Autologous vs Irradiated Homologous Costal Cartilage as Graft Material in Rhinoplasty

Jee Hye Wee, MD; Sue Jean Mun, MD; Woo Sung Na, MD; Heejin Kim, MD; Joo Hyun Park, MD, PhD; Dong-Kyu Kim, MD, PhD; Hong-Ryul Jin, MD, PhD

**IMPORTANCE** Studies comparing surgical results of rhinoplasty using autologous costal cartilage (ACC) and irradiated homologous costal cartilage (IHCC) are rare.

**OBJECTIVES** To compare the clinical results of major augmentation rhinoplasty using ACC vs IHCC and analyze the histologic properties of both types of cartilage.

**DESIGN, SETTING, AND PARTICIPANTS** A retrospective clinical study was conducted among patients who had undergone rhinoseptoplasty using ACC or IHCC from January 1, 2009, to December 31, 2014. Patients were followed up for more than 1 year after surgery and the histologic characteristics of ACC and IHCC were compared. The details of the surgical procedures and complications, including warping, infection, resorption, and/or donor-site morbidity, were evaluated by reviewing medical records and facial photographs. Patients' subjective satisfaction with aesthetic and functional results was evaluated using a questionnaire.

**MAIN OUTCOMES AND MEASURES** The details of the surgical procedures and complications, including warping, infection, resorption, and/or donor-site morbidity; patients' subjective satisfaction with aesthetic and functional results' objective evaluation of surgical outcomes, including symmetry, dorsal height, dorsal length, dorsal width, tip projection, tip rotation, tip width, and overall result; and histologic structures. Objective evaluation of surgical outcomes was graded using the Objective Rhinoplasty Outcome Score, which assessed symmetry, dorsal height, dorsal length, dorsal width, tip projection, tip rotation, tip width, and overall result. Histologic structures were evaluated using hematoxylin and eosin, Masson trichrome, Alcian blue, and Verhoeff elastic stains.

**RESULTS** A total of 63 patients (27 males and 36 females; mean [SD] age, 30.6 [9.5] years) had rhinoseptoplasty using ACC and 20 (9 males and 11 females; mean [SD] age, 35.4 [15.4] years) had rhinoseptoplasty using IHCC. Among observed complications, only notable resorption occurred more frequently in patients using IHCC (6 [30%]) than with ACC (2 [3%]) (P = .002). In subjective evaluations of aesthetic satisfaction, patients who received ACC showed significantly greater satisfaction (37 of 51 patients [73%] were very satisfied) than did those who received IHCC (6 of 20 [30%]) (P = .001). However, there was no between-group difference in subjective functional outcomes: 4 of 51 patients receiving ACC (8%) and 5 of 20 receiving IHCC (25%) were satisfied (P = .50) and 45 of 51 receiving ACC (88%) and 15 of 20 receiving IHCC (75%) were very satisfied (P = .15). Regarding objective aesthetic outcomes, all scores for both ACC and IHCC were more than 3.1 (between good and excellent). Histologic analyses showed larger, more evenly distributed, uniform chondrocytes and more collagens and proteoglycan contents in ACC than in IHCC.

**CONCLUSIONS AND RELEVANCE** Compared with patients receiving IHCC, those receiving ACC for rhinoseptoplasty showed superior aesthetic satisfaction; ACC also had less frequent notable resorption. Autologous costal cartilage also had better histologic properties than IHCC did, suggesting it as an ideal graft material with less chance of long-term resorption.

**LEVEL OF EVIDENCE** 3.
Autologous costal cartilage (ACC) is the graft material of choice for revision rhinoplasty, severe saddle nose deformity, or short contracted nose deformity, when large amounts of cartilage are needed. However, ACC has been criticized owing to its long operation time and high rate of donor-site morbidities, such as pneumothorax, postoperative pain, and scarring. Homologous cartilage, such as irradiated homologous costal cartilage (IHCC), has been used to overcome these disadvantages. Homologous cartilage offers easy availability, with no harvesting morbidity; however, unpredictable rates of infection and resorption as well as the lack of long-term studies on these cartilages have been criticized. Postoperative outcomes and complications associated with autologous and homologous costal cartilage have been reported. However, to our knowledge, studies comparing surgical results of rhinoplasty using these 2 graft materials are rare.

The purpose of this study was to present the clinical outcomes of major dorsal augmentation using ACC and IHCC and to compare the histologic properties of these materials. We intend to provide a reference for choosing the appropriate graft material for augmentation rhinoplasty.

Methods

Clinical Evaluations
The study included patients who underwent primary or revision rhinoplasty using ACC and/or IHCC at Boramae Medical Center, Seoul, Korea, from January 1, 2009, to December 31, 2014. Data from 63 patients (27 males and 36 females) who used ACC and 20 patients (9 males and 11 females) who used IHCC (CGBio Co, Ltd) were analyzed. All patients were followed up for more than 1 year. All operations were performed by one of us (H.-R.J.). Retrospective reviews of medical records, telephone interviews, and analyses of photographs were performed for analysis.

The study protocol was approved by the Boramae Medical Center Institutional Review Board, and the study was conducted according to the principles expressed in the Declaration of Helsinki. Written informed consent was obtained from all patients.

Autologous costal cartilage or IHCC was used primarily to augment volume deficiency of the dorsum and sometimes to restore integrity of the septum and tip. The ACC harvesting method was the same as that described previously. Rib cartilage (4-5 cm) was harvested from the right chest. Grafts were taken from the central portion by symmetrically carving out the periphery using a No. 10 blade. A boat-shaped graft was carved with slight concavity on the undersurface to match the contour of the nasal dorsum and to avoid any dead space. The cartilage was submerged in warm saline 2 or 3 times (for at least 10 minutes) between carvings to help minimize warping after the final carving. The cartilage was soaked in an antibiotic solution (clindamycin phosphate, 300 mg/mL) before implantation. In all patients, large graft was inserted for dorsal augmentation. Dorsal grafts were 30 to 40 mm long, 4 to 6 mm thick, and 8 to 10 mm wide; the size varied according to the patient. When the dorsal augmentation was not sufficiently satisfactory or the graft did not fit, thin graft layers were stacked underneath the dorsal graft to achieve an acceptable dorsal height or complete fitting. The graft was sutured to the underlaying framework to prevent slippage or movement.

Details of the surgical procedures and complications, including warping, infection, resorption, and/or donor-site morbidity, were thoroughly evaluated by reviewing medical records and comparing serial facial photographs. For consistency, standard preoperative and postoperative photographs had been taken of each patient using the same lighting, background, positioning, and photographic equipment. Whenever possible, subsequent postoperative photographs were taken semiannually.

Notable resorption was defined when the patient noticed and reported decreased nose height and the surgeon noticed significant graft resorption when comparing the photographs of the last follow-up with the previous photographs. Obvious warping was defined when the patient noticed and reported implant deviation and the surgeon graded implant deviation as more than 5° from the straight vertical axis of the dorsum at the last follow-up using Adobe Photoshop CS5 (Adobe) by measuring the angle between the straight vertical axis of the dorsum and the axis of thewarped portion.

Patients’ subjective satisfaction for aesthetic and functional results was also evaluated in person at the outpatient clinic or by telephone survey, which used a simple questionnaire that included items on nasal function (smelling and nasal obstruction) and a graded self-evaluation of postoperative nasal appearance (0, dissatisfied; 1, no change; 2, satisfied; and 3, very satisfied). For objective evaluation of aesthetic results, 2 rhinoplasty surgeons (W.S.N. and H.K.) blinded to the study’s purpose compared standardized preoperative photographs with photographs taken at the last follow-up visit. The postoperative result was graded using the Objective Rhinoplasty Outcome Score, which is a modified version of the independent rhinoplasty outcome score suggested by Chin and Uppal. Eight components, including symmetry, dorsal height, dorsal length, dorsal width, tip projection, tip rotation, tip width, and overall result, were evaluated on a 5-point scale (0, 184 JAMA Facial Plastic Surgery May/June 2017 Volume 19, Number 3

Key Points

Questions Does autologous costal cartilage or irradiated homograft costal cartilage have a better clinical outcome in augmentation rhinoplasty and what are the histologic properties relevant to the differences?

Findings In this cohort study of 63 patients who received autologous costal cartilage and 20 patients who received irradiated homograft costal cartilage, notable resorption was less frequent with autologous costal cartilage, with higher subjective patient satisfaction compared with irradiated homograft costal cartilage, but the rates of warping were not different. Autologous costal cartilage showed better histologic properties than irradiated homograft costal cartilage.

Meaning Autologous costal cartilage may be an ideal material with the least chance of long-term resorption for augmentation rhinoplasty.
poor; 1, no improvement; 2, moderate; 3, good; and 4, excel-
 lent). Data were analyzed using SPSS, version 18.0 (SPSS Inc).
 Fisher exact tests and χ² tests were used to compare nominal

Histologic Evaluations
Four different samples each of ACC and IHCC were used for
histologic analysis. All specimens were rehydrated, pre-
served, fixed in 4% buffered formaldehyde, decalcified with
sodium formate solution, dehydrated through a series of graded
ethanols, and embedded in paraffin. The materials were sec-
tioned at 5-μm thicknesses, deparaffinized, and stained ac-
cording to the following methods. The size and number of
chondrocytes and the levels of matrix production were as-
sessed in sections stained with hematoxylin and eosin. Char-
acteristic constituent molecules within the cartilage matrix
were assessed with Masson trichrome staining for collagen con-
tent, Alcian blue staining for proteoglycans, and Verhoeff stain-
ing for elastic fibers.

Results

Clinical Outcomes
The mean postoperative follow-up period was 25.6 months
(range, 12-71 months) for patients receiving ACC and 38.8
months (range, 22-53 months) for those receiving IHCC. The
mean age was 30.6 years (range, 17-53 years) for patients re-
ceiving ACC and 35.4 years (range, 15-68 years) for those re-
ceiving IHCC. Among the 63 patients using ACC, 26 (41%) were
undergoing revision and 2 (3%) had surgery performed with
the endonasal approach. Among the 20 patients using IHCC,
10 (50%) were undergoing revision and 4 (20%) had surgery
performed with the endonasal approach. In addition to the dor-
sum, ACC was used for tip grafts in 24 patients (38%), for the
septum in 15 (24%), and for alar surgery in 5 (8%); IHCC was
used for tip grafts in 15 patients (75%), for the septum in 14
(70%), and for alar surgery in 4 (20%).

Details of complications for each group are summarized in
Table 1. The occurrence of obvious warping (ACC, 4 [6%] vs
IHCC, 2 [10%]; P = .35), minimal warping without disfigurement (ACC, 4 [6%] vs IHCC, 0; P = .32), and infection (ACC, 3 [5%] vs IHCC, 1 [5%]; P = .68) was not different between groups. Notable resorption oc-
curred more frequently in the IHCC group (6 [30%]) than in the
ACC group (2 [3%]; P = .002).

Of 63 patients using ACC, 12 were excluded owing to failure
to participate in a telephone follow-up survey or absence of
long-term postoperative photographs. Therefore, 51 pa-
tients (22 men and 29 women) using ACC and all 20 patients
using IHCC were chosen for subjective and objective aes-
thetic analyses.

Table 2. Subjective Satisfaction With the Aesthetic and Functional Outcomes of Rhinoplasty With ACC and IHCC

<table>
<thead>
<tr>
<th>Subjective Satisfaction</th>
<th>ACC (n = 51)</th>
<th>IHCC (n = 20)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>5 (10)</td>
<td>2 (10)</td>
<td>.64</td>
</tr>
<tr>
<td>No change</td>
<td>5 (10)</td>
<td>3 (15)</td>
<td>.40</td>
</tr>
<tr>
<td>Satisfied</td>
<td>4 (8)</td>
<td>9 (45)</td>
<td>.001</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>37 (73)</td>
<td>6 (30)</td>
<td>.001</td>
</tr>
<tr>
<td>Functional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>2 (4)</td>
<td>0</td>
<td>.51</td>
</tr>
<tr>
<td>No change</td>
<td>0</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Satisfied</td>
<td>4 (8)</td>
<td>5 (25)</td>
<td>.50</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>45 (88)</td>
<td>15 (75)</td>
<td>.15</td>
</tr>
</tbody>
</table>

Abbreviations: ACC, autologous costal cartilage; IHCC, irradiated homologous costal cartilage; NA, not applicable.

* Fisher exact test.
were very satisfied, 4 (8%) were satisfied, 5 (10%) found no change, and 5 (10%) were dissatisfied. Among the IHCC group, 6 patients (30%) were very satisfied, 9 (45%) were satisfied, 3 (15%) found no change, and 2 (10%) were dissatisfied. With respect to aesthetic evaluation, significantly more patients using ACC were very satisfied than those using IHCC ($P = .001$). However, there was no significant between-group difference in functional outcome assessments: 4 of 51 patients receiving ACC (8%) and 5 of 20 receiving IHCC (25%) were satisfied ($P = .50$) and 45 of 51 receiving ACC (88%) and 15 of 20 receiving IHCC (75%) were very satisfied ($P = .15$). The primary reasons for subjective dissatisfaction were obvious warping, nostril asymmetry, low tip projection, or notable dorsal resorption. Objective evaluations for aesthetic outcomes are shown in Figure 1. For both groups, scores for the 8 factors were more than 3.1 (between good and excellent). There was no significant difference between groups in scores for symmetry (ACC, 3.47 vs IHCC, 3.42; $P = .72$), dorsal height (ACC, 3.60 vs IHCC, 3.65; $P = .67$), dorsal length (ACC, 3.81 vs IHCC, 3.62; $P = .05$), or overall results (ACC, 3.51 vs IHCC, 3.35; $P = .19$). Those in the ACC group showed significantly better scores than did those in the IHCC group for dorsal width (3.78 vs 3.33; $P < .001$), tip projection (3.69 vs 3.35; $P = .03$), tip rotation (3.71 vs 3.27; $P = .005$), and tip width (3.85 vs 3.18; $P < .001$).

Histologic Findings

Chondrocytes in IHCC were smaller, less uniform, more unevenly distributed, and had fewer nucleated lacunae than those in ACC (Figure 2A and B). In sections stained with Masson trichrome and Alcian blue, collagen and proteoglycan were less dense in IHCC than in ACC (Figure 2C through F). However, Verhoeff staining, which is directed at elastic fibers, did not show a significant difference between the 2 types of cartilage (Figure 2G and H).

Discussion

We compared surgical outcomes of rhinoplasty using ACC and IHCC and investigated the different clinical outcomes with re-
spect to histologic characteristics. The most notable difference was a much higher resorption rate with IHCC (30%) than with ACC (3%) and subsequent lower aesthetic satisfaction among patients receiving IHCC.

The higher resorption of IHCC, especially when used as a major dorsal augmentation material, is thought to be inevitable considering the preparation process. Because the cartilage is exposed to 30 to 40 kGy of gamma radiation using a cobalt 60 source to remove all donor cells and using major histocompatibility antigens to limit the graft-vs-host response, chondrocyte viability in IHCC is low and increased resorption over time is inevitable.12 A study on the effects of ionizing radiation on costal cartilage also showed that radiation decreases the collagen fiber content of cartilage.13 Our histologic study of IHCC indicated these effects of radiation, showing less nucleated lacunae and fewer and less dense collagen fibers and proteoglycans. Our results showed some nucleated lacunae in IHCC although, theoretically, there should be no viable chondrocytes after radiation. However, the viability of chondrocytes could not be determined because these findings may arise from the limitation of light microscopy, in that it is not sensitive enough to assess the viability of cartilage grafts.14 In a study evaluating the viability of homograft cartilage, on light microscopy the chondrocytes were not histologically dissimilar from viable chondrocytes; however, electron microscopy revealed severe cell degeneration.15

In addition to the inherent histologic inferiority of IHCC, the fact that 50% of patients receiving IHCC were undergoing revision may have played a role in the higher rate of resorption observed in this group, because the poor blood supply in the recipient bed of those undergoing revision would decrease graft viability even more with IHCC than with ACC. The fact that 4 of 6 patients showing notable resorption had undergone revision supports this idea.

This study also showed considerable individual variation in the amount of resorption in the group using IHCC. This variation can be attributed to a few factors. First, the quality of the costal cartilage obtained from cadavers is not always the same between donors. Second, the status of the recipient bed of the graft may differ between individuals. Slight resorption of a dorsal graft may be easily perceived, both by the patient and surgeon, when the dorsum is augmented considerably by a single piece of graft.

Although there are many reports on the use of IHCC in rhinoplasty, the resorption rates are controversial and long-term follow-up studies are rare.4,5,8,10,16 The largest study on IHCC reported a resorption rate of 1.4% after a mean follow-up of 13 years in 357 patients.6 The number of patients enrolled was larger and the length of the follow-up period in that study was longer than in other studies. However, the exact number of patients who experienced resorption was underestimated, because the rate of resorption was not calculated according to the number of patients but according to the number of IHCC grafts implanted. This calculation has some limitations because the graft on the septum cannot be evaluated correctly and the exact location of resorption is not clear when there are multiple implants. The actual number of patients with resorption was 10 of 357 patients, resulting in an increase in the resorption rate to 2.8%. The authors also reported that IHCC grafts were quite stable and maintained structural contours. In contrast, in another study, 18 of 24 grafts (75%) in patients who were followed up for 11 to 16 years were completely resorbed.5

Several studies have reported a rate of warping with IHCC from none to 14.7%.4,8,10,16,17 Our results showed that warping rates were not different between the ACC (8 [13%]) and IHCC (2 [10%]) groups. Warping is associated with the internal stress system within the costal cartilage itself and the interplay of cortical and core portions and to the method and technique of the surgeon carving the cartilage. Here, the core portion of the rib cartilage was used for all major dorsal augmentation, and the carving was performed by 1 surgeon (H.-R.J.); thus, there was likely no surgeon or technique bias.

Objective aesthetic outcomes were better in the ACC group for the factors evaluating the tip, although most scores for factors evaluating the dorsum were not different between groups. It is difficult to explain clearly why the tip parameters were better in the ACC group. When IHCC is used, it is difficult to carve a thin, flat piece of cartilage to be used for tip modification owing to quality problems. It is less pliable and requires thicker pieces than does ACC; because many Asian patients need a septal extension graft to modify the tip shape, carving out a thin piece of cartilage for this purpose is more difficult with IHCC than with ACC. Furthermore, the higher rate of resorption of IHCC may have influenced the final shape of the tip in this group.

Limitations

This study has some limitations. First, ACC harvested from the patients and IHCC supplied by the company were not age-matched. The ages of the cadavers that IHCC was prepared from were not specified. Because composition of costal cartilage changes with age and affects histologic results, an accurate age-matched comparison was impossible.18 Second, this clinical study had a relatively small sample size and short follow-up. Further studies in a larger number of patients with longer follow-up periods could show more clinically significant results. Third, we used subjective methods to measure graft resorption. Further studies that include intraoperative measurement of graft volume and serial follow-up measurements of volume or an anthropometric study will improve the scientific validity of the study.

Conclusions

In the clinical evaluation of ACC and IHCC for major dorsal augmentation, notable resorption was lower and subjective satisfaction higher with ACC than with IHCC, but warping rates were not different. Autologous costal cartilage also showed better histologic characteristics, suggesting that it is an ideal graft material with less chance of long-term resorption.
Costal cartilage grafting in rhinoplasty has dramatically increased in popularity during the past decade, likely owing to many factors. With improved harvesting techniques and introduction of novel methods of using harvested cartilage, such as diced cartilage fascia grafts, the use of costal cartilage will likely continue to increase.\(^1\)\(^2\) Augmentation rhinoplasty is becoming more popular and worldwide demand for the procedure is increasing in Asia and abroad. Augmentation cases require adding volume to the nose either in the form of an alloplastic implant or via autologous means. Alloplastic implants have many potential problems such as infection, extrusion, and deformity. The consumer is driving a movement toward using their own autologous cartilage, with the most abundant source being costal cartilage. There is potential morbidity associated with harvesting autologous costal cartilage that may act as a deterrent for some patients using their own cartilage. An option is irradiated homologous cartilage.

The primary drawback to irradiated homograft cartilage is the potential for resorption over time. In this issue of JAMA Facial Plastic Surgery, Wee et al\(^*\) compared their experience using autologous costal cartilage (ACC) with their use of irradiated homologous cartilage (IHCC). They reviewed 63 patients who underwent rhinoplasty using ACC and 20 patients who underwent rhinoplasty using IHCC. All patients were followed up for more than 1 year (mean, 25.6 months). The IHCC was used in the dorsum, septum, and nasal tip. The incidence of infection and warping was not different between the 2 groups. Notable resorption was seen in 6 pa-