Irradiated Homologous Rib Grafts in Nasal Reconstruction

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**Objective:** To assess the long-term efficacy of irradiated homologous rib grafts (IHRGs) for both augmentation and support function in rhinoplasty in general and for specific recipient sites within the nose.

**Design:** A retrospective study was conducted at an academic medical center to evaluate the loss of volume and support function of IHRGs in 9 specific recipient sites in the nose.

**Results:** We studied 66 patients, with a total of 177 IHRGs, dating back 9 years, with an average follow-up of 51 months. The rate of resorption increased with duration of follow-up. Complete resorption was found in 1 IHRG, and moderate resorption was observed in 55 IHRGs (31%). Resorption was characterized by a loss of support function rather than a loss of volume. Moderate resorption had a negative clinical outcome for shield grafts only.

**Conclusions:** Irradiated homologous rib grafts were safe to use in rhinoplasty. In cases requiring a shield graft, IHRGs should be avoided.

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**METHODS**

This study included all patients undergoing nasal surgery with IHRGs between November 1998 and August 2005 in the Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands.
All IHRGs were obtained from TutoPlast (Tutogen Medical GmbH, Neunkirchen am Brand, Germany). The rib implants were selected according to stringent specifications with respect to donor selection and serologic study results to minimize the risk of transmitting infectious disease. After the removal of the rib cartilage, the process started with several cycles of alternating baths in deionized water and 10% sodium chloride. The cartilage was then soaked in 3% hydrogen peroxide for 24 hours, after which the material was placed in pure acetone several times followed by evaporation under vacuum. Final packaging consisted of placing the cartilage in sterile screw-cap vials and adding sterile normal saline. The grafts were then sterilized by gamma irradiation with a minimum dose of 1780 krad (to convert to grays, multiply by 10) and a maximum dose of 2010 krad.

During surgery, the grafts were aseptically removed from the container and rinsed 3 times in 500 mL of sterile saline solution. To prevent warping, the outer layers were removed, including the perichondrium, leaving only the central portion of the donor cartilage for reconstruction material. Graft implants were shaped, sculptured, and beveled with fresh scalpels. In most cases, the procedure consisted of an open approach through a broken columnar incision. An open approach was not technically necessary in all cases, but it was used to prevent postoperative infection by minimizing intranasal incisions and taking advantage of the elongated distance between the graft implants and the outer world. Amoxicillin (1500 mg in 3 doses for 7 days) was administered orally to all patients to prevent postoperative infection.

**EVALUATION OF THE POSTOPERATIVE RESULTS**

To evaluate the postoperative results, we analyzed the rate of resorption, infection, extrusion, and warping and the condition of the overlying soft-tissue envelope. We also assessed and classified the resorption rates for each individual graft. This evaluation took into account the amount of volume or augmentation, graft integrity, and support function. The amount of volume or augmentation of each implant was studied by comparing postoperative photographs 3 months after surgery with those taken at the time of evaluation. Also, each implant was palpated to assess graft integrity and support function. We developed 3 levels of resorption. The first level, N (none, 0%-25%), was classified as no loss of graft volume and no changes in graft integrity or support function. The second level, M (moderate, 25%-50%), was classified as an evident loss of graft volume and/or evident loss of graft integrity or support function. The third level, C (complete, >50%), was classified as a complete loss of volume and/or a complete loss of graft integrity and support function. This third level was characterized by the necessity for revision surgery.

The rate of postoperative infections was based on the need for local or systemic antibiotic therapy, the localization of the infection, and the need for surgical removal or extrusion of the implant. We evaluated the functionality of the alar batten grafts by comparing the patients’ subjective nasal passages with their condition 3 months after surgery. Finally, we assessed the rate of warping, the reactions in the overlying soft-tissue envelope, and the mobility of the implants. The patients were divided into 3 groups depending on the duration of follow-up: the first group (group 1) was followed up for 18 to 44 months; the second group (group 2) was followed up for 45 to 70 months; and the third group (group 3) was followed up for 71 to 96 months.

Between February 1999 and August 2005, a total of 90 patients underwent reconstructive rhinoplastic surgery with IHRGs. We were unable to evaluate 24 patients (27%). Fourteen of the 24 patients were untraceable: 6 patients were satisfied with the functional and aesthetic result but did not want to participate in the study; 3 patients underwent revision surgery with autogenous cartilage grafts owing to persistent functional or aesthetic problems that were not related to the resorption of the grafts or other IHRG-related complication; and 1 patient died during follow-up as a result of causes that were not related to his nasal surgery.

Sixty-six patients (73%) were evaluated in this study (29 men and 37 women) during a follow-up period ranging from 18 to 96 months (average follow-up, 51 months). The patients’ ages on the date of surgery ranged from 15 to 68 years, with an average of 39 years. A total of 177 IHRGs were implanted in these 66 patients (Table). Ten of the 66 patients underwent primary rhinoplasty, and 56 underwent a revision procedure. Fifty-two of the 56 patients had undergone previous surgery elsewhere, and 4 had undergone previous surgery in our clinic: 2 with IHRGs and 2 without IHRGs. The endonasal approach was used in 8 of the 66 patients, with 58 patients undergoing an external approach. The indication for nasal surgery in 27 patients was a saddle nose deformity without recent infection; 21 patients had functional-aesthetic problems requiring nasal grafts; 15 patients had a unilateral cleft lip; 2 patients had extrusion of a silicone implant; and 1 patient had a septal perforation.

The resorption rate of the IHRG implants was evaluated as described in the “Methods” section. Among the group as a whole (66 patients, 177 nasal grafts), 121 of the grafts (68%) had no signs of graft resorption and 55 (31%) had moderate resorption (Table). One graft had complete resorption, which required revision surgery. In group 1 (29 patients, 75 nasal implants), 64 implants (85%) showed no signs of resorption, and 11 (15%) showed moderate resorption. In group 2 (24 patients, 59 nasal implants), 35 implants (59%) showed no signs of resorption, 23 (39%) showed moderate resorption, and 1 (2%), a shield graft, showed complete resorption. In group 3 (13 patients, 43 nasal implants), 22 implants (51%) showed no resorption, and 21 (49%) showed moderate resorption. Complete resorption was not observed in this group. After the use of alar batten grafts (n = 40), functional improvement in nasal breathing was observed in 37 cases (92%).

In 15 of the 66 patients (23%), 17 complications other than resorption were observed.

<table>
<thead>
<tr>
<th>Complication</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>6</td>
</tr>
<tr>
<td>Extrusion/removal of implant</td>
<td>0</td>
</tr>
<tr>
<td>Warping</td>
<td>2</td>
</tr>
<tr>
<td>Reaction in soft-tissue envelope</td>
<td>7</td>
</tr>
<tr>
<td>Mobility</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

A postoperative inflammatory response was noticed in 6 patients (9%) who had undergone revision surgery.
through an external approach. In all cases, the response was characterized by localized erythema and edema of the soft-tissue envelope without purulent discharge or fever. Five of the 6 patients were treated with oral systemic broad-spectrum antibiotics (amoxicillin/clavulanic acid, 500/125 mg every 6 hours). The other patient was treated with a topical antibiotic ointment. None of the implants needed to be removed, and no recurrent or chronic infections were observed. The onset of the inflammation occurred within 1 month after implantation in all cases. On average, the clinical signs started on the 13th day. The inflammation was localized in the nasal tip in 1 patient, in the dorsum in 1 patient, and in the columella in 3 patients. The erythema was located in the tip and columella region in 1 patient. No association was found between inflammation and a higher resorption rate. There was no extrusion of implants. Minimal warping of a dorsal onlay graft was observed in 2 of 40 cases (5%). In 2 other cases (3%), also with dorsal onlay grafts, the patients complained of mobility in the cranial part of the implant at the site of the frontonasal groove during palpation. In 7 of the 66 patients (11%), reactions were observed in the overlying soft-tissue envelope. Diffuse chronic redness of the skin was detected in 3 patients (5%), 2 of whom had an inflammatory response in the postoperative period (2 of 6 patients [33%]). In 4 of the 66 patients (6%), there were signs of telangiectasia of the soft-tissue envelope overlying a dorsal onlay graft (4 of 40 patients [10%]).

Our data showed that the incidence of graft resorption of IHRGs increased with the duration of follow-up. Clinically, the most important finding was that resorption of IHRGs was characterized by a loss of support function rather than by a reduction of volume. These findings were in agreement with other long-term follow-up studies and animal data. In the literature, it has been suggested that the original grafts are replaced in time by fibrous tissue, resulting in a loss of support function without a loss of volume. This phenomenon, and relatively short follow-up periods, may also explain the more favorable outcomes regarding the rate of resorption in some other studies.

More specifically for rhinoplasty, Kridel and Konior described the largest series so far, with 122 rhinoplastic procedures in which 306 IHRGs were used. In their study, the follow-up ranged from 1 to 84 months, with an average of 15 months. Complete resorption was noted for 2 grafts (both in the same patient). This total resorption was found early in the postoperative phase and resulted from a localized infection at the graft site. Partial resorption (0%-25%) was seen in 2 patients, both cases involving a dorsal onlay graft. Murakami et al described a series of 18 patients with saddle nose deformities. Reconstruction was performed using IHRGs, a dorsal onlay graft attached to a columellar strut. Follow-up ranged from 1 to 6 years (mean, 2.8 years), and none of the IHRGs showed infection, extrusion, or noticeable resorption. Burke et al studied 118 patients who had undergone nasal reconstruction in which a total of 177 IHRGs were used. Four of 13 patients (30%) with follow-up of 5 to 10 years had severe to complete loss of graft volume (51%-100% resorption), whereas 2 of 3 patients (66%) with follow-up of more than 10 years showed this volume reduction. Loss of structural support with compromised nasal function or aesthetics for the same follow-up periods occurred in 3 of 14 patients (21%) and in 1 of 3 patients (33%), respectively. Burke and colleagues also studied the long-term outcome of IHRGs for auricular reconstruction and found resorption in 5 of 7 patients (71%). The typical appearance was an amorphous mass, which was probably due to the replacement of the original grafts by fibrous tissue. The IHRGs from our series were obtained from Tutoplast. Because these grafts were chemically processed with peroxide and acetone before irradiation, they might not behave the same as nonchemi-

### Table. Resorption of Irradiated Homologous Rib Grafts

<table>
<thead>
<tr>
<th>Type of Implant</th>
<th>Group 1&lt;sup&gt;a&lt;/sup&gt; (n=29)</th>
<th>Group 2&lt;sup&gt;b&lt;/sup&gt; (n=24)</th>
<th>Group 3&lt;sup&gt;c&lt;/sup&gt; (n=13)</th>
<th>All 3 Groups, No. (%) (N=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M</td>
<td>C</td>
<td>N</td>
</tr>
<tr>
<td>Columellar strut</td>
<td>42</td>
<td>16</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Caudal septal replacement</td>
<td>24</td>
<td>9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Shield or tip graft</td>
<td>27</td>
<td>12</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Dorsal or nasofrontal onlay</td>
<td>40</td>
<td>16</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Alar batten</td>
<td>30</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Spreader graft</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Side wall onlay</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alar rim graft</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Columellar onlay</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maxilla augmentation graft</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total, No. (%)</td>
<td>177</td>
<td>(100)</td>
<td>64</td>
<td>(85)</td>
</tr>
</tbody>
</table>

Abbreviations: C, complete (>50%); M, moderate (25%-50%); N, none (0%-25%).

<sup>a</sup> Follow-up, 18 to 44 months.
<sup>b</sup> Follow-up, 45 to 70 months.
<sup>c</sup> Follow-up, 71 to 96 months.
cally processed irradiated rib grafts. Irradiated homologous rib grafts from the same manufacturer were used to augment the nasal dorsum as dorsal onlay grafts, or they were diced and wrapped in oxidized cellulose (Surgicel; Johnson & Johnson, New Brunswick, New Jersey). With a mean follow-up of 36 months, recurrence of dorsal depression was observed in 5 of 23 patients (22%). This recurrence was probably attributable to partial resorption. Song et al noted partial resorption of dorsal onlay grafts in 6 of 35 cases (17%). Our study was intended to assess which types of nasal grafts were reliable for a favorable long-term functional and aesthetic outcome. In the evaluation of the resorption rate, the amount of volume and support function were taken into account. Both parameters were evaluated in a subjective manner, but with the use of the classification system described in the “Methods” section, we studied and analyzed the results as objectively as possible. As we stated earlier, the rate of complete resorption in our series was low. Only a shield graft was completely resorbed. In that case, palpation confirmed the presence of graft tissue underneath the overlying soft-tissue envelope, with a reduction of tissue consistency compared with the original IHRG graft. The incidence of moderate resorption, on the other hand, increased with duration of follow-up to levels of 49% in patients with follow-up of 71 to 96 months. However, the clinical consequences of resorption were different for the distinct types of nasal IHRGs used. Nasal IHRGs with a need for structural support were more likely to lose their function. Shield grafts for increasing nasal tip projection were most at risk. In cases of moderate resorption, these grafts showed less tissue consistency during palpation. Clinically, the nasal tip in these cases showed a loss of tip definition and refinement and became more bulbous in comparison with the situation 3 months after surgery. Consequently, there was minimal loss of nasal tip projection. Columellar struts and caudal septal replacement grafts were clearly less rigid on palpation, but, in general, there was little to no loss of projection. In time, IHRG dorsal onlay grafts were also found to have lost tissue consistency on palpation, but the contour was generally well preserved. In all cases involving alar batten grafts, the implants were palpable and showed some reduction of tissue consistency. However, improvement of nasal breathing was achieved in 37 of 40 cases (92%). Improved nasal passage with spreader grafts was found in 4 of 4 cases (100%).

In our study, we found that nasal IHRGs underwent no or minimal reduction in volume, but it is possible that some structural support might be lost over time. For most types of grafts, this loss in tissue consistency did not negatively influence the functional or aesthetic result. However, with the use of IHRG shield grafts, tip definition and refinement were at risk in the long term. For shield grafts, therefore, we recommend the use of autologous cartilage grafts such as auricular or costal cartilage. In a previous study involving patients with leprosy, autogenous costal cartilage shield grafts underwent more resorption (55%) than auricular grafts (23%). The lower resorption rate and more favorable physical properties owing to the natural flexibility of auricular cartilage made this the material of first choice in the lower nasal third in cases in which shield grafts were needed. Auricular cartilage is probably more resistant to resorption caused by microtrauma and stresses from the overlying soft-tissue envelope in the nasal tip area than irradiated and autogenous costal cartilage. Localized erythema and edema of the skin in the postoperative phase was the most frequently noted complication (6 of 66 cases [9%]). This symptom, however, completely disappeared with the use of orally and/or locally administered antibiotics. Frequent postoperative assessments after surgery with IHRGs are therefore essential to avoid progression of the inflammation response and/or infection. At the site of the inflammatory response, however, 2 of the 6 patients developed a diffuse chronic redness of the skin. In our series, minimal warping was observed in 2 of 40 dorsal onlay grafts (5%). Warping can be prevented by using only the centrally cut pieces of rib cartilage. In a controlled experimental study, the rate of warping in irradiated and nonirradiated costal cartilage proved to be similar for at least 4 weeks. Two patients in our series had undergone previous surgery elsewhere involving a silicone implant. Both patients developed a chronic infection that did not respond to antibiotic therapy. In these patients, immediate reconstruction with IHRGs was performed. Immediate reconstruction has advantages over reconstruction at a later date after a period of resolution of the inflammation. When reconstruction is performed immediately, patients need not wait for a secondary reconstruction, and this is emotionally beneficial. Also, there will be less change caused by retraction of the pocket underneath the soft-tissue envelope as a result of scar tissue formation. In both patients, there were no complications in the postoperative period and, in particular, no signs of infection or extrusion. These findings were in line with similar observations in a series of 18 patients described by Clark and Cook. Impregnation of the IHRGs with antibiotics could conceivably result in a further reduction of the risk of postoperative infection in cases in which the implant bed is already infected.

In conclusion, in our study, the use of IHRGs in rhinoplasty resulted in relatively low complication rates. The resorption rate increased with duration of follow-up. Resorption was characterized by a loss of structural support rather than by a loss of volume. This phenomenon was probably the result of the replacement of the original grafts by fibrous scar tissue. Complete resorption requiring revision surgery was uncommon. There was moderate resorption in half of the cases with a follow-up period of 71 to 96 months. For most types of nasal grafts, moderate resorption did not negatively influence the functional or aesthetic result. However, in cases of moderate resorption of IHRG shield grafts, there was loss of nasal tip definition and nasal tip projection. In cases in which a shield graft is a clinical necessity, we recommend the use of autogenous auricular cartilage grafts.

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