely considered an ideal material for reconstructive rhinoplasties due to their biocompatibility and low complication rates.[9] They are, however, associated with prolonged operative time, possible hypertrophic scars, pain, graft warping, and infection.[9,10] Terminally irradiated allografts have attempted to mitigate these deficits but have been noted to have higher rates of resorption and infection.[11,12]

The fresh frozen, nonterminally irradiated, human costal cartilage allograft (CCA) from MTF Biologics (Edison, NJ) is a novel option for reconstructive rhinoplasties. Currently, there are no studies on the use and efficacy of human CCA in reconstructive rhinoplasty. We describe our early experience with the use of human CCA on patients undergoing reconstructive rhinoplasty after BCC cancer resection.

Takeaways

Question: Are fresh frozen cadaveric costal allografts a suitable alternative to current reconstructive rhinoplasty techniques?

Findings: A retrospective chart review of 25 patients who underwent reconstructive rhinoplasties using cadaveric costal allografts showed that there was no significant resorption or deviation at 6 or 12 months postoperatively. All procedures were performed by the corresponding author, Dr. Galiano, at Northwestern Memorial Hospital. There were also no significant complications related to the use of the cartilage.

Meaning: The use of fresh frozen cadaveric costal allografts in reconstructive rhinoplasty delivered low complication rates and aesthetically positive outcomes for patients following Mohs surgery.

METHODS

A retrospective chart review was conducted at our institution after being approved by the Northwestern University institutional review board. The guidelines of the Declaration of Helsinki were followed, and written informed consent was obtained from all patients included in this study. Patients who underwent Mohs surgery with postoperative nasal defects between September 1, 2016, and May 1, 2024, were screened, and only those who subsequently received human CCA for their reconstructive rhinoplasties were selected. These patients were selected to undergo CCA reconstruction because of their age and the size of grafts needed. Given that most participants were older, harvesting from the rib was not an option due to the mineralization that occurs in older patients. Additionally, patients expressed that they did not want cartilage to be taken from their septum or ears, leading to CCA being the most viable option. All procedures were performed by the senior author (R.D.G), who is an attending plastic surgeon at Northwestern Memorial Hospital.

Patient data, including basic demographics, medical history, operative notes, types of grafts, follow-up notes, and complications were extracted from the electronic medical record. Two-dimensional (2D) photographs were taken in the standard photography room with the same lighting in the clinic preoperatively and at 3-month, 6-month, and 1-year intervals postoperatively. Anthropometric measurements, including nasolabial angles and Goode ratios, were taken on 2D photographs to evaluate nose tip projection in patients who underwent nasal tip reconstruction. Complications were reviewed including infection, nasal deviation, resorption, nasal obstruction, flap necrosis, and reoperation. The research team was proactive in minimizing potential bias introduced by MTF Biologics' funding of the project. The surgeon, who is the recipient of MTF's funding, was not involved in taking anthropometric measurements. These are well-defined anatomic landmarks with little room for bias. Additionally, postoperative complications were documented based on honest narratives given by the patients, who did not receive financial compensation for their participation in the study.

Surgical Technique

The cartilage grafts were harvested from sheets of human CCA after the forehead flaps or nasolabial flaps were fully elevated. Before surgery, human CCA was shipped and stored at temperatures between −40°C and −80°C. They were thawed and hydrated in normal saline at room temperature before implantation. This novel material was provided by MTF Biologics and is processed by the Musculoskeletal Transplant Foundation (Edison, NJ) under high-quality aseptic and sterility standards (Fig. 1).

In our cohort, human CCA was used for alar batten grafts and/or nasal tip grafts. Number 10 blades were used to carve out batten grafts to reconstruct the lower rim(s) of the left and/or right ala. For nasal tip grafts, they can be shaped and contoured in 1 or 2 pecks, depending on the size and shape of the defects. Human CCA can be stacked on top of each other. Once the grafts were of the appropriate dimensions, they were secured to the underlying tissues with horizontal mattress 5-0 PDS sutures. The video shows the senior author's surgical technique for the placement of the cartilage and highlights the graft's favorable contour and stability. (**See Video [online]**, which displays the use of nonterminally irradiated fresh frozen human CCAs in reconstructive rhinoplasty.) Postoperative follow-ups and care were no different from rhinoplasties using autologous grafts, and no care for donor sites was required.

Statistical analysis was performed using Microsoft Office Excel Version 2412. Descriptive statistics were also calculated using Excel.

RESULTS

There was a total of 25 patients who met the inclusion criteria, with an average age of 71 years at the time of surgery (range: 42–90); 16 were men (64%), and 9 were women (36%). The mean follow-up duration was 12 months (range: 3–66 mo). Types of grafts used included alar batten graft (n = 17, 68%), nasal tip graft (n = 7, 28%), and alar batten graft with nasal tip graft (n = 1, 4%). One of the patients reported occasional difficulty breathing at the 1-month follow-up; however, this could easily be

Fig. 1. The CCA and packaging.

Table 1. Summary of Patient Demographics and Medical History

Total participants	25
Average age	71 y
Average duration of follow-up	12 mo
Sex	
Female	9
Male	16
Complications	
Yes	3
No	22
Graft	
Alar batten graft	17
Nasal tip graft	7
Alar batten graft and nasal tip graft	1
Medical history	
BCC on right ala	9
BCC on left ala	6
BCC on nasal tip	7
BCC on ala and nasal tip	2

Complications included 2 instances of restricted airflow and 1 instance of occasional difficulty breathing.

remedied with nasal strips for congestion relief. Two patients experienced decreased airflow at the 3-month follow-up. Neither patient required revision surgery, nor did either report long-term respiratory problems. We considered these complications to be unrelated to the grafting material. No other complications for any patient were noted. There was no distortion of the alar-free margin or resorption of the nasal tip. Patient demographic information, skin cancer history, types of grafts, follow-up period, and complications are displayed in Table 1.

All 25 patients experienced adequate structural support as well as aesthetic satisfaction. We demonstrated the warping and resorption of human CCA using the change of various nasal angles as well as the Goode ratio between 2 follow-up time points $\Delta = |\text{Visit}_2 - \text{Visit}_1|$. The nasal angles evaluated included the nasofrontal angle, nasofacial angle, and nasolabial angle. The average changes of the angles between the 6-month postoperative and 1-year postoperative visits are shown in Table 2. Figure 2 shows how these anthropometric measurements were obtained from 2D patient photographs using Mirror. The changes between the 2 follow-up time points were not clinically significant.

Table 2. Average Changes in Anthropometric Measurements From 2D Photographs of Patients Between Postoperative Visits at 6 Months and 1 Year or Longer

Δ Nasofrontal	Δ Nasofacial	Δ Nasolabial	Δ Goode Ratio
2.74 degrees	1.66 degrees	3.94 degrees	0.059

Figure 3 shows the patient with the largest defect in our cohort, who received both nasal tip and nasal alar grafts. The nasal projection remained satisfactory at 7 months after the procedure, and the left alar remained well-supported. The nasal angles and Goode ratio did not significantly change 5 years postoperatively. Additional patient examples are included in Figures. 4–6. These photographs show the postoperative results of both nasal tip and alar batten grafts. All these patients expressed that they were happy with their results at their postoperative visits and did not report any complications.

DISCUSSION

Nasal reconstruction is frequently required following skin cancer excision on the face. Defects on the nose not only affect the patients' psychosocial well-being but can also interfere with airway functionality. Small nasal defects can typically be repaired on the same day as the skin cancer removal by Mohs surgeons. Large and deep defects often require the assistance of plastic and reconstructive surgeons to perform reconstructive rhinoplasties. Although some defects are superficial and can be reconstructed by skin flaps or grafts only, full-thickness lesions that affect the rigid nasal framework need supporting grafts for structural stability and positive aesthetic and functional outcomes.

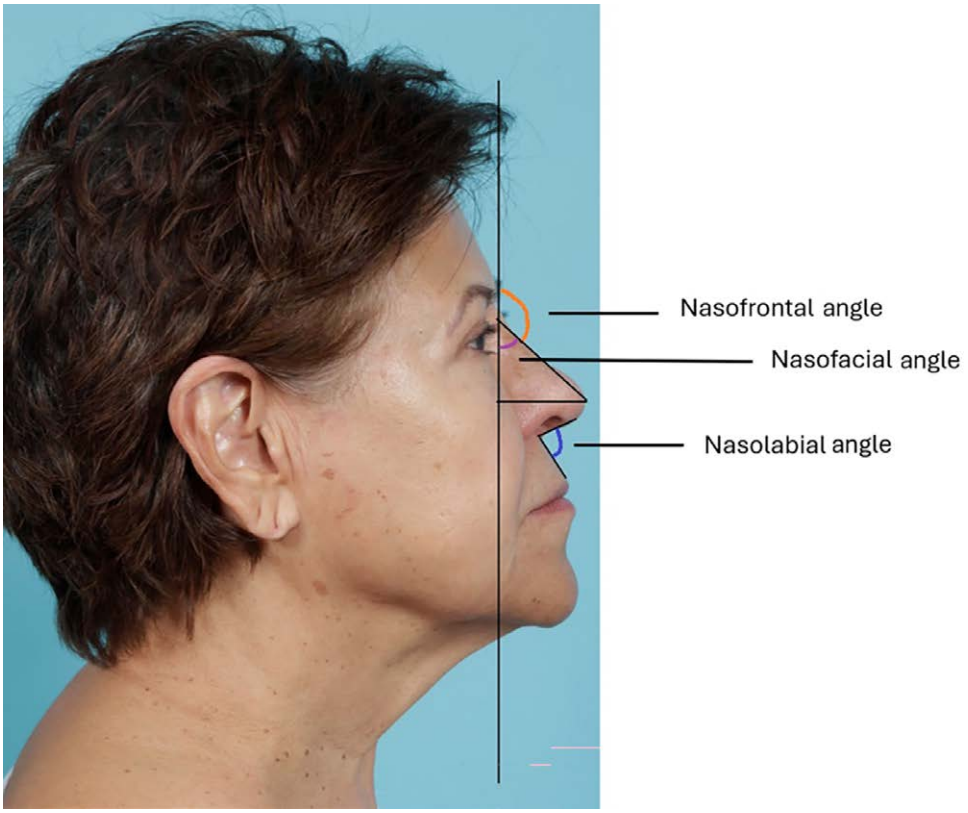

Fig. 2. Anthropometric measurements of the nose and lips.

Fig. 3. Preoperative and postoperative (7 mo and 5.5 y) photographs of a patient who had large full-thickness nasal defects after Mohs surgery. Following reconstructive surgery, the shape and function of the nose were restored.

There are various types of cartilage grafting materials with their own advantages and disadvantages. Autologous cartilage is the favored option among surgeons as well as patients, due to its biocompatibility and low rates of infection, extrusion, displacement, and resorption. Sources for autologous cartilage grafts include the nasal septum, ear concha, and rib.[9] Although septal cartilage is easy to harvest, it is often insufficient or absent in post skin cancer removal patients who need nasal reconstruction.[9] This frequently leads to the use of costal or conchal autografts.

Fig. 4. Preoperative and postoperative photographs (3 and 15 mo) of a patient who had positive aesthetic and functional outcomes following reconstruction of the left ala. An alar batten graft sized to support the entire surface of the left ala was fashioned.

Fig. 5. Preoperative and postoperative photographs (6 and 20 mo) of a patient who had reconstructive surgery following a nasal tip Mohs defect.

Costal cartilage provides the most durable strength and can be harvested in large quantities; therefore, it is often used for total or subtotal nasal defects.[9,13] The procedure of harvesting costal cartilage is not without risk, as it requires general anesthesia, prolonged surgical time, and expensive surgical costs, and places patients at risk for donor-site complications, including pneumothorax and chest wall deformity. Auricular cartilage is commonly used for nasal alar defects after Mohs micrographic surgery because its inherent curvature is ideal for alar reconstruction.[9,13] Auricular cartilage is simpler to obtain than costal cartilage and has less severe donor-site complications compared with autologous costal grafts.[14] However, patients who have their cartilage removed from the conchal bowl can later develop difficulties using in-ear headphones and hearing aids. This can further affect the quality of life among patients, especially the older population. Thus, a material that has the advantages of autologous cartilage but eliminates donor-site morbidities will benefit patients greatly.

Fig. 6. Preoperative and postoperative photographs (4 mo and 4 y) of a patient who received an alar batten graft after a left ala Mohs defect.

Terminally irradiated cartilage allografts provide the advantages of no donor-site morbidity, shorter operation time, and lower cost. They were, therefore, introduced to be used in rhinoplasty procedures. However, numerous studies demonstrate that terminally irradiated cartilage allografts lead to higher rates of resorption, infection, and nondonor-site graft-related complications compared with autologous cartilage.[11,12,15] This is mainly due to the fact that terminally irradiated and sterilized cartilage allografts do not contain any viable chondrocytes.[12,16] Therefore, the terminally irradiated cartilage allografts have not become mainstream in reconstructive rhinoplasty.

Human CCA is a novel material that is not processed using terminal irradiation. It is designed to be used for both reconstructive and cosmetic rhinoplasty.[17,18] Review of existing literature shows that there are currently 10 articles describing the experience of using human CCA in rhinoplasty, with focuses on revision rhinoplasty, augmentation rhinoplasty, and nonselective rhinoplasty. Of the 3 articles focusing on revision rhinoplasty, their formatting includes a case report, a clinical study of 50 patients, and a 9-year retrospective review of 226 patients.[17–19] Two articles were published by our group, with one focused on Asian rhinoplasty and the other being a prospective clinical trial that compared the use of human CCA to autologous costal cartilage.[20,21] Both showed satisfactory outcomes with relatively long-term observation. The sixth article is from Canada and outlines the authors' experience in using the cartilage allografts on 11 primary and 10 secondary rhinoplasties.[22] They had 1 case of graft resorption. The latest article about human CCA analyzed its complications in 282 cases and reported 0 cases of postoperative warping, resorption, or displacement.[23] But the ages of the patients (35.8 y old) are much younger than our cohort (71 y old). Overall, all 7 articles shared similarities within their preliminary data, which highlighted the ease of obtainability, avoidance of donor-site morbidity, flexibility of the graft characteristics, and low complication rates.

In comparison to existing data, our cohort using allografts for alar batten grafts and tip grafts demonstrated good long-term surgical outcomes and did not experience resorption or warping of the cartilage. Table 2 shows slight differences in anthropometric measurements between 6-months and 1-year postoperative photographs, which did not result in visible changes in patient appearance or satisfaction as reported in their visit documentation. Previous literature has revealed that two-thirds of swelling resolves within the first month following rhinoplasty.[24] Approximately 95% and 97.5% of edema resolves by 6 months and 1 year postoperatively, respectively. These findings support that remaining unresolved edema at these time points would have a negligible effect on appearance and anthropometric measurements obtained in Table 2.

In addition to this, our patients benefited from having only 1 surgical site, no surgical time required to harvest the grafts, and no general anesthesia cost. Furthermore, the use of human CCA appears to have the combined advantages of both allografts and autologous cartilage. Although the cost of shipment and storage of human CCA is high, the full price of the procedure is still lower than the use of autologous rib cartilage. In addition to the previously mentioned benefits, it is also important to consider the quality of the cartilage used, primarily due to age. Autologous cartilage has been known to be "stiffer" as a result of calcification from aging. The average age of our patients was 71 years old, which is older compared with that of the donors of human CCA, who were younger than 55 years old.[19] Additionally, human CCAs are recovered and processed from donors who were chosen under strict acceptance criteria, with less than 2% of offered donors

Table 3. Comparison of Autologous Grafts From Different Locations and Fresh Frozen Cartilage in Reconstructive Rhinoplasty for Skin Cancer Patients

Graft Location	Conchal	Septal	Costal	Fresh Frozen
Amount	+	–	++	+++
Quality	Dependent on the health condition and age of the patients	Dependent on the health condition and age of the patients	Dependent on the health condition and age of the patients	Strict screening for donors, <55 y old
Donor-site complications	+	–	++	NA
Shape	Concave	NA	Straight	Any shape
Support	–	+	++	+
Operation time	+	–	++	–

+, Increased; –, decreased.

accepted. Hence, it can be concluded that human CCA is an excellent material for use in older patients who normally have poor cartilage quality (Table 3).

To our knowledge, this is the first extended series demonstrating the use of human CCA for reconstructive rhinoplasty after Mohs surgery. We believe this novel graft can provide potential advances in the care of patients with deep nasal defects following tumor extirpation.

LIMITATIONS

This cohort consisted of a relatively small sample size and used only the CCA for alar batten and nasal tip grafts. Additionally, this observational study did not include any control participants. Despite this lack of a formal control group, we have years of experience doing autologous reconstruction with which we can compare these results. We found that the product performed as well as autologous cartilage but with the additional advantage of no secondary donor site. Another limitation stems from the 2D imaging that we were using for anthropometric measurements, which could lead to slight inaccuracies resulting from the positioning of the camera or the patient in the photograph. Although 3D imaging is generally more reliable, our practice has established physical landmarks that guide standardized patient posture and positioning while taking photographs that mitigate the variability of 2D imaging. Further investigations involving a greater number of patients, more types of rhinoplasty grafts, and assessments of patient-reported outcomes are necessary.

CONCLUSIONS

Our study demonstrated a low complication rate and positive surgical outcomes following the use of nonterminally irradiated CCA for reconstructive rhinoplasties after skin cancer resection. Out of 25 participants, only 3 patients had postoperative complications, none of which required revision surgery. Many patients reported being happy with their results and did not seek further medical attention regarding their nasal function. In addition, CCA provides older patients with high-quality, supportive cartilage that they may otherwise lack. The aesthetic and functional success of CCA in the present study highlights its potential for increased usage in reconstructive and cosmetic plastic surgery procedures. Plastic surgeons should consider the use of CCA for patients who may face additional complications, such as hypertrophic scarring, pain, or surgical site infection, as a result of a secondary donor site. Nonterminally irradiated CCA can be used to restore support in the nose, as demonstrated in the present study, or can be used to favorably alter one's nasal contour such as in Asian rhinoplasty. Further investigation involving a larger sample size and more types of rhinoplasty grafts would add to the existing data supporting the efficacy of CCA over other grafting materials.

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DISCLOSURES

Dr. Galiano is a consultant and is on the Medical Board of Trustees of MTF Biologics. The other authors have no financial interest to declare in relation to the content of this article. This study was funded by MTF Biologics.

PATIENT CONSENT

Patients provided written consent for the use of their images.

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