Outcomes of the Use of Fresh-Frozen Costal Cartilage in Rhinoplasty

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Background: Rhinoplasty is made more challenging when there is insufficient septal cartilage for use as graft material. Several autologous and homologous graft options have been used in the past, although each comes with its own set of challenges. Fresh-frozen costal cartilage (FFCC) is an increasingly popular alternative that yields the benefits of homologous tissue while having a lower theoretical risk profile. Given the relatively novel nature of this option, the authors analyzed the complication rates of Musculoskeletal Transplant Foundation FFCC.

Methods: A retrospective chart review of the use of FFCC in rhinoplasty in the senior author's (R.G.R.) practice was conducted between March of 2018 to December of 2021. A total of 282 cases were reviewed and analyzed for rates of infection, warping, and resorption. Patients with a minimum of 12 months of follow-up were included.

Results: The mean age of the study group was 35.8 years, and 27 male and 255 female patients were included. Forty cases were primary rhinoplasties; the remaining 242 were revisions. The mean follow-up period was 20.3 months. Six patients (2.1%) required empiric antibiotics postoperatively; no patient had clinical signs of warping, resorption, or displacement, and 6 patients (2.1%) required operative revision unrelated to the FFCC.

Conclusions: This study provides follow-up data on the complication profile of FFCC in rhinoplasty. Acute infection, warping, and resorption rates were found to be no greater than rhinoplasty complication rates when autologous or homologous tissue is used. FFCC is a safe, convenient, and patient-centered option for graft tissue in rhinoplasty. *(Plast. Reconstr. Surg.* 154: 324, 2024.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

Rhinoplasty is among the most commonly performed facial surgery procedures in the United States, and approximately 5% to 15% of these procedures are revision rhinoplasties.[1,2] Septal cartilage is the primary choice for graft material in rhinoplasty, and thus, revision surgery is more challenging because alternative sources of graft material are often required to address patients' functional and aesthetic concerns.[2] In addition, patients undergoing primary rhinoplasty with a significantly deviated septum, small quadrangular cartilage, or previous trauma or cocaine use may require alternative graft material to accomplish the goals of surgery. Until recently, the most popular alternatives for graft material were autologous costal cartilage (ACC) and irradiated homologous costal cartilage (IHCC).[3] Autologous tissue has minimal bioreactivity and low resorption rates. However, harvesting ACC is associated with increased operative time and

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donor-site morbidity, including a potentially visible scar and the potential for pneumothorax, chest wall deformities, and additional postoperative pain.[4,5] IHCC is commercially available, does not increase operative time, and avoids donor-site morbidity, but it has an increased susceptibility to resorption because of the allograft sterilization process, which results in low collagen fiber content and decreased chondrocyte viability.[6]

Recent reports describe the use of fresh-frozen costal cartilage (FFCC) grafts (Musculoskeletal Transplant Foundation Biologics [MTF]) for revision rhinoplasty.[7–11] FFCC is prepared using cadaveric costal cartilage tissue that undergoes surface sterilization with surfactants and antibiotics followed by freezing with solid carbon dioxide at −40°C to −80°C.[12] Donors are screened thoroughly for medical conditions, such as active malignancy and sepsis, and infectious diseases, such as human immunodeficiency virus, syphilis, and hepatitis B or C infection. The costal tissue is treated with surfactant to remove cellular components, thus minimizing host immune response toward the graft, and then treated with antiseptic solution to reduce pathogen load. The graft is stored in sterile packaging at −40° to −80°C.

Without exposure to harsh radiation or chemical treatment, FFCC yields the benefits of homologous tissue with a lower theoretical risk of postoperative infection, long-term warping, and resorption.[6,9,12–14] FFCC is available to purchase directly from MTF and arrives in precut packaging, ready to use once thawed.

FFCC has been shown to have a comparable risk profile to IHCC up to 6 months postoperatively, potentially because of a treatment process that does not expose the allograft to harsh radiation or chemicals.[7,12–14] However, a need has been identified for data on the long-term stability of FFCC with regard to infection rate, warping, resorption, and associated surgical revision. The current study provides a retrospective single-surgeon review of the use of FFCC in rhinoplasty in 282 patients over 4 years. In addition, we provide an assessment of complications associated with the use of FFCC in rhinoplasty, including infection rate and surgical revision rate, with more than 1 year follow-up.

PATIENTS AND METHODS

A retrospective chart review was conducted of the senior author's (R.G.R.) practice from March of 2018 to December of 2021. The review included all patients who underwent rhinoplasty during that time period. The study was approved by the Biomedical Research Alliance of New York (BRANY) institutional review board. Informed consent was obtained from all patients whose images were included in the study.

Inclusion criteria consisted of patients undergoing open rhinoplasty in whom MTF FFCC was used because of insufficiency of septal cartilage; this included both revision rhinoplasty and primary rhinoplasty, secondary to trauma, intranasal medication use, cocaine use, previous septoplasty, or generally insufficient cartilage. All patients provided consent to the use of cadaver material, and our office-based surgery center holds a tissue transplantation license from the state of New York. A minimum of 12 months of follow-up was required for inclusion. Manual chart review was conducted to collect patient demographic characteristics and surgical outcomes. Outcomes of interest included clinically evident warping, resorption, or graft displacement requiring surgical intervention, as well as rate of postoperative erythema requiring antibiotic use. Warping, resorption, and graft displacement were determined based on clinical evaluation by the senior author at follow-up visits. Infections were considered to have occurred if patients presented with clinical signs of infection and were treated with antibiotic medications or surgical intervention after completing the routine course of postoperative prophylactic antibiotics.

Surgical Technique

Before surgery, we determined whether patients were candidates for use of FFCC based on their history and clinical examination, as well as whether they consented to use of cadaveric materials. We ensure the FFCC is thawed for 1 hour before usage. The rationale for this is that when the product comes out of the packaging completely frozen, it typically appears very straight. Once thawed, any inherent warping is evident and can be accounted for when carving the cartilage. When the cartilage is carved, warped pieces are discarded and straight cartilage pieces are used. (**See Video 1 [online]**, which demonstrates how to carve MTF cartilage for columellar strut and alar contour grafts.) Carving FFCC requires a similar amount of time as carving septal cartilage and thus does not add to the overall operative time. In our experience, there have been some notable differences in the use and handling of FFCC when compared with septal cartilage. First, FFCC does not respond as well to scoring as septal cartilage, which can be straightened further using this technique. In addition, FFCC is more likely to fracture

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Fig. 1. (*Above*) A woman in her 40s before surgery. She previously underwent 6 rhinoplasties, which left her with an overprojecting elongated nasal tip, an overrotated tip, dorsal indentation, alar retraction, tip asymmetry, and inability to breathe through her nose. The senior author performed a revision rhinoplasty with correction of nasal tip asymmetry; placement of alar contour grafts to correct alar retraction; tip derotation; nasal tip deprojection to shorten the overall length of the nose; correction of dorsal indentation using a mastoid fascia dorsal onlay graft; and placement of a columellar strut graft and spreader grafts using MTF cartilage to add tip support, for tip refinement, and to improve breathing. (*Below*) The patient is shown 2.5 years postoperatively.

while being sutured in place when compared with septal cartilage, in which this is rarely an issue.

RESULTS

Our study includes 282 patients who underwent either primary rhinoplasty secondary to trauma, intranasal medication use, cocaine use, previous septoplasty, or generally insufficient cartilage (14.2%) or revision rhinoplasty (85.8%) with the use of FFCC. Most participants were female (90.4%), with a mean age of 35.8 years (range, 15 to 68 years). The mean follow-up period was 20.3 months, with a minimum of 12 months of follow-up. A summary of demographic data is provided in Table 1. A representative example of a patient who underwent revision rhinoplasty with FFCC is demonstrated in Figure 1.

Table 1. Demographic Characteristics and Complication Rates

Demographic Characteristics	Values
Sex, no. (%)	
Female	255 (90.4)
Male	27 (9.6)
Mean age (range), yrs	35.8 (15–68)
Mean follow-up (range), mo	20.3 (12–46)
Rhinoplasty, no. (%)	
Primary	40 (14.2)
Revision	242 (85.8)
Complication rates, no. (%)	
Infection	6 (2.1)
Warping, resorption, displacement	0
Revision surgery	6 (2.1)

In our cohort, 6 patients (2.1%) demonstrated signs of infection, which required treatment with empiric antibiotics, with all cases resolving without need for further antibiotic or operative management. None of the patients in our review had clinical signs of warping, resorption, or displacement of the FFCC grafts. Six patients (2.1%) required a return to the operating room for further revision rhinoplasty. The mean time to revision for these 6 cases was 15.5 months. In each of these cases, the FFCC grafts were inspected and showed no appreciable signs of warping, displacement, or

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resorption. A summary of the outcomes and complication rates is provided in Table 1.

DISCUSSION

This study provides an assessment of the complications of rhinoplasty using FFCC, with a minimum of 12 months of follow-up. It supports the safe use of FFCC in rhinoplasty as an alternative to autologous septal cartilage, consistent with previous findings in the literature.

The senior author's practice is focused primarily on rhinoplasty, with a large proportion of cases being revision rhinoplasty. When approaching revision rhinoplasty in this practice, FFCC is the preferred source of cartilage when structural support is required and septal cartilage is insufficient. A supply of FFCC is kept on hand at all times and stored per the guidelines set out by MTF. As of this writing, the cost of a medium-profile costal cartilage sheet is $957. When FFCC is required, a selection of pieces is inspected by the senior author and the most appropriate piece is chosen for the case. In our experience, yellow, more calcified cartilage from older individuals is more appropriate for structural support grafts and is less prone to warping. This has been supported in the literature, although future studies can be performed to elucidate the utility of yellow FFCC when compared with lighter-colored FFCC.[14–16] The surgical team is thoroughly trained on the use of FFCC and its intraoperative preparation, further minimizing surgical time. Once thawed, the cartilage is cut to suit its purpose. The senior author primarily uses FFCC to fashion spreader grafts and columellar strut grafts. He prefers to avoid using FFCC for tip grafts or dorsal onlay grafts as it can be firm and become visible through the skin with time. (**See Video 2 [online]**, which demonstrates the use of MTF cartilage as extended spreader grafts and a columellar strut graft to address a foreshortened nose.) To mitigate the risk of warping when FFCC is used to fashion grafts, the senior author ensures that the cartilage has had a full 1 hour to thaw. This is done because the freezing and packaging process may hide the true shape of a piece of FFCC. Allowing for the cartilage to thaw fully yields a more accurate assessment of the shape of the piece of cartilage, and the user can then take the appropriate care to carve straight grafts for use. If the cartilage is carved and placed while still frozen or partially frozen, it is likely to change its shape in situ and produce an unfavorable result. (**See Video 3 [online]**, which shows the senior author explaining the importance of thawing FFCC appropriately.)

The postoperative infection rate in our study was 2.1%, which is similar to that reported for autologous and IHCC.[17] It is likely that some amount of redness within the first few weeks following rhinoplasty with the use of FFCC is related to local antigenic response. Regardless, all cases resolved with empiric antibiotic treatment, with no patient requiring operative management for infection. Rates of warping in our study were also found to be comparable to those of autologous cartilage and IHCC. With regard to resorption, which is reported as high as 30% for IHCC,[14] in our study, no patient had clinically evident resorption requiring operative intervention.

The primary limitations of using FFCC are logistical, centered around its acquisition and storage. The cartilage tissue must be ordered from MTF in advance and stored in a −40°C freezer, with a generator backup, until it is needed. Although our study had a minimum 1-year follow-up period, our patients did not undergo specific evaluation of warping or resorption beyond clinical examination, so we are using the surgical revision rate as an indirect measure of resorption and warping, although the actual rate of subclinical warping and resorption is likely higher. In general, resorption is a subjective measurement, and we acknowledge this as a major limitation in this study, but clinical assessment remains the standard method for assessment of resorption.[6,8,9,11] We present a minimum 12-month follow-up period, with a mean follow-up of 20.3 months. The revision rate at the 1-year mark may not be a perfect marker for lifetime resorption rate; we aim to assess this in future studies with longer follow-up periods. However, in the 6 patients (2.1%) who went back to the operating room for revisionary surgery, there was no appreciable resorption of the previous FFCC noted. Furthermore, we found FFCC to be well incorporated, similar to what we would see from septal or autologous rib cartilage. Our study also carries the limitation of being retrospective in nature and thereby subject to the known limitations of this study design.

Previous work has demonstrated the low rate of acute complication with FFCC for revision rhinoplasty.[7] The need for evaluation of the long-term complication rate associated with use of FFCC has been acknowledged. This study provides long-term evidence supporting the use of FFCC for rhinoplasty. On the basis of our report of utilizing FFCC for rhinoplasty, we find it is well-tolerated as a graft material in rhinoplasty and

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yields acceptable functional, structural, and aesthetic results. Future studies should focus on quantitative statistics to compare the utility of various graft options with FFCC, including autologous septal, conchal, and costal cartilage and IHCC.

Processed cadaveric cartilage is safe, as demonstrated clinically by our findings and those of previous authors.[7,9,11] Further work is needed to better understand the histopathology underlying what has been demonstrated clinically. Rates of complication and surgical revision were found to be acceptable and no greater than when autograft or IHCC are used. When available, autologous septal cartilage is the preferred option; however, FFCC represents a safe, convenient, patient-centered option for graft material in rhinoplasty.

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DISCLOSURE

The authors have no financial interests to report.

PATIENT CONSENT

The patient provided written informed consent for the use of her images.

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