

Irradiated Homograft Rib Cartilage in Facial Reconstruction

Alan J. C. Burke, MD; Tom D. Wang, MD; Ted A. Cook, MD

Objective: To evaluate long-term structural, functional, and cosmetic results as well as resorption with the use of irradiated homologous rib cartilage grafts (IHRGs).

Design: Cases in which IHRGs were used were reviewed for a long-term follow-up study for nasal and auricular reconstruction, dating back 18 years. A retrospective medical chart review was conducted in the cases in which the patients had returned for clinical examination with photographic documentation.

Results: A total of 118 patients who had undergone nasal reconstruction with a mean follow-up of 36 months were identified from our database. There were 12 patients who had undergone auricular reconstruction, with a mean follow-up of 82 months. Resorption with compromise in cosmesis was noted in 11% (11/102) of the grafts used in nasal reconstruction but in 71% (5/7) of those used in auricular reconstruction.

Minor resorption without change in form or function was found in 29% (30/102) of the cases. Loss of support, which was related more to graft displacement rather than resorption, was identified in 19% (21/109) of the cases, and loss of support affecting cosmesis was observed in 8% (9/109) of the cases. Maintenance of form and function appeared to be unrelated to the amount of resorption noted for the nasal grafts but was significant for the auricular grafts ($P < .01$).

Conclusions: The longevity of IHRGs has been favorable for functional, structural, and cosmetic nasal reconstruction, with low levels of resorption identified clinically. The use of IHRGs was associated with an unacceptable rate of graft failure in auricular reconstruction; therefore, they are no longer selected for use in such cases.

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THE USE OF IRRADIATED CARTILAGE in facial reconstruction remains controversial despite its use for many years. The controversy centers on the issue of resorption. The histologic examination of implants has revealed varying levels of resorption and fibrous replacement in both animal and human studies; for this reason, Welling et al¹ advised against the use of irradiated homologous rib cartilage grafts (IHRGs) for long-term structural support. Other factors, such as site of implantation and degree of fibrous tissue replacement, however, may be important for the ultimate success of these grafts.² The greater issue is whether structural, functional, and cosmetic restoration can be maintained over time. The clinical use of IHRGs should be based on these criteria.

Clinical studies have shown conflicting results. Dingman and Grabb³ reported resorption in only 2 of 30 irradiated cartilage homografts implanted into various sites. The 2 cases of resorption occurred in auricular reconstruction. Only 30 of 70 patients were available for evaluation, and follow-up ranged from 7 months to 3½ years. Rasi⁴ reported the results ob-

tained using 398 homografts preserved in merthiosaline implanted into various sites in 353 patients. Of this group, only 49 patients, representing 59 transplants, were formally evaluated, with follow-up ranging from 2 to 18 years. Of the 59 transplants evaluated, 7 (12%) failed because of infection or hematoma. Bulk was maintained without evidence of loss in 19 cases (32%), and some degree of resorption occurred in 33 (56%) cases. Fair to excellent cosmetic results owing to fibrous tissue replacement were seen in 25 (76%) of the 33 cases in which there was resorption. Overall, 38 (77%) of the 49 patients were satisfied with the cosmetic result. Welling et al¹ reported the findings of long-term follow-up on irradiated homografts implanted into various regions of the face. In their study, 42 of 107 patients, representing 62 of 145 grafts, were evaluated by physical examination with comparison photographs. Follow-up averaged 9 years and was correlated with the degree of resorption. The average resorption rate was 75%. Complete resorption was found in 18 of 24 grafts, with follow-up of more than 11 years. Specific data on the degree of patient satisfaction were not reported, but it has been noted that cartilage resorp-

From the Department of Facial Plastic Surgery, Virginia Ear, Nose, and Throat Associates, Richmond (Dr Burke); and the Division of Facial Plastic Surgery, Oregon Health & Science University, Portland (Drs Wang and Cook).

tion did not necessarily correlate with poor patient satisfaction.⁵ In the above-mentioned studies, preserved cartilage grafts were placed into multiple sites in the face. Several authors believe that the site of implantation strongly influences the long-term stability of these grafts. Kridel and Konior⁶ reported the results of 306 grafts used in 122 nasal augmentation procedures, with follow-up ranging from 1 to 84 months. Resorption occurred in only 4 grafts, and infection was thought to be the cause in 2 of them. Donald² reported similar observations. In his experience, grafts placed over the nasal dorsum and malar eminence showed little resorption, while those placed under mimetic musculature tended to resorb.

The ear is another implantation site that has been associated with an increased incidence of resorption. The 2 cases of resorption reported by Dingman and Grabb³ occurred in auricular reconstruction. In a review of the world literature on auricular reconstruction conducted by Berghaus and Toplak,⁷ cases of resorption were reported with "striking frequency," and in some series, resorption occurred in as many as 100% of the cases. Based on their review, they concluded that preserved cartilage grafts could not be recommended for auricular reconstruction.

Irradiated homologous cartilage grafts have been used at Oregon Health Sciences University, Portland, for many years, predominantly in the reconstruction of nasal defects. The objectives of this retrospective study were to determine the longevity of functional, structural, and cosmetic results and to make recommendations regarding the use of IHRGs.

METHODS

A computerized database has been used for the past 18 years to record patient and surgical data in cases in which IHRGs were used. A retrospective medical chart review included only those patients whose charts contained both definitive information regarding graft resorption and postoperative photographs. The surgical results were evaluated by history and by comparison of standardized preoperative and available postoperative photographs. Outcome was determined for individual grafts and for the overall success of the reconstruction in individual patients. Each graft was evaluated clinically for the degree of subjective resorption by comparing the latest photograph with the earliest postoperative photograph, taken at 3 months. The resorption was then graded as none (0%-25%), partial (26%-75%), or total (>75%). Charted information from the postoperative office visits was also reviewed. The postoperative history was reviewed to assess graft infection, fracture, warping, extrusion, and exposure. The maintenance of structural support supplied by the grafts was evaluated and classified as "support maintained," "partial loss of support," and "complete loss of support." Because of the nature of this retrospective study, not all data points were available, which changed the number of patients reported on for different measured criteria. Cosmetic and functional results were graded, and a comparison was made between assessments by the patients and the senior author (T.A.C.), tabulated as a head-to-head comparison. An attempt was made to isolate the contribution of the IHRGs from that provided by other graft materials, if present. Maintenance of function with respect to the nasal airway was graded subjectively by the patients.

This study represents the experience of a single institution. The cartilage homografts were all preserved by irradiation.

Rib cartilage, harvested from young cadaveric donors, was obtained from the Oregon Tissue Bank, Portland. The cartilage was then exposed to a minimum of 1.5×10^6 rad (15000 Gy) of radiation and stored in sterile isotonic sodium chloride solution. The outer cortex of the rib was removed from the grafts at the time of implantation to prevent warping. Dorsal grafts, caudal struts, tip grafts, lateral onlay grafts, and spreader grafts were used for nasal reconstruction. Dorsal grafts were 3.5 to 4.5 cm in length, 5 to 6 mm in height, and 10 to 12 mm in width. Caudal struts were 3.0 to 3.5 cm in height, 2 to 3 mm in width, and up to 10 mm in length. Dorsal grafts were placed over the remaining septum or soft tissue and tucked superiorly into a subperiosteal pocket. Caudal struts were placed into a snug intercrural pocket dissected onto the maxillary crest. When possible, the other grafts were stabilized by placement into precisely created pockets.

Auricular reconstruction involved creating a template of irradiated cartilage based on the size of the contralateral uninvolved ear. The template, which was created with 2 to 3 pieces of cartilage held together with sutures, was then placed into a subcutaneous pocket. This procedure was done as the initial stage along with removal of any vestigial native cartilage. Early in the course of the study, tissue expanders were placed as the first stage but were abandoned because of the high rate of extrusion. Later stages involved release of the ear with placement of a skin graft and repositioning of the lobule.

RESULTS

The database identified 193 patients who had undergone nasal reconstruction and 12 patients who had undergone auricular reconstruction with IHRGs. Adequate follow-up information was available for 118 patients (61%) who had undergone nasal reconstruction. There were 56 female patients (mean age, 46.2 years) and 62 male patients (mean age, 44.0 years). The mean follow-up period for each patient was 36 $\frac{1}{4}$ months (range, 1-216 months). The mean follow-up periods were stratified into smaller groups: 3.3 months (n=17), 9.4 months (n=30), 15.8 months (n=19), 25.0 months (n=33), 79.8 months (n=19), and 138 months (n=3).

The most common cause of the nasal deformity was trauma (**Table 1**). Nine cases involved complex reconstructions requiring replacement of skin in addition to cartilaginous support. Thirty-one cases were revisions for reconstructions performed elsewhere, 18 of which had involved the use of implants. Previously used implants included autogenous rib, irradiated rib, Silastic, ivory, iliac crest, and expanded polytef. The types of nasal grafts used were as follows:

Type of Graft	No. of Grafts
Caudal strut only	55
Caudal strut and dorsal onlay	38
Butterfly valve	35
Dorsal onlay only	16
Tip	3
Spreader	3

A total of 177 IHRGs were used, the majority of which were caudal struts and dorsal grafts. Multiple irradiated rib grafts were used in 43 patients. Most commonly, the multiple procedures involved the use of a caudal strut graft with a nasal dorsal graft. Autogenous conchal cartilage grafts were used in conjunction with

Table 1. Causes of Nasal Defects

	No. of Patients
Posttraumatic	65
Nasal airway obstruction	35
Saddle nose	28
Revision cosmetic	17
Postseptoplasty	12
Septal perforations	11
Post-tumor resection	9
Congenital	5
Degenerative/medical	3
Post-rhinophyma surgery	2
Primary cosmetic	2
Post-burn wound	1
Post-nasal intubation	1

the IRHGs in 30 patients, most commonly to reconstruct the nasal ala or the internal nasal valve.

Revision surgery was performed on 18 patients after their initial surgery at Oregon Health Sciences University. The intraoperative structure of previously irradiated rib grafts was viewed in all 18 patients. In 7 of the 18 patients, the grafts were revised and replaced; the original grafts showed no visible resorption and were thought to be adequate for future use. Operative notes commented on the normal appearance of the grafts in all but 2 of the cases; in these 2 cases, the cartilage grafts had become macerated by trauma. Five patients underwent revisions for ongoing nasal obstruction and had the addition of autogenous conchal cartilage grafts without alteration of their IHRGs. Eight patients had their caudal struts replaced because of the loss of supportive function, the grafts having become displaced.

A portion of a single IHRG obtained during a revision procedure was evaluated histologically. This particular graft had been placed 6 years previously in an 8-year-old girl. Replacement was required because of fracture of the implant but also because of the need for a larger graft. Grossly, the graft showed no evidence of resorption and, most impressively, the actual score marks from the graft carving were clearly visible 6 years later. A senior staff pathologist examined the graft under light microscopy and identified chondrocytes that were indistinguishable from normal viable chondrocytes throughout the graft.

Thirty-six complications were noted in 30 of the 118 patients.

Complication	No. (%) of Patients
Infection	12 (10)
Fracture	10 (8)
Warping	2 (2)*
Exposure	2 (2)
Dermal telangiectasias	2 (2)
Extrusion	1 (1)
Skin slough	1 (1)

*Both cases were explored intraoperatively and were found to have been improperly prepared: rib cortex was present on at least 1 side of each graft, which explained the cause of the warping.

Graft resorption was the most common complication. Resorption that was clinically meaningful, where nasal form

and function were compromised, was found in 11 (11%) of 102 cases. For any perceived degree of resorption, no matter how small, the incidence was 40% (41/102) (**Table 2**). This number leaves 30 cases (29%) that had detectable levels of resorption without altered cosmesis. The incidence of resorption increased with duration of follow-up. Caudal struts were the most commonly involved grafts. Clinically significant resorption (>25%) was associated with graft infection in 4 (36%) of 11 cases and with postoperative trauma in 5 (45%) of 11 cases. Five of the 6 cases that had the greatest degree of resorption were associated with postoperative infection or trauma.

Loss of support was the next most common complication. Clinically, it was most meaningful to tally the percentage of those patients whose loss of support compromised nasal function and cosmesis. These patients, who are categorized in the "mostly lost" or "completely lost" sections of **Table 3**, represent 8% (9/109) of the total. Including all those patients in whom even very minor losses occurred, the total was 21 (19%) of 109 patients (Table 3). The incidence was spread out evenly over the entire follow-up range. Twenty-four percent (5/21) of the cases that had any degree of loss of support involved either trauma or postoperative infection, neither of which was documented in any of the remaining cases.

Adequate follow-up was available for 7 patients who underwent auricular reconstruction. All 7 procedures were performed for unilateral microtia, and all but 1 were for primary reconstructions. The 1 revision case had been reconstructed with a Silastic implant, which had extruded. Three patients underwent placement of a tissue expander before cartilage implantation. Two of the tissue expanders were removed prematurely because of exposure. The mean age of the patients at the time of reconstruction was 10 years (range, 5-24 years). The mean duration of follow-up was 53 months (range, 5-105 months). Resorption was noted in 5 patients (71%), all of whom were unhappy with the cosmetic appearance. The typical appearance was that of an amorphous mass. One patient developed an abscess around the graft and experienced rapid graft resorption, with complete loss noted at 5 months. Four (57%) of the 7 patients experienced exposure of their graft owing to skin loss. Only 1 patient experienced graft loss that was not associated with infection or graft exposure. This patient underwent 5 procedures to reposition the ear, which may have resulted in vascular compromise to the grafts. The mean duration of follow-up in the cases with resorption was 42 months (range, 5-88 months). Only 2 (29%) of the 7 patients did not exhibit clinical signs of graft resorption. One of these 2 patients also experienced graft exposure, which resolved with local wound care (mean duration of follow-up, 82 months).

CASE 1

A 56-year-old man presented with nasal trauma that had resulted in the loss of nasal projection and widening of the nasal width as well as nasal airflow obstruction (**Figure 1**). Irradiated homologous rib cartilage was used to construct strut and dorsal grafts. The patient had

Table 2. Resorption of Irradiated Homologous Rib Grafts Used in Nasal Reconstruction

	No. (%)					
	6 mo	6-12 mo	1-2 y	2-5 y	5-10 y	>10 y
None-mild (0%-25%)	24/26 (92)	14/22 (54)	8/14 (67)	8/24 (33)	4/13 (31)	0
Moderate (26%-50%)	1/26 (4)	6/22 (27)	6/14 (43)	13/24 (54)	5/13 (38)	2/3 (67)
Severe (51%-75%)	0	1/22 (5)	0	2/24 (8)	2/13 (15)	1/3 (33)
Completely lost	1/26 (4)	1/22 (5)	0	1/24 (4)	2/13 (15)	1/3 (33)

Table 3. Structural Support Maintained by Irradiated Homologous Rib Grafts Used in Nasal Reconstruction

	No. (%)					
	6 mo	6-12 mo	1-2 y	2-5 y	5-10 y	>10 y
Total support	27/29 (93)	18/22 (82)	11/14 (79)	20/27 (74)	10/14 (71)	2/3 (67)
Partial loss	1/29 (3)	3/22 (14)	2/14 (14)	5/27 (19)	1/14 (7)	0
Mostly lost	0	0	1/14 (7)	1/27 (4)	2/14 (14)	1/3 (33)
Completely lost	1/29 (3)	1/22 (5)	0	1/27 (4)	1/14 (7)	0

a less than 25% loss of support from the grafts, with mild residual saddling of his supratip and mild bowing of the graft, with the convexity displayed to the right side. His nasal airway has been well preserved over 18 years of follow-up (Figure 1, B and D).

CASE 2

A 26-year-old man presented with nasal trauma that had resulted in a saddle nose deformity (Figure 2). Irradiated homologous rib cartilage was used to construct strut and dorsal grafts. The patient had a 25% loss of support from the grafts, manifested by mild acuity of the nasolabial angle and slight settling of his nasal dorsum.

CASE 3

A 36-year-old woman presented with a traumatic nasal deformity, manifested as a moderate supratip saddle nose deformity (Figure 3). Irradiated homologous rib cartilage was used to construct strut and dorsal grafts. The patient had no loss of support or resorption of the grafts.

CASE 4

A 58-year-old man presented with a traumatic injury to his nose that resulted in the loss of his nasal tip projection and severe ptosis of the nasal tip (Figure 4). Irradiated homologous rib cartilage was used to reconstruct both columella and dorsal grafts. The patient had total structural support and no graft resorption but did have a mildly displaced graft as a result of a graft fracture that had been caused by subsequent nasal trauma.

CASE 5

A 4-year-old boy who had his right aural atresia defect reconstructed using an IHRG developed severe resorption of the graft that resulted in the loss of structural form

and support (Figure 5). Because of the adverse outcome in this case, the senior author (T.A.C.) discontinued the use of IHRGs for aural atresia defects more than 20 years ago.

CASE 6

A 68-year-old man developed a dorsal nasal defect with the loss of projection after undergoing a left medial maxillectomy and postoperative radiation therapy for invasive squamous cell carcinoma (Figure 6). Irradiated homologous rib cartilage was used to construct a dorsal graft. The patient had less than 25% resorption of the graft.

COMMENT

Precise evaluation of nasal reconstruction is limited by the nature of clinical examination. Resorption of irradiated homologous costal cartilage was assessed by visual inspection and palpation along with comparison of preoperative and postoperative photographs. Though imprecise and subjective, this method of assessment was similar to that used in previous clinical studies. Often, all that could be determined was whether or not a graft was present and whether it was still providing its intended form and function. Outcome graded as no resorption or minimal resorption most likely involved a considerable number of grafts with varying degrees of resorption. Even in those cases in which there was a clinical gestalt of significant resorption, there was almost always sufficient fibrous tissue replacement to support the graft's intended function. It was interesting and rather impressive to note the increased incidence of both resorption and loss of support associated with infection and trauma. According to biologic principle, any source of inflammation could result in increased resorption and then loss of support. Also, any trauma that caused graft splintering or increased exposed surface area would similarly increase potential resorp-

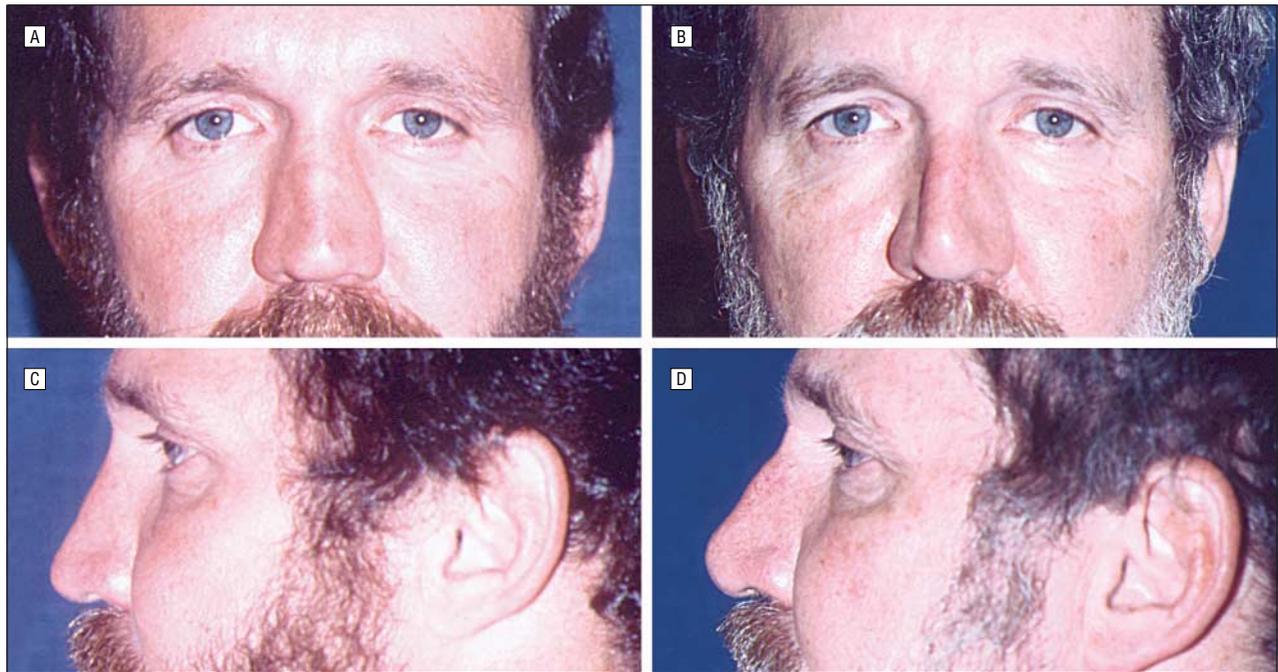


Figure 1. Preoperative (A and C) and postoperative (B and D) photographs of a 56-year-old man who presented with posttraumatic loss of nasal projection and widening of the nasal dorsum.

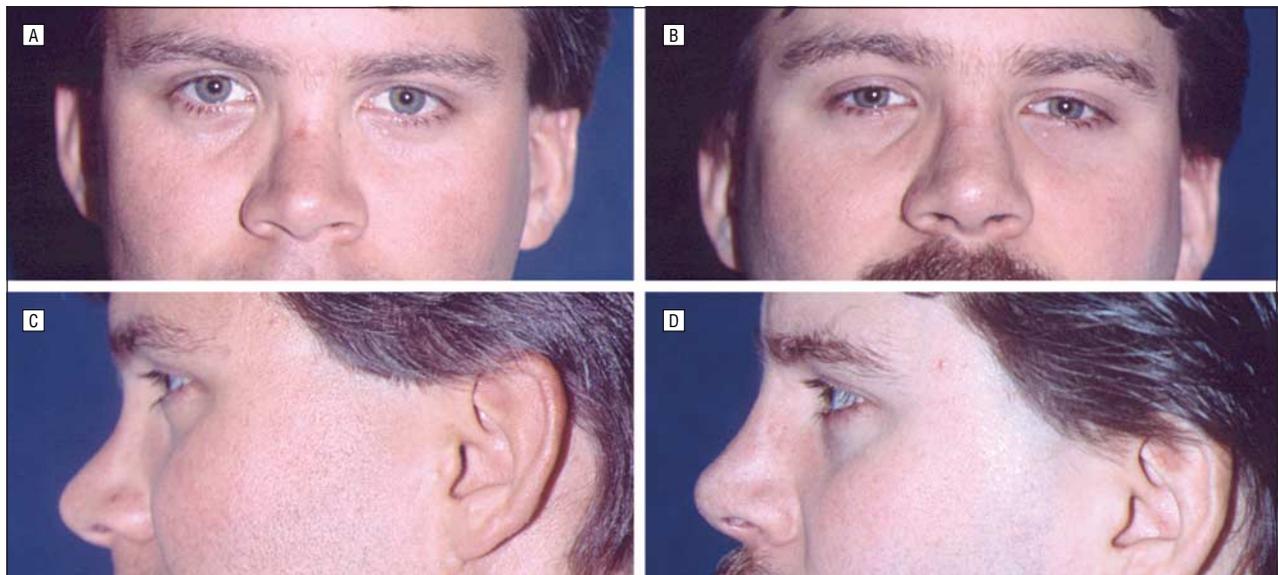


Figure 2. Preoperative (A and C) and postoperative (B and D) photographs of a 26-year-old man who presented with posttraumatic saddle nose deformity.

tion but reduce graft rigidity for any supportive function as well. The data support this hypothesis, admittedly without histologic confirmation.

The intraoperative inspection of the IHRGs was more compelling than any other finding in this study because it represented our most objective assessment of the integrity of the grafts. In most cases in which loss of supportive or structural function might have been labeled as resorption, it was clear that the grafts had slipped but were otherwise intact despite long-term follow-up. Our revision cases support this finding: 12 of 18 cases demonstrated utterly intact but shifted grafts. The altered graft position was responsible for the

change in support and form and was often misinterpreted as graft resorption.

There was a dramatic difference in the outcome of grafts used in auricular reconstruction compared with those used in nasal reconstruction. Resorption was noted in 71% of the auricular grafts compared with 10% of the grafts used in nasal reconstruction. There are a number of reasons for this difference. First, grafts used in nasal reconstruction are more difficult to examine. These grafts are often used in combination with other irradiated rib grafts or autogenous grafts. It is often difficult to isolate the contribution made by a single irradiated rib graft. Resorption probably occurred more frequently in this group

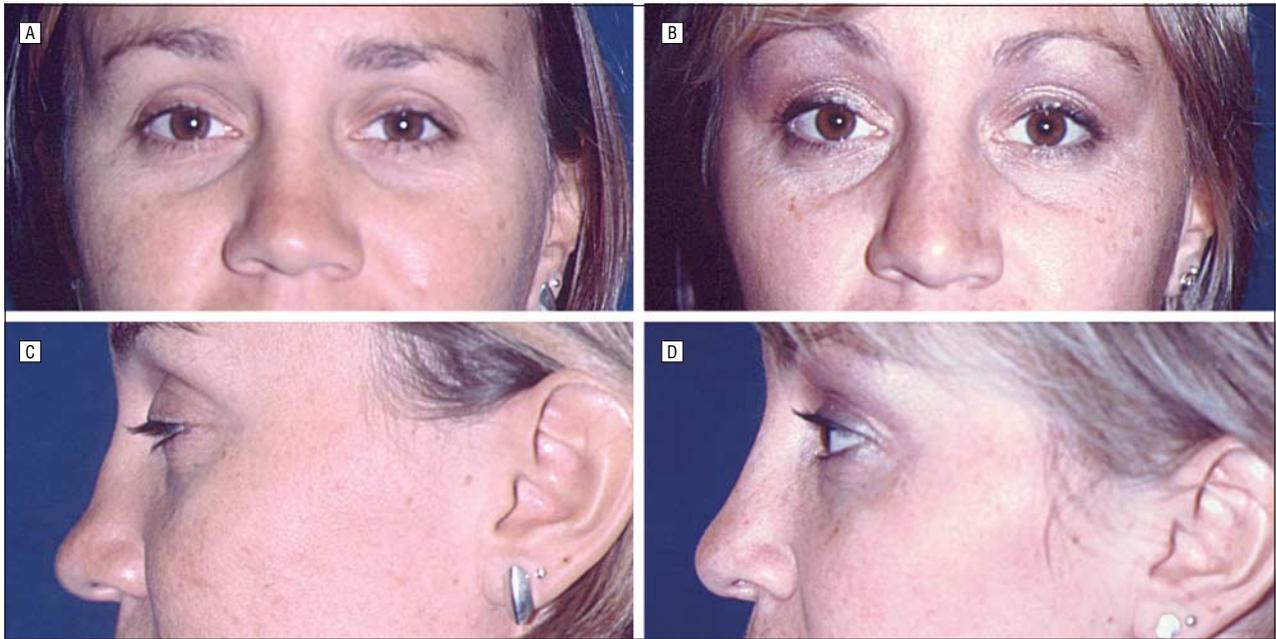


Figure 3. Preoperative (A and C) and postoperative (B and D) photographs of a 36-year-old woman who presented with a moderate supratip deformity.

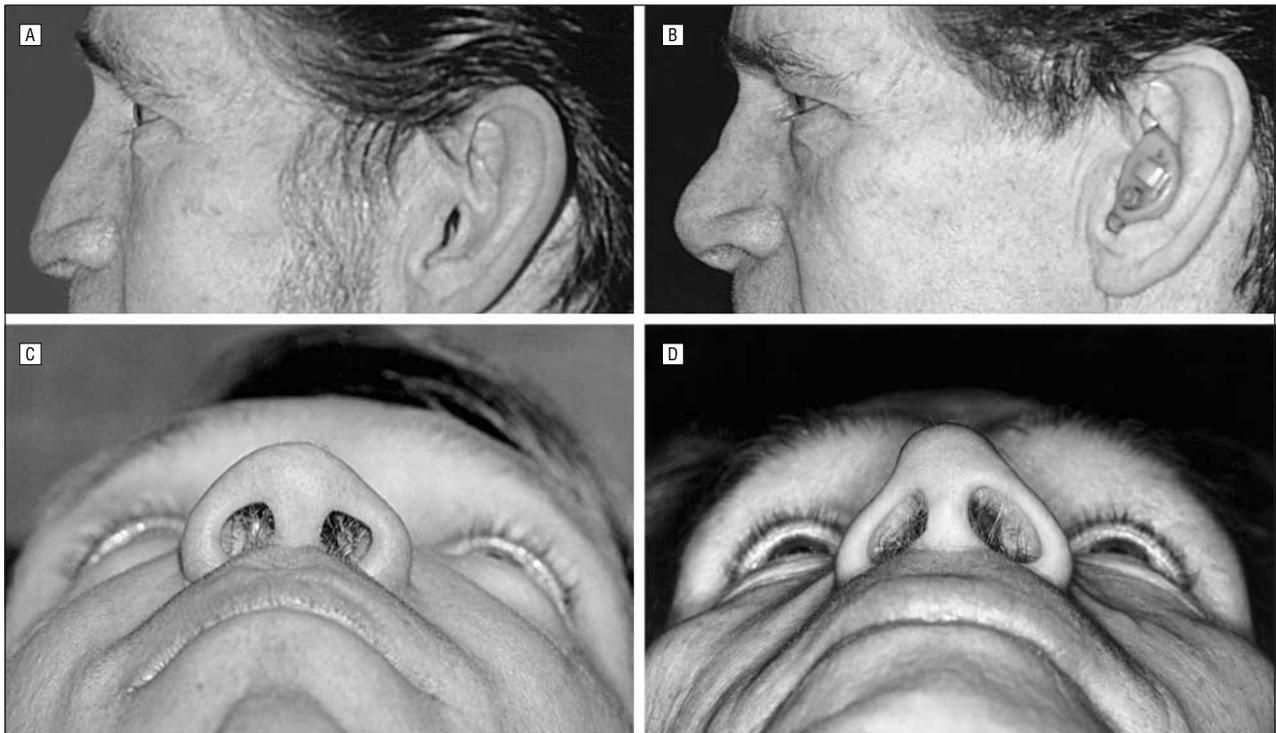


Figure 4. Preoperative (A and C) and postoperative (B and D) photographs of a 58-year-old man who presented with loss of nasal tip projection and severe ptosis of the nasal tip.

than was noted, even though form and function were maintained.

The function of the grafts also differs between the sites of implantation. The function of nasal grafts is to provide bulk and broad structural support. Large grafts secured deep in soft tissue pockets met the need very well despite small degrees of graft compromise by resorption and displacement; therefore, any fibrous replacement was likely to be successful in providing these functions. In contrast, auricular grafts must maintain sharp defini-

tion. Loss of definition results in loss of cosmetic effect. Fibrous tissue replacement did not maintain the contours of these grafts but, instead, resulted in the formation of amorphous masses.

The more exposed location of auricular grafts permits manipulation, compression, and other causes of direct graft trauma. According to our findings, this may be one of the most notable factors increasing resorption, each traumatic event inciting another inflammatory response at the graft–soft tissue interface. Other reasons

for the difference in outcome between sites of implantation include the size of the graft and the environment of the recipient site. The auricular grafts were larger and had less tissue coverage. In addition to making any



Figure 5. Postoperative photograph of a 4-year-old boy showing unsatisfactory outcome after an irradiated homologous rib cartilage graft was used for reconstruction of a right aural atresia defect.

changes in the grafts more readily apparent, the auricular graft host site also provided a correspondingly less robust vascular bed to support these grafts. The nose may provide better vascular support for smaller grafts, which in turn could lead to improved graft survival, more reliable fibrous tissue replacement, or both.

It is noteworthy in this study that an irradiated cartilage graft removed 6 years after transplantation was not histologically dissimilar to normal viable cartilage. Also, the graft showed no evidence of resorption on gross inspection. The most likely explanation for this finding is that light microscopy is not sensitive enough to assess the viability of preserved cartilage grafts. Stoksted and Ladefoged⁸ evaluated the viability of crushed homograft cartilage preserved in merthiolate. In their study, the chondrocytes were not histologically dissimilar from viable chondrocytes up to 3½ years after transplantation. Further evaluation with the use of electron microscopy, however, revealed that these cells had undergone severe degeneration.

One theory that has been postulated for the presence of truly viable chondrocytes is that the host had repopulated the cartilage graft. In Donald's² study in animals, only 4 of 57 preserved cartilage grafts showed evidence of viable chondrocytes: 1 of 50 irradiated grafts and 3 of 7 grafts that had been preserved in merthiolate. Viability was assessed using 35S autoradiography, vital staining, and electron microscopy. It was believed that the viable chondrocytes had differentiated from the surrounding host mesenchymal cells. In an animal study, Babin et al⁹ showed that nonviable cartilage grafts remained nonviable after transplantation. Viability was assessed using light and electron microscopy. Host repopulation did not occur in their study. Although it is possible that host repopulation can occur, it appears that this process is so infrequent that it cannot be relied on for the

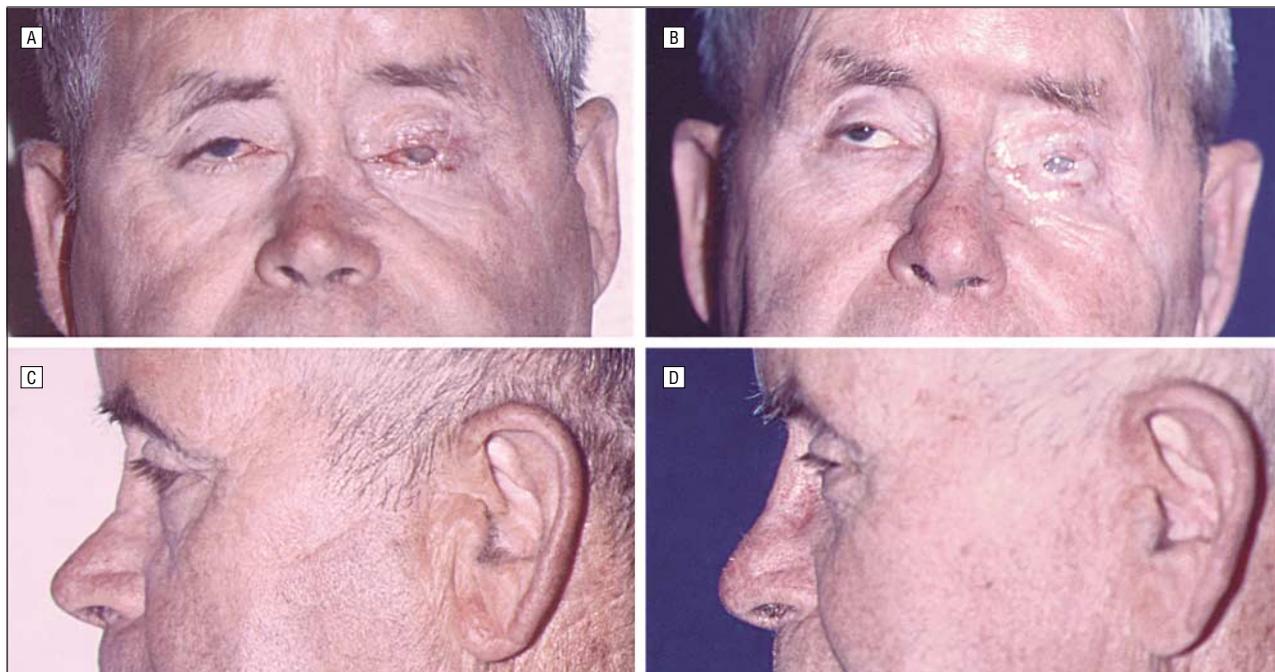


Figure 6. Preoperative (A and C) and postoperative (B and D) photographs of a 68-year-old man who presented with a dorsal nasal defect after extirpation of a nasal tumor.

success of preserved homograft reconstructions. The finding of viable-appearing chondrocytes on light microscopy does, however, remain significant. It indicates that the process of cartilage resorption and its replacement by fibrous tissue occurs very slowly. The slow nature of this process is thought to aid in the maintenance of the shape and architecture of the implant.

CONCLUSIONS

The role of IHRGs in facial reconstruction continues to be defined. The success of these grafts is dependent on the site of implantation and their intended function. Their use should be restricted to situations in which bulk and broad structural support are required. Their use in nasal reconstruction was associated with excellent intended restoration of form and function and very acceptable complication rates. The results remained stable with a mean follow-up of 36 months. The 8% incidence (9/109) of minor loss of support with loss of form and the 11% incidence (11/102) of resorption with loss of form compare favorably with rates reported in contemporary literature. The longevity of IHRGs has been favorable for functional, structural, and cosmetic nasal reconstruction, and IHRGs remain the graft of choice when autogenous septal cartilage is unavailable in our practice. Their use in auricular reconstruction, however, was associated with an unacceptable rate of graft failure in our study, and it is our belief that they should no longer be used for this purpose. The continued evaluation of these cases

will provide even more valuable information pertaining to the longevity of IHRGs.

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Correspondence: Alan J. C. Burke, MD, Department of Facial Plastic Surgery, Virginia Ear, Nose, and Throat Associates, 5875 Bremono Rd, Suite 303, Richmond, VA 23226 (alanjcburke@hotmail.com).

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