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REVIEW

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# A comprehensive overview of FFRG and IHCC allograft cartilages in revision rhinoplasty: a systematic review

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## Abstract

**Background** This study aims to compare the complications and satisfaction associated with favorable allografts, Fresh Frozen Rib Graft (FFRG) and Irradiated Homologous Costal Cartilage (IHCC), in revision rhinoplasty.

**Methods** The PRISMA guidelines were adhered to in the conduct of this systematic review. No limitations were applied to the types of studies included. Studies in English were selected without any time limitations. Five databases, PubMed/Medline, Cochrane Library, Embase, Scopus, Google Scholar, and also, the reference lists of included studies were searched. The ROBINS-I was employed for risk of bias assessment. Patients who underwent revision rhinoplasty utilizing allografts (FFRG and IHCC) were considered.

**Results** The initial search yielded a total of 503 studies. After duplicate removal and paper screening, 7 studies were included. A total of 406 patients for FFRG and 66 patients for IHCC who underwent revision rhinoplasty with the use of FFRG and IHCC were incorporated. Various complications were assessed, including warping, infective/noninfective resorption, infection, extrusion/displacement, and other less common occurrences. The overall complication rates were 9.25% and 15.7% for FFRG and IHCC, respectively. The main complication associated with the two was infection. Notably, both FFRG and IHCC demonstrated significant improvements in patient satisfaction following revision surgery across all subjected studies.

**Conclusion** Based on this review, FFRGs present a lower rate of complications in comparison with IHCCs. However, the biocompatibility makes the autologous rib cartilage the gold standard graft, but in case of donor site limitations to harvesting, FFRG and IHCC would be a safe and reliable alternative.

**Keywords** Allografts, Costal cartilage, Irradiated, Fresh frozen, Rhinoplasty, Revision surgery

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## Introduction

Rhinoplasty is a common-performed procedure in aesthetic facial plastic surgery, to address deformities and asymmetries of the nose, often resulting from congenital, post-traumatic, or iatrogenic conditions or previous surgeries (with major complaints concerning the tip of the nose and the dorsum). While both primary and secondary rhinoplasty are complex procedures, revision rhinoplasty could be significantly more challenging.

Generally, aggressive resection during the initial intervention leads to a lack of stabilization and loss of nasal tissue support, followed by down-rotation of the tip, loss of projection, and polly beak deformities [1].

Considering the limitations of reconstructing the nasal osseocartilaginous framework, different types of grafts (autograft, alloplastic material, and allograft) have been developed to supply the essential structural support.

Predominantly, autologous cartilage grafts, including the nasal septum, ear, and rib cartilage, are the commonly preferred materials. While their low rates of infection and extrusion in comparison with alloplastic implants are beneficial, they reveal substantial complications like donor-site morbidity, prolonged operative time, possible hypertrophic scars, postoperative discomfort, incremental financial burden, warping of the graft, and probable pneumothorax (related to autologous rib cartilage) [2, 3].

Advancements over the past decade have led to the development of diverse allograft materials, addressing the limitations of autologous cartilage and providing an optimal source of alternative cartilage for either primary or revision rhinoplasty procedures. Regarding the absence of a systematic review concerning utilization, limitations, privileges, and complications of available allografts (Fresh Froze Rib/Costal Cartilage and Irradiated Homologous Rib/Costal Cartilage) in revision rhinoplasty and through a single study, this systematic review focused on the comparison of FFRG and IHCC.

Therefore, in this literature, we aim to answer the question, of whether FFRG and IHCC are reliable choices to utilize as allograft material in revision rhinoplasty.

## Materials and methods

### PRISMA guidelines

This systematic review was performed under the statement of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [4]. Our research protocol was specified and registered at PROSPERO (International Prospective Register of Systematic Reviews) no. CRD42024558283.

### PICO question

Patient: Patients underwent revision rhinoplasty utilizing allografts (FFRG and IHCC).

Intervention: Revision rhinoplasty utilizing allografts (FFRG and IHCC).

Comparison: The results for FFRG and IHCC were compared with each other through objective or subjective assessments.

Outcome: Complication rate, limitations, and privileges.

### Information sources and search strategy

Electronic databases consisting of PubMed/Medline, Cochrane Library, Embase, Scopus, and Google Scholar were searched, based on the following search strategy: (((((((Allograft Cartilage[Title/Abstract]) OR (Septum Cartilage[Title/Abstract])) OR (Rib Cartilage[Title/Abstract])) OR (Fresh Frozen Rib Cartilage[Title/Abstract])) OR (Fresh Frozen Costal Cartilage[Title/Abstract])) OR (Irradiated Homologous Costal Cartilage[Title/Abstract])) OR (Irradiated allograft Cartilage[Title/Abstract])) AND ((Rhinoplasty[Title/Abstract]) OR (Revision Rhinoplasty[Title/Abstract])) for PubMed/Medline, Allograft Cartilage AND Rhinoplasty OR Revision Rhinoplasty for Embase and Scopus, and Septum Cartilage OR Rib Cartilage OR Fresh Frozen Rib Cartilage OR Fresh Frozen Costal Cartilage OR Irradiated Homologous Costal Cartilage OR Irradiated allograft Cartilage AND Rhinoplasty OR Revision Rhinoplasty for Cochrane Library and Google Scholar.

Studies in English were selected and no time limitations were applied. Furthermore, reference lists of included studies were manually searched.

### Inclusion and exclusion criteria

#### *Types of studies*

There were no restrictions on the types of studies included. Nevertheless, due to the limited number of studies that meet the inclusion criteria, all seven included were retrospective reviews.

#### *Study selection*

Duplicate studies were excluded. Two reviewers (M.H and S.O.K) independently conducted the two-step screening process, through title and abstract followed by full-text reviewing. In cases where full-text articles were unavailable, reviewers contacted the authors and requested the full text through e-mail. Disagreements were resolved by reviewers' consensus.

#### *Data extraction*

Standardized data extraction tables were employed by reviewers and any possible conflicts were settled. Extracted data were as follows: First author's name, publication date, study time-interval, study design, population (male and female), mean age (years), mean follow-up (months), previous rhinoplasty history, complications

(warping, infective/noninfective resorption, infection, extrusion/displacement, and other less common occurrences). Any further data and information likewise the surgical procedure, objective or subjective evaluation of outcomes, and complication management were exactly reviewed.

#### *Types of outcome measures and measurement methods*

All reported complications and limitations were considered, including warping, infective/noninfective resorption, infection, extrusion/displacement, and others that are more uncommon. Included studies, utilized diverse methods and criteria to assess the outcomes, such as subjective assessment with pre-operative and post-operative standard two-dimensional photography, objective assessment by measuring the alternation of standardized values (deviation angle, nasofrontal angle, total facial convexity, nasofacial angle, and nasolabial angle), and patient satisfaction evaluation.

### Risk of bias assessment (quality assessment)

The Risk of Bias In Non-randomized Studies - of Interventions (ROBINS-I) was employed for quality assessment [5]. Two reviewers independently accomplished the ROB assessment process, and any divergence was resolved by consulting a third reviewer.

According to the ROBINS-I tool, seven domains were investigated: bias due to confounding and bias in the selection of participants into the study (pre-intervention), bias in the classification of interventions (at intervention), bias due to deviations from intended interventions, bias due to missing data, bias in, the measurement of outcomes, and bias in the selection of the reported result (post-intervention). The categories for risk of bias judgments are "Low risk", "Moderate risk", "Serious risk" and "Critical risk" of bias [5].

We determined three categories for the quality of included studies based on the overall bias results: Good (for low risk), fair (for moderate risk), and poor (for serious risk and critical risk). Related data on ROB assessment is available in Table 1.

## Results

### Study selection

The initial search through the mentioned databases yielded a total of 503 studies. Following duplicate removal, title and/or abstract screening, 17 studies were submitted to full-text check. Ten papers were excluded due to not specifying the results related to revision rhinoplasty cases. Eventually, 7 studies were included, as reported in the PRISMA flow diagram, Fig. 1.

**Table 1** Risk of bias assessment for non-randomized studies - of interventions - ROBINS-I tool

| Author | Year | Pre-intervention | | At intervention | Post-intervention | | | Overall bias | Overall quality |
|---|---|---|---|---|---|---|---|---|---|
| | | Confounding | Selection of participants into the study | Classification of interventions | Deviations from intended interventions | Missing data | The measurement of outcomes | The selection of the reported result | | |
| John Milkovich et al. [2] | 2022 | L | L | L | L | L | L | L | L | Good |
| Rod J Rohrich et al. [3] | 2022 | L | L | L | L | L | L | L | L | Good |
| Raja Mohan et al. [4] | 2019 | L | L | L | L | L | L | L | L | Good |
| Steven A Hanna et al. [5] | 2023 | L | L | L | L | L | L | L | L | Good |
| J Madison Clark et al. [6] | 2002 | L | L | L | L | L | L | L | L | Good |
| Russell W H Kridel et al. [7] | 2009 | L | L | L | L | L | L | L | L | Good |
| Ferit Demirkan et al. [8] | 2003 | L | L | L | L | L | L | L | L | Good |

L: Low risk, M: Moderate risk, S: Serious risk, and C: Critical risk of bias

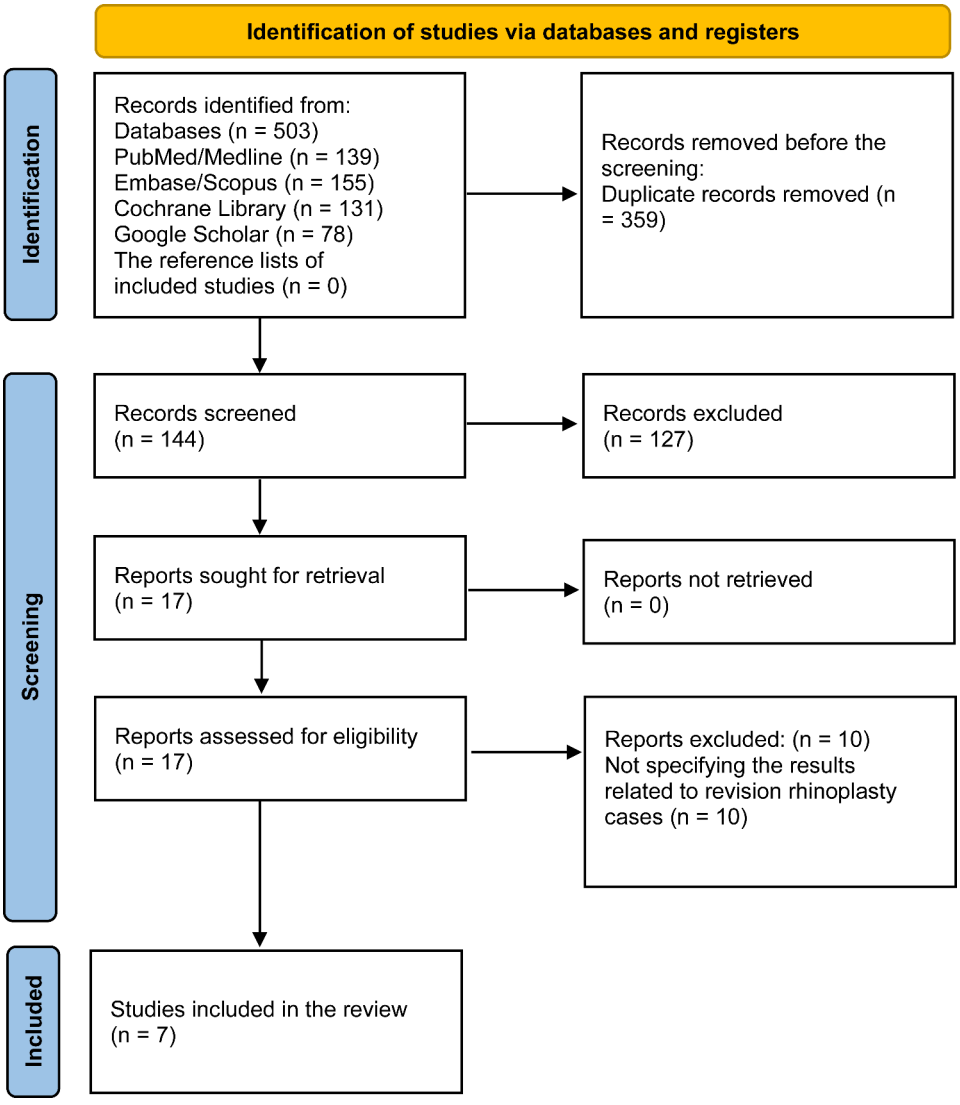


**Fig. 1** PRISMA flow diagram for included studies. An initial search of the specified databases yielded 503 studies. After removing duplicates and conducting title and abstract screening, 17 studies were selected for full-text review. Ten papers were excluded due to a lack of specific results related to revision rhinoplasty cases. Ultimately, seven studies met the inclusion criteria and were included in the final analysis, as illustrated in the PRISMA flow diagram

### Study characteristics

The FFRG and IHCC were used in 4 and 3 studies, respectively.

In the FFRG group, a total of 406 patients (out of 579, 84 males and 495 females with an average age of 38.8) in which all cases received FFRG through secondary rhinoplasty were enrolled. The mean follow-up period was 12.7 months.

About the IHCC group, a total of 66 patients (out of 440, 174 males and 248 females with an average age of 32.6), in which all cases received IHCC through revision rhinoplasty have been entered the study. The mean follow-up period was 24.1 months. It is important to note that the study conducted by J. Madison Clark et al. (2002) in the IHCC group did not report the number of male and female participants or the mean age. Consequently, these criteria are not included in the overall findings reported for the IHCC group. Tables 2 and 3 illustrate a summary of the included studies' characteristics.

### Complications and satisfaction

Based on the included studies, the mean complication rate in the FFRG group was 9.25% (35 out of 406 revision rhinoplasty cases who received FFRG). Comprehensively, 0.2% of infective or noninfective resorption, 1.4% of warping, 3.2% of infection, and 3.6% of less common complications (tip erythema and requirement of revision intervention unrelated to the FFRG) were reported, Table 4.

Toward the IHCC, the average complication rate was 15.7% (11 out of 66 cases who received IHCC). In detail, 3% of infective or noninfective resorption, 4.5% of

**Table 2** The FFRG studies' characteristics

| Author | Year | Study time-interval | Study design | Total population | Male | Female | Mean age (years) | Mean follow-up (months) | Revision rhinoplasty cases with the use of FFRG |
|---|---|---|---|---|---|---|---|---|---|
| John Milkovich et al. [1] | 2022 | 2019–2022 | Retrospective review | 21 | 4 | 17 | 39 (range 27–58) | 15 | 10 out of 21 |
| Rod J Rohrich et al. [2] | 2022 | 2011–2020 | Retrospective review | 226 | 41 | 185 | 40.6 (range 19–74) | 12.2 | 104 out of 226 |
| Raja Mohan et al. [3] | 2019 | 2014–2017 | Retrospective review | 50 | 12 | 38 | 40 (range 21–70) | 3.35 | 50 out of 50 |
| Steven A Hanna et al. [4] | 2023 | 2018–2021 | Retrospective review | 282 | 27 | 255 | 35.8 (range 15–68) | 20.3 | 242 out of 282 |

warping, 6% of c, and 3% of less common complications (skin rashes developed over the tip graft) were reported, Table 5.

The most prevalent complication associated with both FFRG and IHCC was infection. Across all included studies, both FFRG and IHCC demonstrated significant improvements in patient satisfaction following surgery.

## Outcomes of the included studies

### *FFRG group*

In 2022, John Milkovich et al. presented another cohort study on the use of Fresh Frozen Rib Cartilage in Canada. In this study, 21 patients (4 males and 17 females with a mean age of 39) underwent 11 primary or 10 revision rhinoplasties performed by a single surgeon. These FFRGs were aseptically processed, nonterminally sterilized, and were used for columellar strut, septal extension, alar contour, dorsal onlay, extended spreader, splinting, infratip shield, lateral crural strut, and diced cartilage with a mean of 15 months follow-up. In conclusion, 19 patients (90.5%) indicated a high level of satisfaction with the aesthetic outcomes as "very satisfied", and 2 others (9.5%) required a revision intervention. In one patient (4.8%) who underwent dorsal augmentation, the FFRG was modified to be used as diced cartilage and wrapped in the autologous temporal fascia, eventually resulting in a degree of resorption. The authors revealed no other major complications. However, the authors have noted some limitations like the small sample size but they believe that the results offer the FFRG as a reliable alternative cartilage in cases with inadequate autologous sources [2].

In 2022 Rod J Rohrich et al. published a case series of open rhinoplasty with the use of FFRGs and 226 patients (41 males and 185 females with a mean age of 40.6) whose 104 cases were revision rhinoplasty. As they mentioned, about 54% of patients had experienced one prior rhinoplasty and 4% had four or more prior nose surgeries. The average period for follow-up was 12.18 months (from 6 months to 8 years). The FFRGs were employed for alar contour (49%), septal extension grafts (40%), and columellar struts (23%). Various complications were assessed and revealed a 2.7% infection rate (6 patients) which the majority (2.3%) were treated with antibiotic intervention and only one needed explantation of the FFRG. Further, 4% showed mild erythema of the tip, which resolved spontaneously within three weeks and the perhaps cause could be an immunologic reaction. The incidence of resorption had not been investigated, and only 2.7% for warping and 0% for displacement or extrusion were reported. This retrospective study supports the FFRG as a safe and effective graft material in comparison to autologous or irradiated rib grafts [6].

**Table 3** The IHCC studies' characteristics

| Author | Year | Study time-interval | Study design | Total population | Male | Female | Mean age (years) | Mean follow-up (months) | Revision rhinoplasty cases with the use of IHCC |
|---|---|---|---|---|---|---|---|---|---|
| J Madison Clark et al. [5] | 2002 | 1986–2000 | Retrospective review | 18 | NS | NS | NS | 26 | 18 out of 18 |
| Russell W H Kridel et al. [6] | 2009 | 1984–2008 | Retrospective review | 357 | NS | NS | 37.24 (range 5–95) | 13.45 | 24 out of 357 |
| Ferit Demirkan et al. [7] | 2003 | 1998–2002 | Retrospective review | 65 | NS | NS | 28 | 33 | 24 out of 65 |

NS: Not Specified

Raja Mohan et al. reported a cohort study in 2019 with a sample of 50 patients (12 males and 38 females, with a mean age of 40) who underwent revision rhinoplasty between 2014 and 2017. The graft material was Fresh Frozen, Nonirradiated, Cadaveric Rib Cartilage (FFRG) and patients were followed up for a mean duration of 3.35 months. The homologous carved grafts were utilized for the spreader graft, infratip graft, dorsal onlay graft, columellar struts, alar contour graft, and septal extension graft. The post-operative infection was recorded as a complication in only 1 patient (2%) and was successfully resolved with surgical debridement and antibiotics therapy. Any other complication such as warping and extrusion was not reported. According to the results, FFRG could be a reliable allograft cartilage repository with a reduced incidence of complications. Besides, the authors suggested the consequence of the age effect of the donor on FFRG efficiency. Whiter grafts (younger donors) due to their softer and pliable matrix are better choices in the tip and alar contour grafts while yellowish ones (older donors) are stiffer to use where the columellar strut or septal extension is needed [7].

The recent literature in 2023 by Steven A Hanna et al. focused on FFRGs as a case review with 282 patients. 27 males and 225 females with a mean age of 35.8 years who experienced primary rhinoplasty (40 cases) or revision rhinoplasty (242) were included and followed up for a mean of 20.3 months. The infection appeared in six cases (2.1%) and was managed with empiric antibiotics. Unrelated revision surgery to the FFRG was necessitated in six patients (2.1%). No warping, resorption, or displacement was observed. The author proposed several considerations to enhance the outcomes of FFRG utilization, such the authorizing the graft to thaw for at least one hour before usage. The exact thawing would disclose any inherent warping of the graft which can later be discarded through carving. Furthermore, due to the greater calcification in yellowish FFRG (from older donors), it could amplify the cartilage structure support. In this study, FFRGs mainly were accepted for spreader grafts and columellar strut grafts. Considering their rigid nature, they are not appropriate for tip grafts and dorsal onlay grafts. FFRG could not react to scoring the same as the septal cartilage and it is not a feasible technique to straighten the costal graft more. Also, FFRG has increased susceptibility to fracture upon suturing, in comparison to septal cartilage. Consistent with previous studies, Hanna et al. demonstrated FFRG as an appropriate, safe, and patient-centric graft in both primary and secondary rhinoplasty [8].

### *IHCC group*

In 2002 J Madison Clark et al. presented a study concerning irradiated homograft costal cartilage. Cases

**Table 4** The FFRG studies' reported complications

| Author | Complications | Warping | Infective or noninfective resorption | Infection | Extrusion/Displacement | Other |
|---|---|---|---|---|---|---|
| John Milkovich et al. [1] | 1 out of 10 (10%) | 0 | 1 | 0 | 0 | 0 |
| Rod J Rohrich et al. [2] | 21 out of 104 (20.1%) | 6 | NS | 6 | 0 | 9 tip erythema |
| Raja Mohan et al. [3] | 1 out of 50 (2%) | 0 | 0 | 1 | 0 | 0 |
| Steven A Hanna et al. [4] | 12 out of 242 (4.9%) | 0 | 0 | 6 | 0 | 6 required operative revision unrelated to the FFRG |

NS: Not Specified

were selected based on 4 inclusion criteria: a minimum of one past rhinoplasty, extruded nasal implant prior to the intervention, urgent reconstruction surgery by using IHCC, and a minimum of 1 year follow-up. 18 patients met the inclusion criteria and the average duration of follow-up was 26 months. To provide final assessments, standard post-surgical rhinoplasty photographs were employed. The dominant population of extruded alloplastic materials was related to Silastic. 0% of infection or extrusion was observed following IHCC usage. Clinical resorption was least possible and only in one patient warping phenomenon caused the IHCC to be removed and replaced. Authors advocated for IHCC as a well-founded allograft in reconstruction procedures [9].

In 2009, Russell W H Kridel et al. published a retrospective review to answer substantial inquiries concerning long-term complications, reliability, safety, and essential proceedings to reduce unfavorable consequences of IHCC. 357 patients (132 males and 225 females) with a mean age of 37.24 and an average follow-up of 13.45 months were investigated. 274 cases had a history of previous rhinoplasty and 24 cases of them were treated with IHCC. 1025 IHCC and 374 other grafts were used. Altogether, 7 complications (1 warping, 2 infective resorptions, and 4 infections) were recorded to IHCC grafts in the revision group. This must be noted that the complication rate of IHCC in primary rhinoplasty was higher in comparison with second surgery and third surgery (25 cases). As the results justified, IHCC is a safe and reliable graft that impressively prevents donor site morbidity [10].

A study by Ferit Demirkan et al. in 2003 worked on the results of IHCC usage in both secondary and primary rhinoplasty. 65 patients (42 males and 23 females) were included. Participants were divided into four groups: group I, secondary septorhinoplasty ($n = 24$), group II, traumatic deformity ($n = 21$), group III, primary septorhinoplasty ($n = 13$), and group IV, deformity due to previous septal surgery ($n = 7$). The mean age of participants was 28 and the average period of follow-up was 33 months. The authors reported any cases of resorption, while some minor complications were presented in four patients (6%, 1 in group II, and 3 in group I), such as dorsal graft deformity, extreme graft length, and erythematous nasal tips. In group I (secondary septorhinoplasty) 3 complications (1 warping and 2 skin rashes extended over the tip graft) were detected. This probable allergic reaction was successfully treated with topical steroid ointments. The overall aesthetic and functional outcomes were acceptable in residual cases. Relied on these results, they suggested the IHCC as a safe and dependable source of graft for both primary and secondary septorhinoplasties [11].

**Table 5** The IHCC studies' reported complications

| Author | Complications | Warping | Infective or noninfective resorption | Infection | Extrusion/Displacement | Other |
|---|---|---|---|---|---|---|
| J Madison Clark et al. [5] | 1 out of 18 (5.5%) | 1 | 0 | 0 | 0 | 0 |
| Russell W H Kridel et al. [6] | 7 out of 24 (29.1%) | 1 | 2 | 4 | 0 | 0 |
| Ferit Demirkan et al. [7] | 3 out of 24 (12.5%) | 1 | 0 | 0 | 0 | 2 Skin rashes extended over the tip graft |

## Discussion

In this paper, we performed a comprehensive review of two commonly used allografts in nose surgeries: the FFRG and the IHCC. Our review covers various aspects, including revision rhinoplasty challenges and considerations, indications for allografts utilization, preferences for their usage, and their production methods. Additionally, we summarize relevant previous researches, highlighting methodologies and results, all with a specific emphasis on revision surgery.

Our findings indicate that FFRG demonstrates a lower complication rate of 9.25% compared to 15.7% for IHCC. However, due to significant differences in data distribution, sample size, and mean follow-up periods between the FFRG and IHCC groups, we were unable to perform a statistical analysis. Consequently, we cannot determine whether the observed difference in complication rates is statistically significant.

Over decades, there has been a growing trend for rhinoplasty as one of the major procedures in aesthetic facial plastic surgery, to address deformities and asymmetries of the nose. Contrary to significant advancements in rhinoplasty, excessive bone and cartilage removal to meet unrealistic aesthetic demands can lead to serious complications targeting patients' respiratory conditions and psychological health, which may necessitate a secondary surgical intervention to manage these side effects.

The most common adverse outcomes associated with over-resection of the nose include: saddle-nose deformity or deviated dorsal and caudal septum, the extremely narrow middle part, internal nasal valve collapse or inverted-V shape (in overabundant cartilage removal of the upper nose), pinched-look, retracted alar, and tip deformity (one of the lower third challenges to preserve the precious cartilage complex, quality and quantity of the skin), unnaturally narrow nostrils and nose flare (by inordinate alar flare reduction), and inappropriate visibility of columella after aggressive cephalic trim into the upper portion of the lower alar cartilage [1].

Fundamentally, three key considerations must be taken into account before revision rhinoplasty:

I. The altered osseocartilaginous framework: Primary surgery may weaken or deform the nasal bone and cartilage [1].
II. A stiff and thickened soft tissue that necessitates enhanced support: Thickened and fibrotic nasal soft tissues following previous surgery, would threaten the ultimate natural look of the nose [1].
III. Details of previous surgery are frequently unavailable or unknown: Since incomplete or inaccurate records of the patient's previous rhinoplasty surgery are presumable, planning and executing an effective rhinoplasty may be difficult [1].

Previous nose surgeries may more complicated challenges during revision rhinoplasty. Repeated surgical trauma can alter tissue biological response, and the availability of autologous cartilage for grafting will be diminished [1].

To overcome the mentioned issues, allograft materials have been developed to supplement cartilage supplies. These include materials containing FFRG and IHCC.

Graft materials providing structural support, decline the side effects of static forces (gravity and aging) and dynamic forces (tissue contraction, scarring, muscle activity, and regular breathing pressure changes), and eventually, contribute to the long-term stability and functionality of the reconstructed tissues [1].

Besides homologous cartilage grafts, other alloplastic materials such as heterologous cancellous bone can be employed in conjunction with autologous cartilage to address potential challenges associated with revision surgery in certain cases. A case report published in 2020 by Barbera Giorgio et al. described the successful treatment of a 36-year-old patient with Binder syndrome undergoing secondary rhinoplasty. The procedure involved a combination of autologous cartilage and a heterologous cancellous bone graft. At 12 months of follow-up, the aesthetic and functional outcomes, graft resorption rate, and graft stability were acceptable with no evidence of infection [12].

A survey study conducted in 2022 by Nicole C Starr et al. reported the percentage of preference for different graft materials. The study utilized a 12-question survey

and included 178 participants. The results indicated, 96.6% for autologous septal cartilage, 93.8% for autologous auricular cartilage, 75.8% for autologous rib cartilage, and 56.7% for cadaveric rib graft [13].

Due to the complicated nature of the revision surgery and greater need for cartilage graft, especially in over-resected cases (who needed more than 4 mm augmentation in nasal dorsum) or septoplasty cases (following post-traumatic or drug abuse-related septal perforation), septal and auricular cartilages would be insufficient. Autologous rib graft with acceptable biocompatibility and a lower rate of resorption and infection is the gold standard for these patients [1]. Besides its advantages, there are several drawbacks, comprising donor-site morbidity, prolonged operative time, possible hypertrophic scars, postoperative discomfort, incremental financial burden, warping of the graft, and the possibility of pneumothorax. Undoubtedly, alloplastic materials as an alternative option have distinct types of complications, such as extrusion, infection, and superior rates of mobilization [14].

Therefore, homologous grafts and novel approaches for their modification have been widely spread.

#### FFRG Production

In the process of FFRG production, young donors (< 55 years old) with negative test results for HIV, HBV, HCV, sepsis, and any malignancies will be candidates and regarding these substantial terms and conditions, less than 2% of grafts will be considered for further tissue processing. The seventh to ninth ribs are usually used for harvesting. Soft tissue will be removed from harvested blocks and be trimmed and reshaped to provide a particular sheet generally consisting of fourteen diverse sizes with two shapes. Contrary to traditional approaches, which use irradiation to sterilize cadaveric cartilages, in the fresh frozen technique, the harvested graft will be debridement of blood and cellular components through rinsing (with surfactant solution) and then decontaminating (with antibiotic solution) before sterilizing. Eventually, the graft will be frosted and stored at -40 ℃ to -80 ℃, and safely shipped on dry ice to maintain this temperature interval. The FFRG needs to be thawed out before the grafting procedure [1, 15].

#### IHCC Production

Generally, there are two types of IHCCs, Tutoplast (a commercial product by Tutogen Medical, GmbH, Neunkirchen am Brand, Germany) and IHCC from the donor bank. Tutoplast production steps included cadaveric rib graft harvesting, using intermittent baths of deionized water and 10% sodium chloride, chemically treating with 3% hydrogen peroxide (for 24 h), followed by pure acetone, evaporation under vacuum, and finally, irradiation with a minimum dose of 17.8 kGy. Contrary to that, IHCC from the donor bank, are cadaveric harvested ribs that just be irradiated with a minimum dose of 30 kGy. Both types are stored in saline solution [16, 17].

A distinguished population of facial plastic surgeons confirms the use of cadaver rib grafts. For surgeons with a high number of annual rhinoplasties (> 50), cadaveric grafts could save their time. These allografts are available in various dimensions, facilitating to minimization of the operative duration dedicated to graft trimming and reducing graft wastage. Additionally, some up-to-date studies reported similar outcomes and complication rates (including warping, resorption, infection, contour irregularity, or revisions) for autologous and homologous grafts in dorsal augmentation [14, 18].

#### Non- or minimally irradiated homologous costal cartilage (NIHCC)

Even though there have been several studies toward the desirable outcomes of conventional IHCC, up to 2020, there has been no clinical research on non- or minimally irradiated homologous costal cartilage (NIHCC) as an alternative. Joelle Rogal et al. (2021) presented a retrospective review of 26 patients with a mean age of 42 years (6 males and 20 females), and a mean follow-up of 15.9 months, in which 19 cases were revision rhinoplasty candidates. Results demonstrated three cases of complication (overall 3.6% rate) consisting of two (2.6%) noninfective resorption (out of 77 palpable or superficial NIHCC grafts) and one (1.0%) infection out of 100 NIHCC grafts. No other complication was reported. In cases of partial resorption, patients demanded a minor revision operation and in case of infection, who had a history of infected silicone implant, the situation had been managed through oral antibiotic post-surgery. In general, the authors recommended NIHCC as a safe and effectual option for either revision or primary rhinoplasty [19].

Given that this study did not specify the results of primary and revision cases, its data has been excluded from our systematic review data tables. Nonetheless, due to the significance of being the sole study identified according to NIHCC, we have elected to mention its findings separately.

#### Limitations

The major limitation of this study was the heterogeneous data collection. Since most recent studies in the field of cadaveric cartilage grafts focus on the fresh frozen technique, there is a notable lack of up-to-date data on irradiated cartilage. Likewise, dispersion and uneven distribution of data, as well as a significant difference in sample size and mean follow-up period, could potentially affect an effectual comparison. Additionally, the mean

follow-up period is remarkably different between FFRG (12.7 months for 4 studies) and IHCC (24.1 months for 3 studies). Concerning FFRG, more studies with long-term follow-up similar to those conducted on IHCC are still required to more accurately evaluate some complications such as warping and graft resorption.

## Conclusion

Based on this systematic review concerning the privileges, limitations, and complications of FFRG and IHCC usage as allograft material in revision rhinoplasty, no significant rate of complications has been reported. Furthermore, this review illustrated that FFRGs have a lower rate of complications in comparison with IHCCs. Therefore, even though autologous rib cartilage is still the gold standard regarding its biocompatibility, in cases with limitations of autologous cartilage harvesting, allografts, especially, the FFRG (as a new trend) would be a safe and reliable alternative to reduce the contingency of donor site morbidity.

### Abbreviations

| | |
|---|---|
| FFRG | Fresh Frozen Rib Graft |
| IHCC | Irradiated Homologous Costal Cartilage |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| PROSPERO | International Prospective Register Of Systematic Reviews |
| ROB | Risk of Bias |
| ROBINS-I | Risk of Bias In Non-randomized Studies - of Interventions |
| FACE-Q | FACE-Q Scales |
| CCA | Cadaveric Costal Allograft |
| CCSA | Costal Cartilage Segment Allograft |
| HIV | Human Immunodeficiency Virus |
| HBV | Hepatitis B Virus |
| HCV | Hepatitis C Virus |
| NIHCC | Non- or Minimally Irradiated Homologous Costal Cartilage |

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Artificial intelligence: The authors declare that they have not used Artificial Intelligence in this study.

### Author contributions

MH contributed to designing the study, wrote the paper, and substantively reviewed the study. SOK contributed to the study conception and substantively revised the paper. All the authors have read and approved the final manuscript.

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### Data availability

No datasets were generated or analysed during the current study.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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