Dorsal Onlay Cartilage Autografts
Comparing Resorption in a Rabbit Model

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Objective: To compare the resorption characteristics of dorsal onlay cartilage autografts from the septum, auricle, and rib.

Methods: Fourteen New Zealand white rabbits underwent harvesting of equal-sized septal, auricular, and costal cartilage grafts free of perichondrium. All autografts were implanted subcutaneously on the nasal dorsum and then removed after 3 months. Graft mass, chondrocyte density, and histologic features from hematoxylin-eosin–stained sections were compared before and 3 months after implantation.

Results: At 3 months after implantation, septal cartilage grafts averaged 30.8% resorption by weight, followed by auricular (23.1%) and costal (7.6%) cartilage. All 3 groups demonstrated similar changes in chondrocyte density and minor calcification at 3 months. There was no evidence of necrosis or inflammatory changes in any of the specimens.

Conclusions: Although the septum is often the preferred source of autogenous cartilage for nasal reconstruction, short-term resorption of septal cartilage appears to be higher for dorsal onlay grafts. The low resorption of costal cartilage may be due in part to its compact shape compared with septal and auricular cartilage. It remains to be seen whether these differences in resorption persist in the long term.

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HE ROLE OF GRAFTS and implants in aesthetic and reconstructive surgery of the face has evolved considerably during the past several decades. The search for the ideal implant material has led to an exponential growth in research and development of different allografts, with silicone, expanded polytet, and polyamide mesh being some of the most widely used. The advantages of a suitable allograft are clear: unlimited supply, custom contouring, maintenance of shape, permanence, and lack of donor site morbidity. Although allografts have gained widespread acceptance in several areas of the body, their use in the nose has been associated with an unacceptably high rate of extrusion, infection, and rejection.1,3 Certain unique anatomic features of the nose account for this: it occupies a prominent position in the center of the face, and its lower portion is mobile. Consequently, nasal implants are subject to repeated trauma and constant functional stress, causing persistent tissue irritation and impeding stability.1,3 While recent studies demonstrating long-term stability of expanded polytet (Gore-Tex soft-tissue patch; W. L. Gore & Associates, Flagstaff, Ariz) in the nasal dorsum appear promising,6 cartilage and bone grafts remain the material of choice for dorsal augmentation by most surgeons.

Several types of cartilage and bone dorsal onlay grafts have been used, including autografts, homografts, and xenografts. The cartilage autograft is preferred for most purposes, as it offers several distinct advantages: it is perfectly biocompatible; the tissue is readily available with minimal donor site morbidity; it can be easily fashioned into any desired shape; it maintains its structural resilience, yet may be gently morselized, if needed, to break its memory; unlike bone, it does not require direct contact with bone or cartilage to survive; long-term survival is well documented; extraction, if necessary, poses minimal damage to surrounding tissues; and there is no risk of disease transmission.7

Many animal and human studies have addressed the question of cartilage graft resorption, and few have succeeded in quantifying and comparing the absorption rates of autologous cartilage from dif-

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fferent donor sites. In addition, most animal studies have not specifically addressed the nasal dorsum as the recipient site for cartilage implants. In our clinical experience, dorsal onlay cartilage grafts undergo much more resorption than do tip grafts such as lower lateral cartilage onlays, intercrural struts, and shield grafts.

The goal of this prospective study was to quantify the level of resorption of dorsal onlay cartilage autografts taken from the septum, auricle, and rib. The adult rabbit was chosen for our animal model because (1) its cartilage is similar to human cartilage\(^6,10\) and (2) it is an established recipient site model for nasal dorsal implants.\(^6\)

### METHODS

Fourteen adult male New Zealand white rabbits weighing 4.0 to 4.4 kg each were used. All procedures were performed under animal care guidelines of the Committee on Animal Care, Institutional Review Board. Each rabbit underwent implantation of a cartilage autograft from the auricle, septum, and rib, onto the nasal dorsum. Anesthesia consisted of ketamine hydrochloride, 40 mg/kg intramuscularly, and xylazine hydrochloride, 5 mg/kg intramuscularly for induction, followed by inhaled 1% to 2% isoflurane to effect for the duration of the procedure. The ventral surfaces of the ear, the nose, and the lower chest wall were shaved and prepared with povidone-iodine in a sterile manner.

For the auricle autografts, the technique described by Brown et al\(^11\) was used. A 3-cm incision was made on the dorsal aspect of the base of the ear. A flap of ventral skin and perichondrium was raised at the base of the ear, and a 15 \times 10-mm rectangle of auricular cartilage was taken. The donor site was closed primarily with interrupted 4-0 chromic catgut in a single layer.

For the septum, the approach described by Gubisch et al\(^9\) was used. This involved folding back the alar ridge of the nose to obtain extramucosal exposure of the septum. After hemitransfixion incisions, bilateral mucoperichondrial flaps were elevated, and a 15 \times 10-mm rectangle of cartilage was removed.

The technique described by Coutts et al\(^12\) was used for the rib autografts. An oblique incision was made along the inferior costal margin. The medial cartilaginous portion of the ribs was exposed, and a 15-mm length of the inferior-most cartilaginous rib was excised by means of meticulous dissection. The chest was closed in 3 layers with 4-0 polyglactin 910 for muscle and dermis closure and 4-0 chromic catgut for skin.

Each donor cartilage specimen was cleaned of surrounding fibrous attachments and soft tissue, washed with isotonic sodium chloride solution, and blotted dry. A No. 11 blade was used to carefully cut the specimens into 2 pieces, the first 10 mm long and the second 5 mm long. The smaller portion of each graft was placed in 10% buffered formalin and set aside for histologic analysis. The larger portion was weighed under sterile fashion on an analytic balance and set aside for implantation.

For weight analysis, each autograft was carefully dried and weighed immediately before implantation and again on removal at 3 months.

Preimplant and postimplant weight measurements and chondrocyte counts were compared by standard \(\chi^2\) analysis. Because there were 3 different autograft types, we chose the nonparametric paired Wilcoxon test to compare resorption between the 3 groups. This involved isolating 2 of the 3 groups and comparing resorption between them independent of the third group. Consequently, multiple paired comparisons were produced: rib-septum, rib-auricle, and auricle-septum.

Table 1 shows the weight change for each group of autografts. Septal cartilage autografts averaged a weight loss of 30.8%, followed by auricular cartilage (23.1%) and costal cartilage (7.6%). A pairwise comparison of resorption between the 3 autograft types is shown in Table 2, with the use of the 2-tailed paired Wilcoxon test. With a Bonferroni correction of 3 for the multiple comparisons, the cutoff for statistical significance was \(P<.05/3\) or .0167. The mean difference between septum and rib weight changes was −23.2% (range, +1.8% to −71.9%), which was statistically significant (\(P<.01\)). The difference between auricle and rib resorption was marginally statistically significant (mean, −15.5%; range, +59.6% to −64.9%; \(P<.02\)). The difference between septrium and auricle resorption did not reach statistical significance (mean, −7.7%; range, +50.7 to −75.5%; \(P>.05\)).

Preimplant and postimplant chondrocyte density (Table 3) differed only marginally in all cartilage types and did not reach statistical significance according to a 2-tailed paired Wilcoxon test with Bonferroni correction. Histologic comparison of hematoxylin-eosin-stained slides showed minor levels of calcification in about one third of the postimplant specimens, regardless of cartilage type. There was no evidence of necrosis or inflammatory changes.

### COMMENT

The most common sources of cartilage autografts are the nasal septum, auricle, and rib. Septal and auricular cartilage, when available, are preferred, as rib cartilage has
Auricle
Rib

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using radiographic analysis, Donald et al\textsuperscript{19} found mini-
mal resorption (1 of 20) in irradiated cartilage homo-
grafts implanted in the sheep facial skeleton. Babin et al\textsuperscript{20}
morbidity. In addition, the tendency of rib cartilage to
grafts also carry the added risk of significant donor site
modeling the graft may undergo. Irradiated costal car-
tilage homografts (irradiation, formalin, glutaral-
dehyde, and alcohol) did not influence observed fibrosis
and resorption.

Recently, Tjelmeland and Stal\textsuperscript{23} examined rabbit au-
ricular and costal cartilage autograft resorption at 1 year.
They found 18.5% resorption by weight of auricular car-
tilage implanted in the nose, compared with 14.5% im-
planted in a control site (occiput). There was essentially
no resorption of costal cartilage. Septal cartilage was not
examined.

The aim of the present study was to compare the re-
soption of the 3 most commonly used sources of autog-
enous cartilage when used as dorsal onlay grafts. The re-
ults show a statistically significantly lower rate of
resorption by weight of costal cartilage than either sep-
tal or auricular cartilage at 3 months. Changes in chon-
drocyte density were negligible.

Since the specimens were washed with isotonic so-
dium chloride solution and blot dried before weighing,
the difference in preimplant and postimplant weights may
merely reflect the tissues' ability to retain fluid rather than
a change in amount of ground substance. However, the
fact that there was no significant change in chondrocyte
density makes this scenario less plausible.

Another possible reason for the observed differ-
ence in weight changes is that costal cartilage has a much
lower surface area per unit weight than either septal
auricular cartilage. Cartilage resorption is thought to be
caued at least in part by exposure to local mediators of
wound healing such as interleukin 1.\textsuperscript{24} The compact shape

a tendency to warp, although internal stabilization of rib
grafts with wire has been reported.\textsuperscript{13} Rib cartilage au-
tografts also carry the added risk of significant donor site
morbidity. In addition, the tendency of rib cartilage to
calcify with age makes costal grafts difficult to carve.\textsuperscript{14}

One of the most important issues regarding carti-
lage grafts in the nose is the degree of resorption and re-
modeling the graft may undergo. Irradiated costal car-
tilage homografts have been studied extensively, with
resorption levels quoted in human studies ranging from
0% to 75%.\textsuperscript{7,13-17} Donald\textsuperscript{18} investigated animal costal car-
tilage autografts and homografts implanted in the sheep facial skeleton. Babin et al\textsuperscript{20} found that fresh cat costal cartilage autografts and homografts underwent minimal resorption, but that both

### Table 1. Cartilage Weights Before and 3 Months After Implantation

<table>
<thead>
<tr>
<th>Animal No.</th>
<th>Septum Weight, g</th>
<th>% Change</th>
<th>Auricle Weight, g</th>
<th>% Change</th>
<th>Rib Weight, g</th>
<th>% Change</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>25.2</td>
<td>−9.4</td>
<td>28.7</td>
<td>−37.3</td>
<td>31.6</td>
<td>−6.3</td>
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<td>2</td>
<td>22.9</td>
<td>−6.5</td>
<td>35.1</td>
<td>−27.9</td>
<td>28.5</td>
<td>−5.6</td>
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<tr>
<td>3</td>
<td>20.4</td>
<td>−2.5</td>
<td>38.1</td>
<td>−12.3</td>
<td>30.4</td>
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<tr>
<td>4</td>
<td>27.0</td>
<td>−8.9</td>
<td>35.5</td>
<td>−33.0</td>
<td>28.0</td>
<td>−2.9</td>
</tr>
<tr>
<td>5</td>
<td>25.5</td>
<td>−6.3</td>
<td>36.0</td>
<td>−24.7</td>
<td>29.9</td>
<td>−5.0</td>
</tr>
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<td>6</td>
<td>29.0</td>
<td>−17.0</td>
<td>32.6</td>
<td>−58.6</td>
<td>29.4</td>
<td>−13.3</td>
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<tr>
<td>7</td>
<td>31.2</td>
<td>−14.4</td>
<td>39.4</td>
<td>−66.2</td>
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<td>+3.3</td>
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<td>−7.2</td>
<td>34.9</td>
<td>−34.6</td>
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<td>+18.5</td>
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<td>24.4</td>
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<td>−27.0</td>
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<td>−7.5</td>
<td>35.3</td>
<td>−41.9</td>
<td>31.6</td>
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<td>11</td>
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<td>−18.3</td>
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<td>−22.4</td>
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<td>13</td>
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<td>−29.1</td>
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<td>14</td>
<td>20.7</td>
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<td>38.2</td>
<td>−17.9</td>
<td>29.5</td>
<td>−3.7</td>
</tr>
<tr>
<td>Mean</td>
<td>23.3</td>
<td>−7.5</td>
<td>35.2</td>
<td>−30.8</td>
<td>30.3</td>
<td>−2.3</td>
</tr>
</tbody>
</table>

### Table 2. Two-Tailed Paired Wilcoxon Test Comparing Weight Change Between Autograft Types

<table>
<thead>
<tr>
<th>Autograft Type Compared</th>
<th>Mean Difference in Weight Change, %</th>
<th>Range, %</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septum vs rib</td>
<td>−23.2</td>
<td>+1.8 to −71.9</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Auricle vs rib</td>
<td>−15.5</td>
<td>+59.6 to −64.9</td>
<td>&lt;.02</td>
</tr>
<tr>
<td>Septum vs auricle</td>
<td>−7.7</td>
<td>+50.7 to −75.5</td>
<td>&gt;.05</td>
</tr>
</tbody>
</table>

### Table 3. Two-Tailed Paired Wilcoxon Test Comparing Change in Chondrocyte Density at 3 Months

<table>
<thead>
<tr>
<th>Autograft Type</th>
<th>Mean Change in Chondrocyte Density, %</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septum</td>
<td>−4.3</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Auricle</td>
<td>−5.1</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Rib</td>
<td>+1.9</td>
<td>&gt;.05</td>
</tr>
</tbody>
</table>
of rib cartilage may limit the exposure to these local factors and thus reduce resorption.

Septal cartilage showed the highest resorption of the 3 cartilage types. There are 2 possible explanations for this finding. First, septal cartilage has the highest surface area per unit weight, being flat like auricular cartilage but much thinner in the rabbit. Second, the thin, delicate nature of the rabbit septum makes it much more susceptible to traumatic injury during harvest, which may result in cartilage resorption.11 Of course, in humans, septal cartilage tends to be thicker and more firm than auricular cartilage. Thus, the relatively higher resorption rates seen in rabbit septal cartilage may not translate to humans.

Another explanation for the variable but significant resorption of all 3 types of cartilage is the recipient site. We believe that dorsal onlay cartilage grafts act much more like synthetic bulking implants and may be subject to more resorption than tip grafts, eg, intercrural struts, lower lateral cartilage onlay grafts, and shield grafts. This may be due to the increased pressure exerted on dorsal onlay grafts, as they are sandwiched between the tight skin–soft tissue envelope and a fixed bony framework.

**CONCLUSIONS**

It is clear from this study that dorsal onlay cartilage grafts show variable but significant resorption at 3 months. Septal and auricular grafts undergo a considerably higher level of resorption than rib. This is significant, since the septum is often the preferred source of autogenous cartilage in nasal reconstruction. In our clinical experience, tip grafts undergo much less resorption and remodeling than do dorsal onlay grafts. Further studies are needed to determine the extent of cartilage resorption and remodeling over the long term, particularly in onlay and nasal tip grafts.

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**REFERENCES**