

# Fresh Frozen Rib Cartilage Grafts in Revision Rhinoplasty: A 9-Year Experience

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**Background:** Revision rhinoplasty is undoubtedly one of the most challenging procedures in facial plastic surgery. The complexity is compounded when there is a paucity of native septal cartilage to perform the required framework reconstruction. Harvest of autologous costal cartilage can result in increased operative times and possible secondary-site complications such as contour irregularity, poor scarring, and even pneumothorax.

**Methods:** A retrospective review was conducted of the senior author’s (R.J.R.) patients from 2011 to 2020 who underwent primary or revision rhinoplasty. Inclusion criteria consisted of patients with fresh frozen off-the-shelf cartilage used in revision rhinoplasty only with a minimum of 6 months’ follow-up. Outcomes for evaluation were warping, resorption, displacement, and infection.

**Results:** The authors identified 226 patients who underwent open rhinoplasty with the use of fresh frozen rib cartilage grafts and met inclusion criteria. The mean follow-up period was 12.18 months (range, 6 months to 8 years). The majority of patients had undergone one prior rhinoplasty procedure (54 percent); however, 4 percent of patients had undergone four or more prior procedures on their nose. The overall infection rate was 2.7 percent ( $n = 6$ ), with the majority successfully managed with antibiotics alone (2.3 percent).

**Conclusions:** The results in revision rhinoplasty are significantly enhanced with the creation of a stable nasal framework using off-the-shelf, easily accessible, specifically tailored fresh frozen cadaveric rib grafts. The long-term outcomes and complication rate in this 9-year retrospective study demonstrates the safety of fresh frozen rib graft in comparison to autologous or irradiated rib graft. (*Plast. Reconstr. Surg.* 150: 58, 2022.)

**CLINICAL QUESTION/LEVEL OF EVIDENCE:** Therapeutic, IV.

Revision rhinoplasty is considered one of the most challenging procedures in aesthetic facial plastic surgery, because of the altered framework, increased scar burden, and loss of natural tissue planes. The complexity is compounded when there is a paucity of native septal cartilage to perform the required framework reconstruction to improve on the patient’s functional and aesthetic concerns. In some situations, patients are undergoing tertiary or quaternary rhinoplasty, and need a resilient structure that can withstand contracting scar tissue and has a low risk of in situ alteration (warping, resorbing) to decrease the need for additional intervention. The available options for donor cartilage

include autologous costal and conchal cartilage, which are often limited by size and availability. Cadaveric cartilage, both irradiated and fresh, has also been used in patients who either lack autologous options or refuse autologous harvest. Autologous costal cartilage is an excellent source for cartilage but has its associated surgical-site risks and results in a prolonged operative time.<sup>1,2</sup> Costal cartilage donor-site complications include pain, contour irregularity, prominent

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scarring, and even pneumothorax.<sup>1</sup> Conchal cartilage is indicated primarily in situations where limited quantities are required and some warping is acceptable. Irradiated rib graft is a popular option, but has been criticized for its tendency to resorb, resulting in structural loss and nasal distortion.<sup>3-5</sup> Traditional irradiated grafts are treated with 30,000 to 50,000 Gy and stored in normal saline. However, there are alternative methods of treating cartilage (Tutoplast; RTI Surgical, Alachua, Fla.), which include dehydration with peroxide and acetone, and subsequent irradiation with up to 25,000 Gy.<sup>6</sup> The utility of these grafts in dorsal nasal augmentation are nonetheless reported to result in high levels of complications (31 percent).<sup>7</sup>

Over the past 9 years, the senior author (R.J.R.) has used fresh frozen rib cartilage grafts from the Musculoskeletal Transplant Foundation (MTF Biologics, Edison, N.J.) for revision rhinoplasty procedures. Fresh frozen rib grafts are able to maintain intrinsic tissue properties, as they are not treated with harsh processing methods including chemicals or terminal radiation, typical for allograft sterilization. The processing details have been previously published when evaluating the preliminary outcomes of the graft in revision rhinoplasty.<sup>8</sup> The allografts undergo high-quality sterilization (U.S. Pharmacopeia <71>) and are evaluated for brittleness and warping before packaging. In brief, the seventh to ninth ribs are harvested and frozen, débrided of all soft-tissue attachments, and cut to desired shape. The cartilage is then treated with a surfactant to remove any noncartilaginous materials, decontaminated in antibiotic solution, and packed in sterile conditions after rinsing. Negative cultures from the final product are obtained before distribution, and the cartilage is maintained in frozen condition throughout until being thawed for implantation. The Profile costal cartilage allograft is available as a sheet (three sizes) (precut to approximately 2-mm thickness) and as a rib segment (two sizes). The precut allograft sheet in particular saves time because of its ideal thickness to fashion spreader grafts, septal extension grafts, alar rim grafts, and others.<sup>9</sup> The long-term resorption and warping are reported to be similar to those of autologous cartilage.<sup>10</sup> The purpose of this study was to evaluate the complication profile of fresh frozen rib cartilage grafts cartilage in revision rhinoplasty (in comparison to reported historical data) using autologous and irradiated costal cartilage.

## PATIENTS AND METHODS

A retrospective review was conducted of the senior author's (R.J.R.) patients from 2011 to 2020 who underwent revision rhinoplasty. The study protocol was approved by the Integreview Institutional Review Board. Informed consent was obtained from patients whose photographs are included in this article.

Inclusion criteria included any patient undergoing revision open rhinoplasty with the use of fresh frozen off-the-shelf cartilage graft, and with a minimum of 6 months of follow-up. Long-term clinical outcomes data were collected with manual chart review, including any complications and reoperation in the postoperative period. In addition, we reviewed the location of grafts, number of prior rhinoplasties, patient age, and length of follow-up (Table 1). Outcomes analyzed included clinically evident warping, displacement, and infection. Warping was defined as alteration of shape resulting in a curvature of the graft causing deviation externally. Displacement was defined as change in position of the graft from desired location. Infection was classified as any clinical infection requiring nonprophylactic antibiotic therapy or the presence of a fluid collection necessitating incision and drainage. Minor infection was categorized as infections that resolved with oral antibiotic therapy, whereas major infection was classified as infection that required surgical intervention. Our data were compared to the historical complication rates in the published plastic surgery literature using autologous and irradiated rib grafts.<sup>1,6</sup>

## RESULTS

We identified 226 patients who underwent open rhinoplasty with the use of fresh frozen rib cartilage grafts and met inclusion criteria. The majority of patients were female (81.9%), with a mean age of 40.59 years (range, 19 to 74 years). The mean follow-up period was 12.18 months (range, 6 months to 8 years). The majority of patients had undergone one prior rhinoplasty procedure (54 percent); however, 4 percent of

**Table 1. Cartilage Graft Location Frequency**

Location	Value (%)
Columellar strut	23
Septal extension	40
Alar contour	49
Dorsal onlay	12
Lateral nasal wall	4

patients had undergone four or more prior procedures on their nose (Table 2). The most common indication for cartilage use was for alar contour grafts (49 percent) and septal extension grafts (40 percent) (Table 1)

The overall infection rate was 2.7 percent ( $n = 6$ ), with the majority successfully managed with antibiotics alone (2.3 percent). One patient (0.4 percent) required operative intervention for graft explantation because of infection. Mild nasal tip erythema in the early postoperative period was noted in nine patients (4.0 percent), without additional evidence of infection. All of these events were self-limiting and resolved within 2 to 3 weeks. Six patients (2.7 percent) experienced warping of the graft resulting in variable deformity (three with dorsal onlay graft, two with alar contour grafts, and one with septal extension graft). Four patients (of six) underwent reoperation for replacement or repositioning after warping; however, two patients with slight deformity after alar contour graft warping declined further surgical intervention. None of the patients experienced displacement or extrusion of their grafts. These results are summarized in Table 3, in comparison with historical data of autologous and irradiated grafts.

## DISCUSSION

The use of fresh frozen cartilage in revision rhinoplasty has notably changed the practice of the senior surgeon (R.J.R.). The benefits of fresh frozen rib cartilage grafts include the avoidance of harsh processing methods and irradiation, while maintaining high standards for sterility. The Musculoskeletal Transplant Foundation maintains a high standard in donor selectivity, as less than 2 percent of potential donors are considered candidates. Donors are screened for medical conditions or disease processes that would disqualify their candidacy, and they are further tested for infectious diseases (including hepatitis B and C,

human immunodeficiency virus, and syphilis).<sup>11</sup> As mentioned previously, the processing is aimed to minimize trauma to the cartilaginous structure of the allograft.

In revision rhinoplasty, the paucity of cartilage options can be challenging, especially given the risks and operative times associated with autologous costal cartilage, and the increased complications associated with irradiated homologous grafts.<sup>1,6</sup> The primary concerns associated with autologous cartilage include donor-site morbidity, scarring, and additional operative time. Furthermore, autologous costal cartilage introduces risks for warping, based on the segment of costal cartilage, age of the patient, and limited duration of ex vivo observation.<sup>12,13</sup> To minimize warping, grafts need to be obtained from the central aspect, and with larger cross-sectional areas.<sup>12,14</sup> Fresh frozen cartilage offers a viable, off-the-shelf alternative in revision rhinoplasty. In our study, low rates of warping were noted, likely because of a prolonged observation period after harvest and shaping of the graft, allowing for maximal warping before grafting.

The senior author (R.J.R.) routinely uses the Profile costal cartilage sheet allograft (three sizes), which can be evaluated for personalized use, before opening the sterile packing and thawing. The precut allograft sheet is approximately 2 mm in thickness, which is ideal for use in revision rhinoplasty for creation of the framework. In our experience, if structural rigidity is desired, allografts with a more yellowish hue are chosen because of their thickness and stiffness (Fig. 1). Allografts that are pale or that have a whitish hue are noted to be thinner and more pliable, and are thus ideal for providing soft contour augmentation (Fig. 2). These observational characteristics are associated with the age of the donor, as increasing cartilage age is associated with increased calcification and a lower warping tendency.<sup>10,13</sup> These structural variabilities allow for customization of the graft for the desired purpose.

Autologous cartilage and fresh frozen rib cartilage grafts appear to have similarly low rates of resorption, in stark contrast to irradiated homologous cartilage.<sup>6,15</sup> The terminal radiation process for sterilization likely contributes to decreased viability and contextual structural integrity of the graft, which is avoided in fresh frozen rib cartilage grafts. Resorption rates as high as 30 percent or more have been reported with irradiated grafts.<sup>15</sup> The longevity of fresh frozen rib cartilage grafts allows for stability of the constructs and minimizes the need for reoperation. In our study, there were

**Table 2. Patient Cohort Demographics**

Characteristic	Value
Sex	
Male	18%
Female	82%
Age range, yr	19–74
Follow-up	6 mo–8 yr
No. of prior rhinoplasties	
1	54%
2	24%
3	18%
≥4	4%

**Table 3. Comparison of Autologous, Irradiated Homologous, Tutoplast Homologous, and Fresh Frozen Nonirradiated Allografts in Revision Rhinoplasty**

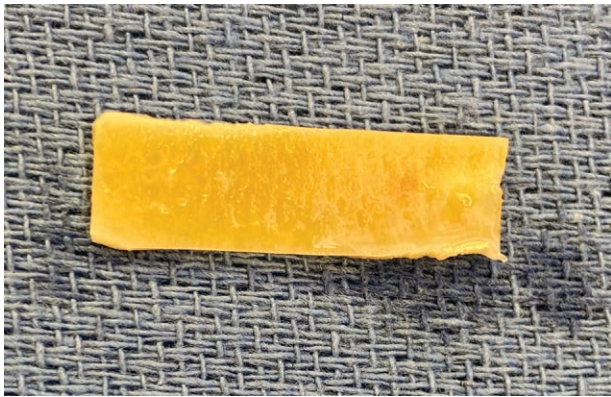
Complication	Autologous (%) <sup>*†</sup>	Irradiated Homologous (%) <sup>†</sup>	Tutoplast Homologous (%) <sup>†</sup>	Fresh Frozen (%) (n = 226)
Warping	3.1–6	5	4	2.7
Infection	0.6–2	3	0	2.7
Resorption	0.2–1	4	11	N/A
Pneumothorax	0 (0–0.3)	N/A	N/A	N/A
Revision surgery	5–14.1	7	3	2.2

N/A, not applicable.

<sup>\*</sup>Wee JH, Park M-H, Oh S, Jin H-R. Complications associated with autologous rib cartilage use in rhinoplasty: A meta-analysis. *JAMA Facial Plast Surg.* 2015;17:49–55.

<sup>†</sup>Vila PM, Jeanpierre LM, Rizzi CJ, Yaeger LH, Chi JJ. Comparison of autologous vs homologous costal cartilage grafts in dorsal augmentation rhinoplasty: A systematic review and meta-analysis. *JAMA Otolaryngol Head Neck Surg.* 2020;146:347–354.

no cases of operative intervention for resorption of the graft resulting in loss of projection or irregularities because of partial resorption. However, resorption was not routinely evaluated postoperatively in our patients.



**Fig. 1.** Older, more yellowish allograft should be used when more sturdy support and less warping potential are desired.



**Fig. 2.** Younger, more white allograft, which is softer and more compliant.

The risk for postoperative infection with fresh frozen rib cartilage grafts is similar to that for both autologous and irradiated grafts, and was adequately managed with antibiotic therapy. In our study, only one patient required operative intervention for removal of the graft, caused by an infection after double-layer dorsal onlay grafting. The patient subsequently underwent revision surgery with graft replacement 6 months after explantation, without additional complications. We routinely prescribe prophylactic antibiotics for 1 week postoperatively; this interval is increased in duration if there is any clinical concern for subclinical infection (i.e., tenderness, mild erythema). It is possible that this acute period of postoperative redness of the nasal tip, which universally resolved, may well represent an immunologic reaction to the implant and not necessarily infection, but it is unknown at this time. However, the low risk of complications was associated with low rates of reoperation to address aesthetic or functional concerns (2.2 percent), lower than reported for autologous and irradiated grafts.

In this retrospective review of our experience in Musculoskeletal Transplant Foundation fresh frozen rib graft in 226 patients over 9 years, we demonstrate an acceptably low complication rate that is comparable to other options. The cost associated with fresh frozen rib cartilage grafts used is possibly ameliorated with decreased operative times, favorable risk characteristics, and long-term reliability of results. Cost was not directly studied in this review but was extrapolated based on the elimination of a rib donor site and average graft costs being between \$200 and \$800. The additional benefit of elimination of secondary donor-site pain and incision makes its use in the cartilage-deficient multiple revision rhinoplasty patient further palatable and decreases overall patient morbidity. The pain from autologous rib graft harvest is often the main memory patients have from their rhinoplasty,

even years later. As mentioned in the previous study, a major limitation of fresh frozen grafts is the need to maintain temperatures between  $-40^{\circ}$  and  $-80^{\circ}\text{C}$  throughout the process of transport and storage before use.<sup>8</sup>

The limitations of the study include the short follow-up period in some patients, and the lack of routine evaluation for resorption. There are insufficient data available in the literature regarding irradiated cartilage allografts and cartilage autographs to have definitive long-term answers. However, at 9 years, it is shown that these cartilage grafts are at least as safe as the other potential options. The follow-up period of at least 6 months ensures that all patients were evaluated during the acute postoperative phase, and no additional infections occurred. However, warping and resorption are long-term complications and might not be clinically significant in short-term follow-up. Resorption was not specifically evaluated in the study, but no patient required surgical intervention because of partial or complete graft loss. In addition, according to the Musculoskeletal Transplant Foundation, it is yet unknown whether the allogenic chondrocyte population survives with freezing, but it is theorized that the structural integrity is preserved through the harvesting process.<sup>16,17</sup>

## CONCLUSIONS

Revision rhinoplasty results are significantly enhanced with the creation of a stable nasal framework using off-the-shelf, easily accessible, specifically tailored, fresh frozen cadaveric rib grafts. The long-term outcomes and complication rate in our 9-year retrospective study demonstrate the safety and longevity of fresh frozen rib graft in comparison to autologous or irradiated homologous cartilage.

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