Plastic and Reconstructive Surgery Advance Online Article

DOI: 10.1097/PRS.0000000000011125

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

Steven A. **Hanna**, MD, FRCSC [1], David **Mattos**, MD, MBA [1,2], Shaishav **Datta**, HBSc [3], Richard G. **Reish**, MD, FACS [1,2]

1. Department of Plastic Surgery, Manhattan Eye, Ear and Throat Hospital, New York, NY, USA
2. New York Plastic Surgical Group, New York, NY, USA
3. Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada

Corresponding Author: Dr. Richard G. Reish MD, FACS New York Plastic Surgical Group 1040 Park Avenue, Suite 1BC New York, NY, United States of America, 10028 Email: Rreish@lipsg.com Phone: 212-879-8506

Financial Disclosure Statement:

Steven Hanna has no disclosures

David Mattos has no disclosures

Shaishav Datta has no disclosures

Richard Reish has no disclosures

Short Running Head (no more than 40 characters in length): Fresh Frozen Cartilage in Rhinoplasty

Author Contributions: Steven Hanna contributed significantly to the writing of the manuscript as well as gathering and analysis of data.

David Mattos contributed significantly to the writing of the manuscript and gathering of data.

Shaishav Datta contributed to the writing of the manuscript as well as organization and analysis of data.

Richard Reish oversaw the project and contributed significantly to the writing of the manuscript, the conceptualization of the study, and was clinically responsible for all patients in the study.

ABSTRACT

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, though 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, this study aims to analyze the complication rates of MTF (Musculoskeletal Transplant Foundation) FFCC.

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

Results: The mean age of our study group was 35.8 years old, with 27 males and 255 females. 40 cases were primary rhinoplasties while the remaining 242 were revisions. Mean follow-up period was 20.3 months. Six patients (2.1%) required empiric antibiotics postoperatively, zero patients had clinical signs of warping, resorption, or displacement, and six patients (2.1%) required operative revision unrelated to the FFCC.

Conclusions: This study provides ~~long-term~~ 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 are used. FFCC is a safe, convenient, and patient-centered option for graft tissue in rhinoplasty.

INTRODUCTION

Rhinoplasty is among the most commonly performed facial surgery procedures in the United States of America and approximately 5-15% 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 prior 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 the donor-site morbidity including a potentially visible scar and the potential for pneumothorax, chest wall deformities, and additional post-operative pain.[4,5] Conversely, while IHCC is commercially available, does not increase operative time, and avoids donor-site morbidity, this option has an increased susceptibility to resorption due to the allograft sterilization process, which results in low collagen fiber content and decreased chondrocyte viability.[6]

More recently, there have been reports that describe the use of fresh frozen costal cartilage (FFCC) grafts (Musculoskeletal Transplant Foundation (MTF) Biologics, Edison, N.J.) 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 ^{o}C to -80 ^{o}C.[12] Donors are screened thoroughly for medical conditions, such as active malignancy and sepsis, and infectious diseases, such as human immunodeficiency virus, syphilis, hepatitis B and C. The costal tissue is treated with surfactant to remove cellular components, thus

minimizing host immune response towards the graft, 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 post-operative infection, long-term warping, and resorption.[6,9,12-14] Currently it is available to purchase directly from the Musculoskeletal Transplant Foundation (MTF) and arrives in pre-cut packaging, ready to use once thawed.

FFCC has been shown to have a comparable risk-profile to IHCC up to 6 months post-operatively, potentially due to 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 regards to infection rate, warping, resorption, and associated surgical revision. The present study aims to provide a retrospective single-surgeon review of the use of FFCC in rhinoplasty in 282 patients over 4 years. Additionally, we provide an assessment of complications associated with the use of FFCC in rhinoplasty, including infection rate and surgical revision rate, with greater than one year follow up.

METHODS

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

Inclusion criteria consisted of patients undergoing open rhinoplasty where MTF FFCC was utilized due to insufficiency of septal cartilage; this included both revision rhinoplasty patients as well as primary rhinoplasty patients, 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 NY state. A minimum of 12 months of follow up was required for inclusion. Manual chart review was conducted to collect patient demographics 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 post-operative prophylactic antibiotics.

SURGICAL TECHNIQUE

Preoperatively we determine if patients are candidates for use of FFCC based on their history and clinical examination, as well as if they consent for use of cadaveric materials. We ensure the FFCC is thawed for one hour prior to 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 (Video, Supplementary Digital Content 1). Carving of FFCC requires as 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 to 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 while being sutured in place when compared to 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 mean age of 35.8 years old (range: 15 to 68 years old). The mean follow-up period was 20.3 months, with a minimum of 12 months 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.

In our cohort, there were six patients (2.1%) who 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. There were six patients (2.1%) who required a return to the operating room for further revision rhinoplasty. The mean time to revision for these six cases was 15.5 months. In each of these cases, the FFCC grafts were inspected and showed no appreciable signs of warping, displacement or resorption. A summary of the outcomes and complication rates is provided in Table 1.

DISCUSSION

The present 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 the prior findings in the literature.

The senior author's practice is focused primarily on rhinoplasty, with a large proportion of his 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, MTF biologics current charge for 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, though future studies can be performed to better elucidate the utility of yellow-colored FFCC when compared with lighter colored FFCC.[14,15,16] 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, dorsal onlay grafts as he feels that it can be quite firm and become visible through the skin with time (Videos, Supplementary Digital Content 1 & 2). 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 unfavourable result (Video, Supplementary Digital Content 3).

The postoperative infection rate in our study was 2.1%, which is similar to that which is 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 zero patients requiring any

operative management for infection. Rates of warping in our study were also found to be comparable to that of autologous cartilage and IHCC. With regards to resorption, which is reported as high as 30% for IHCC, in our study there were zero patients with clinically evident resorption requiring operative intervention.[14]

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 must be stored in a -40 ^{o}C freezer, with a generator back-up, until it is required. Although our study had a minimum one-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 sub-clinical warping and resorption is likely higher. In general, resorption is a very subjective measurement, and we acknowledge this as a major limitation in this study, but clinical assessment remains the method standard 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. Revision rate at the 1-year mark may not be a perfect marker for life-time resorption rate thus this is something we aim to assess in future studies with longer follow-up periods. However, in the six (2.1%) patients that went back to the operating room for revisionary surgery, there was no appreciable resorption of the prior FFCC noted. Further, we found FFCC to be well incorporated, very similar to what we would see from septal, or autologous rib cartilage. Our study also carries with it the limitation of being retrospective in nature and is 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. The present study provides long-term evidence supporting the use

of FFCC for rhinoplasty. Based on our report of utilizing FFCC for rhinoplasty, we find it is well tolerated as a graft material in rhinoplasty and 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 but not limited to autologous septal, conchal, and costal cartilage, and IHCC.

Processed cadaveric cartilage is quite 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 adequately available, autologous septal cartilage is still the preferred option, however FFCC represents a ~~is a~~ safe, convenient, and patient-centered option for graft material in rhinoplasty.

References

1. 2020 Plastic Surgery Statistics. American Society of Plastic Surgeons. Updated April 27, 2021. Accessed December 22, 2022. https://www.plasticsurgery.org/news/plastic-surgery-statistics
2. Neaman KC, Boettcher AK, Do VH, et al. Cosmetic rhinoplasty: Revision rates revisited. *Aesthet Surg J*, *33*(1), 31-37.
3. Vargas G, Biguria R. Cartilage allografts for aesthetic nose surgery. *Plast Reconstr Surg – Glob Open*. 2018;6(9):e1859.
4. Chen K, Schultz B, Mattos D, Reish RG. Optimizing the Use of Autografts, Allografts, and Alloplastic Materials in Rhinoplasty. *Plast Reconstr Surg*. 2022;150(3):675e-683e.
5. Pfaff MJ, Rezzadeh KS, Malapati SH, et al. When less is more: A costal cartilage-sparing technique for cartilage graft harvest in rhinoplasty. *Plast Reconstr Surg*. 2021;148(4):681e-682e.
6. Wee JH, Mun SJ, Na WS, et al. Autologous vs irradiated homologous costal cartilage as graft material in rhinoplasty. *JAMA Facial Plast Surg*. 2017;19(3):183-188.
7. Rohrich RJ, Abraham J, Alleyne B, Bellamy J, Mohan R. Fresh frozen rib cartilage grafts in revision rhinoplasty: A 9-Year experience. *Plast Reconstr Surg*. 2020;150(1):58-62.
8. Rohrich RJ, Shanmugakrishnan RR, Mohan R. Rhinoplasty refinements: Revision rhinoplasty using fresh frozen costal cartilage allograft. *Plast Reconstr Surg*. 2020;145(6):1050e-1053e.
9. Mohan R, Krishnan S, Raja R, Rohrich RJ. Role of fresh frozen cartilage in revision rhinoplasty. *Plast Reconstr Surg*. 2019;144(3):614-622.

10. Rohrich RJ, Shanmugakrishnan RR, Mohan R. Rhinoplasty refinements: Addressing the pollybeak deformity. *Plast Reconstr Surg*. 2020;145(3):696-699.
11. Saadi R, Loloi J, Schaefer E, Lighthall JG. Outcomes of cadaveric allograft versus autologous cartilage graft in functional Septorhinoplasty. *Otolaryngol Head Neck Surg*. 2019;161(5):779-786.
12. MTF Biologics. Profile® costal cartilage allograft. Available at: https://www.mtfbiologics.org/our-products/detail/profile . Accessed December 5, 2022.
13. Rorick CB, Mitchell JA, Bledsoe RH, Floren ML, Wilkins RM. Cryopreserved, thin, laser-etched osteochondral allograft maintains the functional components of articular cartilage after 2 years of storage. *J Orthop Surg Res*. 2020;15(1):521.
14. Rohrich RJ, Dayan E, Durand PD, Brito I, Gronet E. Warping characteristics of rib allograft cartilage. *Plast Reconstr Surg*. 2020;146(1):37-42.
15. Balaji SM. Costal cartilage nasal augmentation rhinoplasty study on warping. Annals of Maxillofacial Surgery. 2013;3(1):20-24.
16. Forman JL, Kent RW. The effect of calcifcation on the structural mechanics of the costal cartilage. Computer Methods in Biomechanics and Biomedical Engineering. 2014;17(2):94-107.
17. Kridel RW, Ashoori F, Liu ES, Hart CG. Long-term use and follow-up of irradiated homologous costal cartilage grafts in the nose. *Arch Facial Plast Surg*. 2009;11(6):378-394.

FIGURE LEGEND

Figure 1. A woman in her 40s is shown (A, C, E, G, I) preoperatively. She previously underwent six rhinoplasties which left her with an over-projecting elongated nasal tip, an over-rotated 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 de-rotation, nasal tip deprojection to shorten the overall length of her 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, tip refinement, and improve her breathing. The patient is shown 2.5 years post-operatively (B, D, F, H, J)

TABLE LEGEND

Table 1. Patient demographics and complication rates.

SDC LEGEND

Video 1. Senior author demonstrating carving MTF cartilage for columellar strut and alar contour grafts.

Video 2. Intraoperative video demonstrating the use of MTF cartilage as extended spreader grafts and a columellar strut graft to address a foreshortened nose.

Video 3. Senior author explaining the importance of thawing FFCC appropriately.

Patient Demographics	
Sex	
Female	255 (90.4%)
Male	27 (9.6%)
Age	
Mean	35.8 yr
Range	15 – 68 yr
Follow-up	
Mean	20.3 mo
Range	12 – 46 mo
Rhinoplasty	
Primary	40 (14.2%)
Revision	242 (85.8%)
Complication Rates	
Infection	6 (2.1%)
Warping, Resorption, Displacement	0%
Revision Surgery	6 (2.1%)

Table 1

Figure 1a

Figure 1b

Figure 1c

Figure 1d

Figure 1e

Figure 1f

Figure 1g

Figure 1h

Figure 1i

Figure 1j