

# Long-term Use and Follow-up of Irradiated Homologous Costal Cartilage Grafts in the Nose

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**Objective:** In 1993, Kridel and Konior published a preliminary report (in the *Archives of Otolaryngology–Head and Neck Surgery*) on the use of irradiated homologous costal cartilage (IHCC) or homograft cartilage in the nose. This is a follow-up study to share our experience in answering fundamental questions: (1) What are the major long-term complications of IHCC, and are they any greater than with the use of the patient's own cartilage? (2) Is IHCC a reliable and safe implant? (3) Does IHCC resorb over time? (4) What measures are implemented in our practice to minimize the sequelae?

**Design:** We performed a retrospective review of patient medical charts in a university-affiliated private practice setting. A total of 357 patients underwent primary or revision rhinoplasty using IHCC grafts with postoperative follow-up duration ranging from 4 days to 24 years (mean [SD], 13.45 [2.83] years). A total of 1025 IHCC grafts and 373 other grafts (including 218 autogenous cartilage [AC] grafts) were used. A total of 201 grafts were dorsal onlay grafts, and 74 of them have been further followed up since the previous report. The grafts were evaluated for warping, infection, infective resorption, noninfective resorption, mobility, and extrusion. Patient satisfaction evaluation was performed in 42 patients.

**Results:** The total complication rate related to IHCC grafts was 3.25%, which included 10 warped grafts of 941 palpable or superficial IHCC grafts (1.06%), 9 infections of 1025 IHCC grafts (0.87%), 5 cases of infective resorption of 1025 IHCC grafts (0.48%), 5 noninfective resorptions of 943 palpable IHCC grafts (0.53%), and 3 cases of graft mobility of 941 palpable grafts (0.31%). Nine cases of local infection were treated and could have arisen from any of the 1025 IHCC grafts as well as from the 373 other grafts. Among the 9 cases of infection, in 2 patients IHCC grafts were used alone, and in 7 patients IHCC grafts were used in combination with other types of graft materials; therefore, the actual infection rate related to the pure use of IHCC was 2 of 1025 or 0.2%. Of the 218 AC grafts used at the same operative intervention along with IHCC grafts, 3 grafts (1.37%) underwent minimal resorption. The overall comparative resorption rates were 1.01% (IHCC) vs 1.37% (AC). The complication rate in conjunction with the use of 162 IHCC s in 53 cases of septal perforation repair was

2.46% (4 cases), including only 1 case of infection, 1 case of mobility of the graft, 1 case of warping, and 1 case of infective resorption (0.61% for all). Of the 25 AC grafts used in septal perforation cases, there were 2 cases of noninfective resorption (8%). The overall comparative complication rates in septal perforation cases were 2.46% for IHCC vs 8% for AC, which indicated a 3.25-times higher complication with the AC than with IHCC. No allergic reaction or systemic disease was reported by patients as a result of use of the IHCC. Irradiated homograft cartilage also proved to be a reliable graft in 2 patients with progressive autoimmune diseases over 2.08 years and 10 years of follow-up. The average rates of patient satisfaction increased during a mean follow-up of 7.87 years, from 91.31% to 94.18%, in 4 categories, including nasal appearance, nasal breathing, nasal symptoms, and quality of life.

**Conclusions:** Based on careful and extensive review of the data, we have concluded that IHCC is well tolerated as a grafting material in rhinoplasty and yields superb functional, structural, and cosmetic results in the most complex and challenging operative cases necessitated by previous unsuccessful nasal surgery, septal perforations, and even in autoimmune diseases that led to nasal deformity. Not only did very few complications occur following the use of 1025 IHCC grafts in 357 patients after 386 rhinoplasties over 24 years (rate, 3.25%), but the rate of complications was no greater than rhinoplasty complication rates when AC grafts are used. The results indicate safety and reliability and justify the convenient use of IHCC grafts for primary and revision rhinoplasty without creating donor site morbidity. Irradiated homograft cartilage grafts are quite stable in the nose and maintain structural contour and support in most cases. Irradiated homograft cartilage grafts should be considered as an alternative or even a primary grafting material when the patient does not have adequate quantities of septal or auricular cartilage remaining to provide the correction or when the shape or quality of such an AC does not adequately provide the structure required. Autogenous rib cartilage is also an alternative material but also increases operative and anesthesia time and adds potential morbidity. The use of IHCC is both cost- and time-effective.

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**I**N 1953, NORTH<sup>1</sup> DEFINED THE CRITERIA for an ideal grafting material as follows: (1) It should be easily obtainable without a considerable and painful operation on the donor area. (2) It should be well tolerated by the tissues of the recipient area. (3) It should show no tendency to perforate through the skin or mucous membrane surfaces when placed in close proximity to

them even in an area subject to frequent minor trauma, such as the nose and ear. (4) It should show no marked tendency to distortion, or (5) late absorption.

*For editorial comment  
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Some of the earliest graft materials used in rhinoplasty were heterografts, most

commonly bovine bone or cartilage, but these evoked an intense inflammatory reaction and have been abandoned because of their high rate of resorption. The primary disadvantages to the use of synthetic alloplastic implants are the foreign body response and higher rates of infection and extrusion.<sup>2-4</sup>

Autografts are usually the material of choice, with lower rates of tissue reaction, resorption, and infection than with alloplasts. Other, less favorable, options include the use of calvarial bone graft for dorsal augmentation, but these grafts lack any flexibility and often need to be drilled to be secured in place. In addition, bone grafts have great metabolic demands for survival and are more prone to resorption.<sup>5,6</sup> Autogenous cartilage (AC) grafts are alternative options and can be obtained from the nasal septum or the auricular concha for smaller defects and from rib cartilage for larger defects.<sup>2,4,7</sup> Experimental transplantation of cartilage in modern time was initiated by Bert in 1865.<sup>8</sup> Autogenous cartilage transplant in humans was also performed by Koenig in 1896,<sup>9</sup> followed by a successful rhinoplasty using rib cartilage by Von Mangoldt in 1900.<sup>10</sup> In 1941, Mowlem<sup>11</sup> reported the use of cartilage and bone transplants and was one of the earliest investigators who warned about distortion of cartilage grafts when used for large defects. The earliest use of septal cartilage was reported by Metzenbaum in 1929,<sup>12</sup> and grafting of composite auricular cartilage was advocated by Gillies in 1943.<sup>13</sup> There are many reports indicating a high success rate of AC by virtue of its availability, unique structure, low anaerobic metabolism, and its relative avascularity,<sup>14</sup> but AC also has disadvantages.

Septal cartilage is usually considered the preferred first-line grafting material. It is usually firm and flexible and may provide structural support as a grafting material. Sometimes, however, in certain patients, it is thin and flimsy and unsuitable for use. Especially in revision rhinoplasty, the quantity and quality of remaining septal cartilage may be inadequate for reconstruction because of an aggressive previous septoplasty or simply because of the extent or numbers of defects requiring repair. Auricular cartilage may be of limited use because of its intrinsic curved shape, which may make it an inappropriate material when caudal struts, caudal septal replacement grafts, or long straight dorsal augmentation onlays are necessary, and it does require another operative site. Correction of a complex nasal defect or deformity may present a considerable reconstructive challenge requiring many grafts. Harvesting of the patient's own auricular or costal cartilage may leave the patient with a new scar, keloid, postoperative pain, and the possibility of pleural injuries, pneumothorax, hemothorax, and chest wall deformities.<sup>15-19</sup> The harvest procedure alone adds to operative and anesthetic time and expense. Furthermore, as we age, rib cartilage begins to calcify, making some harvested rib cartilage nonhomogeneous in structure and difficult to carve.

Because of the shortcomings and potential problems with rib harvesting, the use of banked irradiated homograft costal cartilage (IHCC) might be a preferred alternative.<sup>20-23</sup> Homografts represent the last general category of natural, nonchemically processed grafting material. The use of homograft rib cartilage preserved un-

der refrigeration in methiolate-saline solution was reported by O'Connor and Pierce in 1938.<sup>24</sup> Later, Peer used ethanol for preservation of cartilage.<sup>25</sup> In 1941, Straith and Slaughter<sup>26</sup> popularized the usage of preserved homologous cartilage grafts in 100 facial contouring cases with a very high success rate. Brown and DeMere, in 1948, introduced the establishment of a homologous cartilage bank.<sup>27</sup> In 1956, Asbury et al<sup>28</sup> reported superiority of cobalt Co 60 irradiation of canine costal cartilage homografts with a lesser degree of resorption when compared with methiolate-treated and lyophilized homografts. They concluded that irradiated cartilage kept in normal saline (hereinafter, saline) in sealed containers provided a convenient and satisfactory method for sterilization of cartilage and could be stored at room temperature without fear of damage and with lesser degree of resorption. Gibson and Davis<sup>29</sup> in 1958 introduced the principle of a "balanced cross section" to minimize cartilage distortion. In 1959, they<sup>30</sup> concluded that cartilage grafts in man remain alive for at least 2 years and probably indefinitely; therefore, they suggested on-the-shelf preservation as a "bank."

In 1961, Dingman and Grabb<sup>31</sup> reported clinical applications of IHCC and showed that only 2 of 30 grafts implanted for ear reconstruction had any resorption. Only 1 graft was used for dorsal contouring of the nose. The follow-up period was 7 months to 3½ years.<sup>31</sup> In 1972, they<sup>32</sup> reported the use of IHCC in more than 600 patients for mostly chin or orbital remodeling with excellent results. They advocated that the IHCC had the advantages of availability, ease of preparation, carvability, and lack of infection, extrusion, deformation, or absorption if it is not used in ear reconstruction.

The greatest drawback of all grafts preserved by various techniques, namely that of absorption, seemed to be obviated by the irradiated method. Homografts have many of the advantages of the autologous graft, but without the disadvantage of donor site morbidity. Homograft cartilage material is readily available, semipliable, easily carved, and has low rates of infection and extrusion. Such grafts are available in large quantities and eliminate the need for a donor site. Cartilage, owing to its unique architecture, is remarkably well tolerated by host tissue, eliciting minimal antigenic response.<sup>3,21,33</sup> Costal cartilage is obtained from donors who are young (<25 years, so that the ribs are not calcified) and have been screened and found negative for systemic diseases and local infection, metastatic cancer, or intravenous drug use, and were nonreactive to the Venereal Disease Research Laboratory test and tests for hepatitis and human immunodeficiency virus (HIV) antibodies.<sup>34</sup> The cartilage blocks are then stored in a saline solution and exposed to 30 000 to 50 000 Gy of gamma radiation using a cobalt Co 60 source.<sup>3,35</sup>

Cartilage is composed of chondrocytes, bound water, and a complex proteoglycan matrix containing fibers, most of which are type II collagen fibers. The antigenicity of cartilage, which is determined to be from class II antigens present in the perichondrium, could be eliminated by gamma irradiation or removal of perichondrium.<sup>36,37</sup> Gamma irradiation could also cause stiffness and suppress resorption of cartilage.<sup>38</sup> In 1977, Schuller et al<sup>39</sup> reported the use of 145 IHCC grafts (60 of which were

used in the nose) in 107 patients over a 3-year period for facial contour restoration with overall resorption rate of 1.4%. Eleven years later Welling et al<sup>40</sup> published a surprising article indicating a 75% resorption rate of IHCC in 42 of the original 107 patients reported by Schuller et al<sup>39</sup> during a mean follow-up period of 9 years. They concluded that IHCC progressively resorbs over time and therefore cannot be recommended for structural support. But in their study, IHCC grafts were used in a variety of locations on the face, including the ear, and they concluded that substituted fibrous scar tissue could provide bulk and preserve aesthetic results. Despite the findings by Welling et al<sup>40</sup> and those of Donald<sup>23</sup> in sheep and Babin et al<sup>41</sup> in the cat, which created a setback for the use of IHCC for some time, the courage of surgeons and the improvement in skills in using IHCC caused IHCC to regain its good reputation in rhinoplasty.

In 1991 Murakami et al<sup>21</sup> reported the use of IHCC in the nose in 18 patients without infection or resorption during a mean follow-up period of 2.8 years. The discrepancy among these reports might be due to limited sample size, short periods of follow-up, or the fact that earlier studies were not specifically focused on the use of homograft cartilage in rhinoplasty, which persists differently than grafts placed in other anatomical regions of the face.<sup>31,32,38,39</sup>

In 1993, Kridel and Konior<sup>42</sup> published a preliminary report on the use of IHCC for implantation in 117 patients over a follow-up period of 1 month to 7 years. A total of 306 grafts were used in 122 nasal augmentation procedures. Most of these grafts were used to augment the nasal dorsum as an onlay graft or to support the nasal tip as a columellar strut. Forty patients underwent primary nasal surgery, and 82 patients underwent revision procedures. Complications included infection (4 cases), mobility (3 cases), warping (2 cases), infective resorption (2 cases), and noninfective resorption (2 cases). No extrusion case was reported. The editorial comment by Crumley<sup>43</sup> on the original article<sup>42</sup> suggested that this patient series would be an ideal source for long-term follow-up data regarding resorption, with particular interest on dorsal grafts.

Since then, the use of IHCC has gained more popularity in various clinical settings that are briefly reviewed. In 2002, Clark and Cook<sup>44</sup> reported successful application of IHCC for nasal reconstruction with only 1 case of warping. The sample size was 18 with a follow-up period of 13 to 48 months (mean, 30.5 months). All 18 patients were satisfied with the cosmetic outcomes of their nasal reconstructions. There were no cases of extrusion or infection of the IHCC implant even subsequent to immediate reconstruction of a previously placed extruded alloplast. Clinical resorption of the IHCC was minimal, with a mean follow-up period of 26 months. Only 1 patient had a complication, warpage, which required removal of the IHCC graft.<sup>44</sup> In the following year, Strauch and Wallach<sup>45</sup> reported on 130 IHCC grafts in 52 cases of rhinoplasties and 3 penile reconstructions. They reported 1 case of partial resorption during a follow-up period of 7 months to 12 years. They had no cases of warping or infection, and both clinical and histologic examination of the grafts in 2 patients after 7 months and 7 years did not show signs of resorption, which they believed indicated longevity of irradiated cartilage. Lefkovits,<sup>46</sup> in his comment on the re-

port by Strauch and Wallach,<sup>45</sup> emphasized that IHCC has the qualities of an ideal implant and suggested its usage be considered in augmentation rhinoplasty when septal cartilage is insufficient. In 2004, Burk et al<sup>47</sup> conducted a comparative study by reviewing 118 cases of nasal reconstruction using IHCC grafts with a mean follow-up period of 36 months vs 12 cases of auricular reconstruction using IHCC grafts. They noticed that IHCC grafts work better in nasal rather than in auricular reconstruction, which may explain some earlier controversies revolving around reliability of IHCC grafts.

A commercially available product named Tutoplast (Tutogen Medical, GmbH, Neunkirchen, Germany), a costal cartilage or allogeneous cartilage graft, has been the subject of recent studies with not-so-uniform results. Tutoplast is a solvent-dehydrated human costal cartilage that has undergone 17.8- to 25.0-kGy gamma irradiations. Tutoplast should not be confused with IHCC, which has not been chemically treated. The two may be quite dissimilar as to how they react in the body and nose, and for that reason we do not use Tutoplast, and studies involving Tutoplast should not be combined or considered to be equal to those of nonsolvent IHCC grafts. In 2003, Demirkan et al<sup>48</sup> reported on the use of Tutoplast in 65 cases of rhinoplasty with a mean follow-up period of 33 months without notable resorption that affected the outcome. Tosun et al,<sup>49</sup> in a study of 41 patients who underwent augmentation rhinoplasty using 22 grafts harvested from septal and costal cartilages and 19 Tutoplast costal cartilage grafts, found no difference between them during a 10-year study. In contrast, Song et al,<sup>50</sup> in a study using Tutoplast costal cartilage in 35 rhinoplasty patients, found a 17% rate of resorption, 9% rate of warping, 3% rate of unfavorable contour, and a 3% rate of graft fracture that led them to preclude the use of this chemically processed costal cartilage in augmentation rhinoplasty.

A review of multiple articles in the literature indicates that many factors (eg, the way the IHCC is processed, the site of the graft, the predisposing health condition of patients, the severity of nasal deformity, the length of the follow-up period, the method of evaluation, the surgical techniques, the method of dressing, the postoperative care, and whether all the rhinoplasty cases in 1 report were performed by the same surgeon) are all variables that may play an important role in the outcome of the rhinoplasty. Unfortunately, some reports provide less clarity and specificity, which compounds the interpretation. The study by Kridel and Konior<sup>42</sup> was the first large-scale study to focus exclusively on nasal grafts using IHCC and contributed preliminary long-term data to the literature. In order to assess the reliability and suitability of IHCC grafts for use in rhinoplasty, a very large sample size in terms of number of patients and grafts, long follow-up period, a consistent and meticulous operative technique performed by a single surgeon, and optimal patient care, as well as evaluation performed by independent investigators, are required to minimize bias. The present work, which meets these criteria, is an attempt to put our 1993 report<sup>42</sup> in a longer perspective and shows that IHCC possesses similar advantages to AC without additional morbidity.

## METHODS

### PATIENTS

Irradiated homograft costal cartilage as a principal rhinoplasty material was used in 357 patients, of whom 117 were included in an earlier study.<sup>42</sup> The patients in the present study were seen in the senior author's (R.W.H.K.) private practice setting from January 1984 through May 2008. The mean (SD) postoperative follow-up period was 13.45 (2.83) years (range, 4 days to 24 years). Their mean age was 37.24 (12.67) years; ages ranged from the youngest patient, who was 5 years old and underwent repair of a congenital nasal defect, to the oldest patient, who was 95 years old and underwent reconstruction after a major excision for cancer. Age-wise, patients were divided into 4 categories: 5 to 24 years (46 patients), 25 to 44 years (215 patients), 45 to 62 years (82 patients), and 63 to 95 years (14 patients).

The patients represented diverse sex and ethnic groups. Two hundred twenty-five of the patients were female (63.02%), and 132 (36.97%) were male. Ethnic demographics included 283 whites (79.27%), 25 Hispanics (7%), 17 blacks (4.76%), 16 Asians (4.48%), 8 other ethnicities (1.68%), 5 who were Middle Eastern (1.40%), 5 Asian Indians (1.12%), and 1 Turkish patient (0.28%) (eFigure 1, <http://www.archfacial.com>). Before the use of IHCC grafts, the advantages and disadvantages of the implant materials were explained to the patients. The reasons for the use of IHCC in the 83 cases (23.24%) of primary rhinoplasty were inadequacy of available AC, the magnitude of grafts needed to correct multiple nasal defects, or the preference of patients to avoid morbidity as a result of harvesting their own ear or costal cartilages. Of the total 357 patients, 274 (76.75%) had undergone previous rhinoplasties (range, 1-13) performed elsewhere (**Table 1**).

### GRAFTS

Most of the revision procedures required IHCC grafts owing to the lack of autologous donor tissue, often after previous septal surgery or to correct structural and volume deficiencies attributable to previous overaggressive resection in the rhinoplasties that had been performed elsewhere. Common findings included loss of nasal tip projection, resection of the caudal end of the septum, and saddling of the nasal dorsum, all of which require straight, strong, large pieces of cartilage. Grafting with alternative implant materials then becomes necessary in order to restore functional integrity and volume.<sup>4,35</sup>

Most of the IHCC grafts were obtained either from the University of Texas Health Science Center at Dallas and a lesser amount from the Northern California Tissue Bank, San Francisco. The rib cartilage pieces used in the present study were treated with gamma irradiation (15-24 kGy for 1.5-2.0 hours) and were stored in saline in a sealed, sterile container. Tissue storage is recommended at 25°C or room temperature. Grafts that had undergone freezing, sterilization, resterilization, or chemical processing were not used. The supplied bottles are easily stored in the office or operating room for ready access. In the operation room the container is opened aseptically. The brochure for the product, from Southwestern Medical Center in Dallas, Texas, regarding the safety of the product, indicates that the blood samples from donors are routinely tested by a Clinical Laboratory Improvement Amendment/College of American Pathologists and US Food and Drug Administration (FDA) certified laboratory using FDA approval tests for pre-mortem blood samples or post-mortem tests as appropriate. The tests need to be nonreactive for hepatitis B (HB) surface antigen, hepatitis C virus (HVC) antibody (Ab), HIV 1/2 Ab, sexually transmitted diseases, human T-cell lymphotropic virus I/II, HB core

Table 1. Operative Background<sup>a</sup>

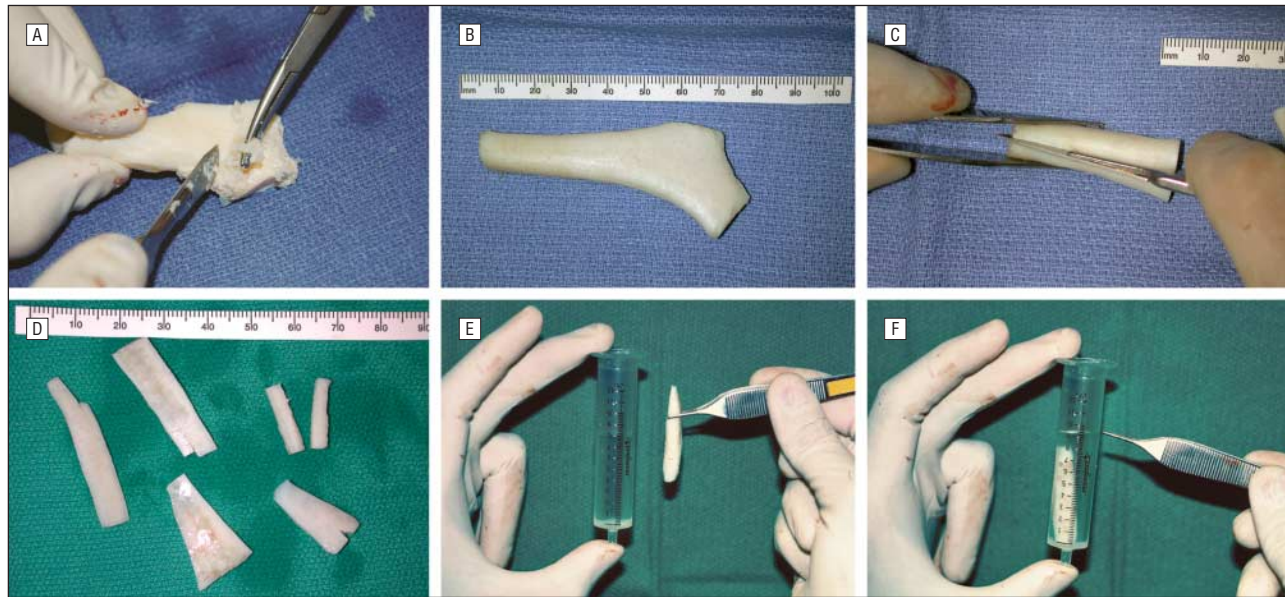
Surgical Procedures Performed Prior to Presenting to R.W.H.K. for Revision, No.	Patients, No.
1	144
2	68
3	39
4	13
5	5
6	2
7	2
13	1

<sup>a</sup>Of 357 patients, 83 were primary cases (they had not undergone any previous rhinoplasty), and 274 patients were secondary (revision) cases (they had undergone 1-13 rhinoplasties elsewhere). Irradiated homograft costal cartilage grafts were used because of the inadequacy of autogenous cartilage, severity of cases, and the preference of patients. Most patients had multiple indications for their rhinoplasties.

Ab, HIV-1 nucleic acid test (NAT), HCV NAT, and West Nile virus NAT prior to release.

Irradiated homograft costal cartilage grafts are available in different sizes, such as 2 cm or smaller or 5 cm or larger, based on need. If dorsal augmentation is being considered, one should obtain a rib graft that is at least 5 cm in length. After trimming, most grafts need to be about 4 cm long to recreate a dorsum completely in 1 homogeneous straight piece. At the time of surgery, a culture of the solution in the container is grown to ensure that there is no bacterial contamination. The IHCC grafts are aseptically removed from the containers and placed into 500 mL of a sterile saline solution containing 80 mg of gentamicin sulfate. Prior to sculpting a graft, a No. 10 scalpel is used to remove all perichondrial remnants from the graft's outer surface, to remove any cellular components, and to prevent "perichondrial memory" from causing warping. The rib graft is examined in all dimensions to determine the best orientation for carving that will produce the straight grafts. The rib is usually a long piece with a genu at the end. Because this is a full circumference rib, one can usually cut it in half along the long axis to create 2 similar pieces, thus providing the surgeon with 2 usable pieces should a problem arise from 1 of them (initial warping, wrong size, breakage, etc). Each half is capable of producing multiple grafts. The cartilage is typically L-shaped, with the longer arm best suited for the long dorsal grafts and the shorter genu more suitable for nasal tip grafts, batten grafts, columellar struts, septal replacement grafts, and spreader grafts (**Figure 1**). Residual irregularities are smoothed by shaving the graft's surface with a No. 10 scalpel blade.<sup>35,42</sup> Alternatively, the graft may be shaped with a drill burr. The carved cartilage is left to sit on the back table for approximately 20 minutes prior to insertion, to allow time for any initial warping that might occur. If visible warping occurs, then another piece is selected for use rather than attempting to reshape the warped piece. All the grafts are measured and the date recorded so that if reoperation is necessary, a second measurement can be made to access any change in the graft. Volumetric displacement measurements are also made of the larger dorsal onlay augmentation for similar reasons.

In addition to autogenous grafts, other graft materials used in conjunction with IHCC have included Alloderm (LifeCell Corp, Branchburg, New Jersey), Mersilene (Johnson & Johnson Gateway, Piscataway, New Jersey), Supramid (S. Jackson Inc, Alexandria, Virginia), Nylamid (S. Jackson Inc), GORE-TEX (W. L. Gore, Flagstaff, Arizona), and Medpor (Porex Surgical Inc, College Park, Georgia).



**Figure 1.** The method of irradiated homograft costal cartilage (IHCC) graft preparation. A, Removing the perichondrial layer from an original piece of IHCC. B, Rib cartilage after removal of the perichondrium and ready for sculpturing. C, The long axis of the rib cartilage is halved for further sculpturing. D, Different grafts are made from IHCC. E and F, The method of measuring the volume of a dorsal onlay graft made of IHCC by immersing the graft in a sterile syringe filled with normal saline. Displaced liquid indicates volume of the graft.

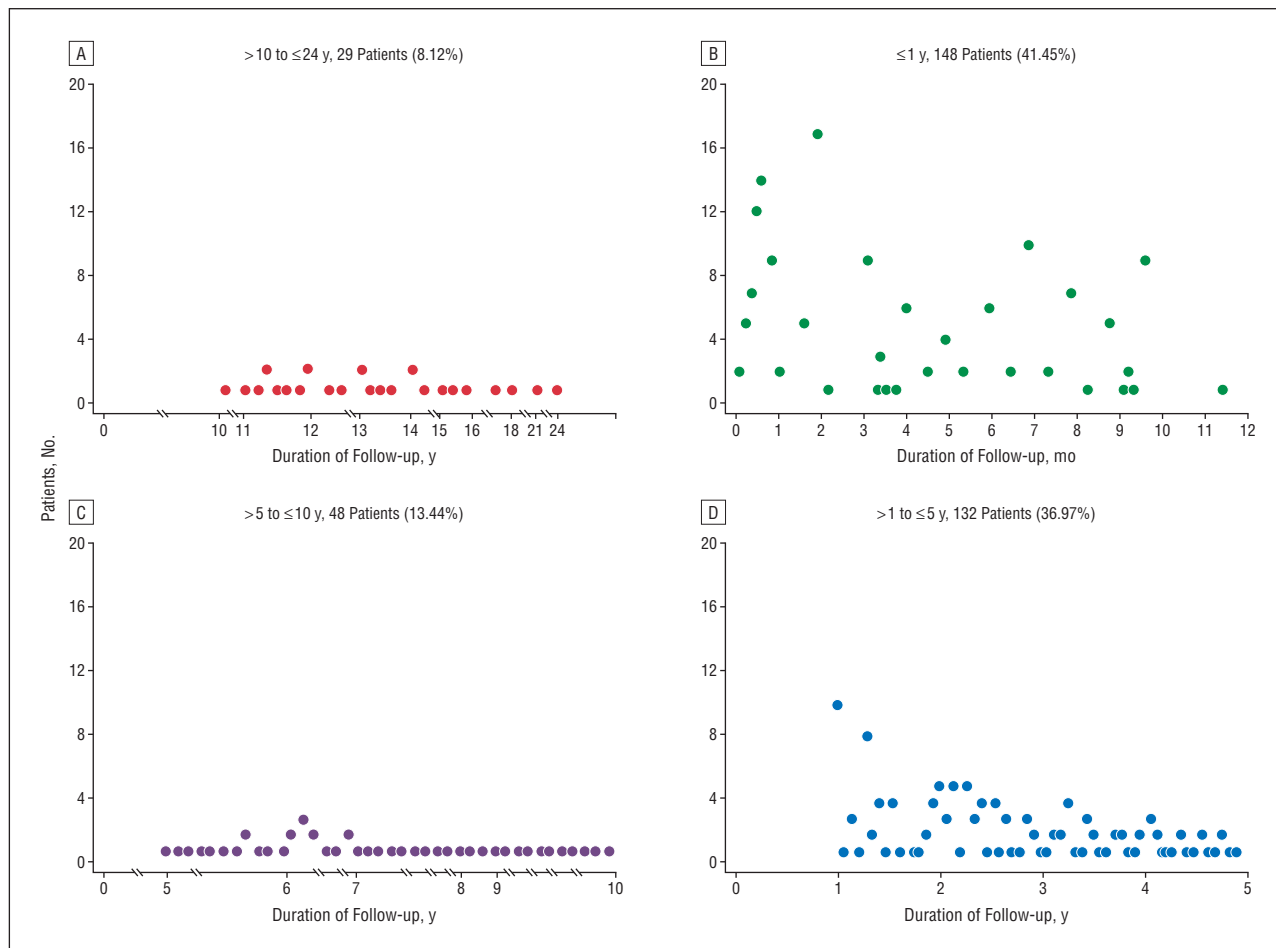
## SURGICAL PROCEDURE

All 386 IHCC rhinoplasties were performed by the first author (R.W.H.K.) and assisted by his fellows, including co-author E.L. Almost all the surgical procedures (excluding minor revisions) were performed using the open rhinoplasty approach, which is favored by R.W.H.K. because it permits exact graft positioning and maximizes the distance between the incision lines and most graft sites.<sup>42</sup> Whenever possible, the dorsal onlay grafts are stabilized using precisely created pockets over the nasal dorsum. The pocket should be made just wide enough to accommodate the graft snugly, in order to minimize the potential for graft mobility. In addition, interrupted 6-0 PDS circumferential sutures are used to tightly secure the portion of dorsal graft that is over the upper lateral cartilages where sutures may be placed. If a large augmentation is anticipated, such as with a saddle-nose deformity, the graft needs to extend the full length from nasion to supratip in order to avoid a “step-off” deformity, and usually it is at least 4 cm in length.<sup>3</sup> Stacking or piggybacking of grafts usually is not necessary because of the large-size blocks of IHCC that are available.

Early in the initial series of study patients, braided polyester or braided polyglycolic acid sutures were used when grafts needed to be sewn into place. Following a minimal number of well-localized suture infections, absorbable 6-0 polydioxanone and 6-0 polypropylene monofilament sutures were substituted to secure the IHCC grafts whenever mobility or stability was a concern, resulting in a decrease in the infection rate. Over the dorsum, 3 to 4 such sutures are used to secure the graft to the underlying cartilaginous dorsum to prevent twisting and migration of the graft. These sutures are tied tightly enough to cause an actual indentation in the graft itself, again to ensure stability. Closure of the columellar incision is accomplished in layers. In some revision cases the skin envelope may be tight, calling for smaller grafts than might otherwise be desired. If there is blanching of the overlying skin, the grafts should be reduced in size. When the projection is increased, there may be some increased tension on closure, which can be eased by the layered closure. Small Telfa packs (Kendall, Mansfield, Massachusetts) covered with topical gentamicin sulfate

cream are placed in the nose bilaterally. A standard external nasal splint consisting of a piece of compressible Gelfoam (Pfizer Pharmaceutical, New York, New York) is taped over the dorsum, followed by a metal splint; another layer of brown tape is placed and a mustache dressing is applied. The mean operative time is 3 to 4 hours. For additional prevention against infection, all patients received oral antibiotics (cephalexin monohydrate, 500 mg) 12 hours prior to surgery and 2 times a day for 1 week following surgery, as well as an intravenous dose (cefazolin sodium, 500 mg) just prior to the procedure.<sup>42</sup> Clindamycin hydrochloride or ciprofloxacin hydrochloride was used for patients who were allergic to cephalosporin.

The methodology of present report is similar to that of our previous study.<sup>42</sup> Clinical factors used to evaluate the degree of graft resorption and maintenance of nasal augmentation included reviewing the medical charts; surgical notes; intraoperative diagrams; and preoperative, intraoperative, and postoperative life-size photographs. For consistency in comparing results, standard preoperative and postoperative photographs were taken of each patient using standardized lighting, background, and patient positioning. The profile views were most important for making accurate preoperative and postoperative comparisons. Early postoperative photographs were first taken at 6 weeks to document the amount of augmentation achieved at the time of surgery. Postoperative photographs taken earlier than 6 weeks were not used for comparison because of the anticipated postoperative edema that occurs with rhinoplasty surgery. Whenever possible, subsequent postoperative photographs were taken at least on a semiannual basis. The photographic views of the face were anteroposterior, right and left lateral, right and left lateral oblique, cephalocaudal (sky view), and caudocephalad (base view). The photographs were loaded into the computer imager, and measurements were made. Each patient's nose was also carefully inspected and palpated prior to surgery and on all following postoperative visits to assess for graft integrity and degree of graft resorption. During any postoperative examination, a palpable depression or irregularity in what initially was a smooth graft indicates that some resorption or warping has occurred in that area. In those patients who underwent a second-stage revision rhinoplasty for



**Figure 2.** The duration of follow-up and number of patients per each follow-up (dots) in 4 categories. A, Twenty-nine patients (8.12%) for more than 10 and up to 24 years (red dots); B, 148 patients (41.45%) for 1 year or less (green dots); C, 48 patients (13.44%) for more than 5 and up to 10 years (purple dots); and D, 132 patients (36.98%) for more than 1 and up to 5 years (blue dots). Note that there were 77 patients who had more than 5 and up to 24 years of follow-up.

replacement of a resorbed IHCC graft, the volume of resorbed grafts was measured metrically as well as by volume displacement via insertion of a graft in a syringe filled with saline. The amount of resorption was expressed as none (0%), minimal ( $\leq 25\%$ ), moderate ( $> 25\%$  to  $\geq 50\%$ ), near-complete ( $> 50\%$  to  $\leq 75\%$ ), or complete ( $> 75\%$  up to  $\leq 100\%$ ). The amount of resorption for those grafts that were evaluated qualitatively by palpation was classified as complete (no graft was palpable), partial (nearly half of the original size of the graft was lost), and minor (loss of less than half of graft size).

## FOLLOW-UP

The study was retrospective and case-controlled in nature in that the preoperative physical findings and facial photographs were used as the control or untreated state (without use of IHCC), and postoperative physical findings and photographs were regarded as the treated state (with use of IHCC). The term *preoperative* in our study means the state of the patient before being operated on by R.W.H.K. Preoperative patients could be either revision cases (patients who had undergone their initial rhinoplasties elsewhere) or primary cases (patients who had no previous rhinoplasty). Patients answered questionnaires by looking at their preoperative and postoperative photographs and comparing the preoperative and postoperative nasal shape. They were asked to comment on their breathing and note any change in their quality of life as a result of the IHCC rhinoplasty. At each postoperative visit, in addition to the physical

examination, the size, location, shape, and stability of the grafts were examined (as primary outcomes). Improvement in nasal appearance, nasal breathing, and quality of life were examined or questioned (as secondary outcomes), and the results were routinely charted on a separate IHCC form. Because of difficulty in inspection of 84 nonpalpable grafts placed in deep nasal tissues (75 spreader grafts + 7 plumping grafts + 2 nasal septum grafts = 84), these nonpalpable grafts were excluded from the total number (1025) of IHCC grafts ( $1025 - 84 = 941$ ) for evaluation of warping, noninfective resorption, and mobility. This means that for the calculation of any warping, noninfective resorption, and mobility, 941 palpable IHCC grafts were used as the base. As for the calculation of any infection (which could be caused by any of the 1025 IHCC grafts) and infective resorption (which occurred as a result of infection of any of the 1025 IHCC grafts), 1025 IHCC grafts were used as the base.

The patient follow-up period was divided into 4 categories ( $\leq 1$  year,  $> 1$  to  $\leq 5$  years,  $> 5$  to  $\leq 10$  years, and  $> 10$  to  $\leq 24$  years) (Figure 2). A 5-point Likert-scale questionnaire<sup>51</sup> was given to patients to evaluate the short-term (2-3 months after rhinoplasty) and long-term ( $> 3$  months after rhinoplasty) postoperative outcomes of their rhinoplasties (Figure 3). Patient satisfaction in 4 categories, including nasal appearance, nasal breathing, nasal symptoms (dryness, discharge, bleeding, or undesirable smell), and quality of life were quantified as much better (1: +100%), slightly better (2: +50%), no change (3: baseline), less normal (4: -50%), and much less normal (5: -100%). For each category, a mean of the percentile of re-

By comparing preoperative and postoperative changes of your nasal appearance (by looking at photographs of your face), nasal breathing, nasal symptoms (dryness, discharge, bleeding, or uncomfortable smell), and quality of life, please answer the following questions using the 5-scale key answers listed below.

**Key to answer questions:**

A = Much better (+100%) B = Slightly better (+50%) C = No change (0)  
D = Slightly worse (-50%) E = Much worse (-100%)

**Nasal Appearance:**

Your POSTOPERATIVE NASAL APPEARANCE is \_\_\_\_\_ than your PREOPERATIVE APPEARANCE.

**Nasal Breathing:**

Your POSTOPERATIVE NASAL BREATHING is \_\_\_\_\_ than your PREOPERATIVE state.

**Nasal Symptoms:**

Your POSTOPERATIVE NASAL SYMPTOMS are \_\_\_\_\_ than your PREOPERATIVE state.

**Quality of Life:**

Your POSTOPERATIVE QUALITY OF LIFE is \_\_\_\_\_ than your PREOPERATIVE state.

**Figure 3.** Five-point Likert-scale questionnaire used by patients to evaluate the postoperative outcome of their rhinoplasties using irradiated homograft costal cartilage grafts in short-term (>2 to ≤3 months) and long-term (>3 months) postoperative periods.

**Table 2. Preexisting Conditions for 386 Irradiated Homograft Costal Cartilage Rhinoplasties Performed on 357 Patients in 1 to 3 Stages<sup>a</sup>**

Preexisting Condition <sup>a</sup>	Rhinoplasties, No. (%)		
	First Surgery	Second Surgery	Third Surgery
Revision	274 (70.98)	19 (5)	5 (1.29)
Undesirable appearance	267 (69.17)	6 (1.55)	0
Nasal breathing difficulty	261 (67.61)	6 (1.55)	2 (0.51)
Poor nasal tip support	97 (25.12)	1 (0.25)	0
Trauma	61 (15.80)	0	0
Septal perforation	49 (12.69)	3 (0.77)	1 (0.25)
Congenital anomaly	11 (2.84)	1 (0.25)	1 (0.25)
Infection	11 (2.84)	0	0
Tumor	4 (1.03)	0	0
Autoimmune disease	3 (0.77)	0	0

<sup>a</sup>Percentiles are based on 386 IHCC rhinoplasties (for details, see Table 3). Generally, after each rhinoplasty less needed to be performed in each successive rhinoplasty because of the progress made previously.

sponses (excluding the “no change” response) were calculated. Because the use of the Likert scale started late in the study, only 42 of 357 patients completed in the questionnaire. More detailed information about patient follow-up and operative methods is explained in the “Report of Cases” section.

## RESULTS

### GENERAL FINDINGS

Among 357 patients, there were 83 primary cases (patients who had not undergone any previous nasal surgery) and 274 revision cases (patients who had undergone 1-13 rhinoplasties before being operated on by R.W.H.K.), which are shown in Table 1. Figure 2 shows the number of patients per each follow-up period. Follow-up periods were divided as follows: 1 year or less (148

**Table 3. Patients Who Underwent Irradiated Homograft Costal Cartilage (IHCC) Rhinoplasties and Revisions**

IHCC Rhinoplasty, No.		
First Surgery	Second Surgery	Third Surgery
333 Patients received 1 IHCC rhinoplasty (333 IHCC rhinoplasties) <sup>a</sup>	19 Patients received 2 IHCC rhinoplasties (38 IHCC rhinoplasties) <sup>a</sup>	5 Patients received 3 IHCC rhinoplasties (15 IHCC rhinoplasties) <sup>a</sup>
<ul style="list-style-type: none"> <li>• 304 of 333 patients did not need revision</li> <li>• 10 of 333 patients needed further revisions without use of IHCC</li> </ul>	<ul style="list-style-type: none"> <li>• 10 of 19 patients did not need revision</li> <li>• 4 of 19 patients needed further revisions without use of IHCC</li> </ul>	<ul style="list-style-type: none"> <li>• 3 of 5 patients did not need revision</li> <li>• 2 of 5 patients needed further revisions without use of IHCC</li> </ul>

<sup>a</sup>Most of the 357 patients (304 [85.15%]) did not need any revision after initial IHCC rhinoplasty. Total number of IHCC rhinoplasties: 333 + 38 + 15 = 386.

patients [41.45%]), more than 1 year and up to 5 years (132 patients [36.97%]), more than 5 years and up to 10 years (48 patients [13.44%]), and more than 10 years and up to 24 years (29 patients [8.12%]) years. The mean (SD) follow-up period was 13.45 (2.83) years.

**Table 2** shows the preexisting conditions for the patients who underwent 3 stages of rhinoplasty with IHCC grafts. **Table 3** provides detailed and simplified information about 386 IHCC rhinoplasties that were performed on 357 patients. **Table 4** depicts detailed information on the type, number, and placement of IHCC and other grafts used for each incidence of rhinoplasty.

### COMPLICATIONS RELATED TO THE USE OF IHCC GRAFTS

**Table 5** shows detailed information about the type and number of complications following each stage of rhinoplasty.

#### Warping

The major complication in the present study was warping (10 of 943 palpable IHCC grafts [1.06%]), and it was noticed in the following postoperative periods: 20 days, 21 days, 22 days, 1 month (2 cases), 1.6 months, 6.6 months, 7 months, 8 months, and 3.66 years. Because the dorsal onlay augmentation grafts were the largest and the most visible, it was easier for the patient to notice warping of this graft and contact us for revision. Of 10 dorsal onlay grafts that underwent warping (1.06%), 6 grafts were replaced with new IHCC grafts and did not show warping in a follow-up period of 5 months to 15.25 years. A warped case of IHCC in (case 2) occurred following nasal fracture not related to the IHCC per se and therefore was not included in the warping complication statistics.

#### Infection

Because 1025 IHCC grafts were used along with 373 other grafts (for a total of 1398), any of the grafts could have been

**Table 4. Type and Number of Irradiated Homograft Costal Cartilage (IHCC) Grafts and Other Grafts Used Concomitantly**

IHCC Graft	No.			Total, No. (%) <sup>a</sup>
	First Surgery	Second Surgery	Third Surgery	
Type of IHCC graft (n=1025)				
Columellar strut <sup>b</sup>	204	5	3	212 (20.68)
Dorsal onlay <sup>b</sup>	189	12	0	201 (19.60)
Nasal tip <sup>b</sup>	177	9	4	190 (18.53)
Strut/caudal septum <sup>b</sup>	93	4	0	97 (9.46)
Alar rim notching <sup>b</sup>	78	0	0	78 (7.60)
Spreader <sup>c</sup>	75	0	0	75 (7.31)
Nasal valve <sup>b</sup>	75	4	0	79 (7.70)
Alar batten <sup>b</sup>	40	5	0	45 (4.39)
Lateral onlay <sup>b</sup>	38	0	1	39 (3.80)
Plumping <sup>c</sup>	6	0	1	7 (0.68)
Nasal septum <sup>c</sup>	2	0	0	2 (0.19)
<b>Total</b>	<b>977</b>	<b>39</b>	<b>9</b>	<b>1025</b>
Type of other graft (n=373)				
Septal cartilage <sup>d</sup>	176	0	0	176 (47.18)
Alloderm <sup>e</sup>	60	6	0	66 (17.69)
Composite ear cartilage	35	3	1	39 (10.45)
Ear cartilage <sup>d</sup>	34	7	1	42 (11.26)
Temporalis fascia	25	1	1	27 (7.23)
Mersilene <sup>e</sup>	7	0	0	7 (1.87)
Supramid <sup>e</sup>	2	1	0	3 (0.80)
Nylamid <sup>e</sup>	3	0	0	3 (0.80)
GORE-TEX <sup>e</sup>	7	0	0	7 (1.87)
Skin	0	1	0	1 (0.26)
Bone	1	0	0	1 (0.26)
Medpor <sup>e</sup>	1	0	0	1 (0.26)
<b>Total</b>	<b>351</b>	<b>19</b>	<b>3</b>	<b>373</b>

<sup>a</sup> Percentages are based on the total number of relevant grafts.

<sup>b</sup> Palpable IHCC graft (n=941 grafts).

<sup>c</sup> Nonpalpable IHCC graft (n=84).

<sup>d</sup> Autogenous cartilage grafts (n=218 grafts).

<sup>e</sup> Manufacturer information: Alloderm (LifeCell Corp, Branchburg, New Jersey), GORE-TEX (W. L. Gore, Flagstaff, Arizona), Medpor (Porex Surgical Inc, College Park, Georgia), Mersilene (Johnson & Johnson Gateway, Piscataway, New Jersey), Nylamid and Supramid (S. Jackson Inc, Alexandria, Virginia).

**Table 5. Information About Complications After Each Irradiated Homograft Costal Cartilage (IHCC) Rhinoplasty**

Complication	No.			Complications, No. (Rate, %) <sup>a</sup>
	First Surgery	Second Surgery	Third Surgery	
Warping	9	1	0	10 of 941 palpable IHCC grafts (1.06)
Infection	5	4	0	9 of 1025 total IHCC grafts (0.87)
Noninfective resorption	5	0	0	5 of 941 palpable IHCC grafts (0.53)
Infective resorption	3	2	0	5 of 1025 total IHCC grafts (0.48)
Mobility	3	0	0	3 of 941 palpable IHCC grafts (0.31)
Extrusion	0	0	0	0
<b>Total</b>	<b>25</b>	<b>7</b>	<b>0</b>	Mean rate, 3.25

<sup>a</sup> Percentages of warping, noninfective resorption, and mobility were based on 941 palpable or inspectable IHCC grafts (including columellar strut, dorsal onlay, nasal tip, strut/caudal septum replacement, alar rim notching, nasal valve, alar batten, and lateral onlay grafts). Because all 1025 palpable and nonpalpable IHCC grafts were subject to infection and subsequent infective resorption, complication rates related to infection and infective resorption were calculated based on 1025 total IHCC grafts.

a source of infection. Because it was not possible to identify the specific graft that might have been the source of any infection, all infections were attributed to IHCC grafts. In this view, all 1025 IHCC grafts were included in the calculation of percentages of infection and infective resorption (resorption of IHCC graft after infection) because any of them could be subject to infection and subsequent infective resorption. Regarding 9 cases of infection, the rate of infection was calculated based on 1025 IHCC grafts, or 0.87%; however, the actual infection rate based on a total

of 1398 grafts was 0.64%. Infections occurred 21 days to 7.16 years after surgery. Five infections occurred after the first use of IHCC, and 4 infections occurred after second rhinoplasty with IHCC. All cases of infection were treated promptly and adequately. **Figure 4** provides comprehensive information about preexisting risk factors, number and type of IHCC and other grafts used in 9 infection cases, 5 associated cases of infective resorption (grafts in cases 1, 2, 4, 6, and 9), timing, replacement, and follow-up. All cases had common preexisting risk factors, such as 1 to 13 pre-



Case No.	Preexisting Nasal Conditions	IHCC Grafts	Other Grafts	Suture Materials	Infection Onset	Resorption Onset and Outcome
1	• Nasal surgery×2	• Nasal tip • Columellar strut		• Mersilene	4 wk	• 1.75 y • Partial resorption of nasal tip • No complication 2.5 y After replacement of nasal tip made of IHCC
2	• Nasal surgery×13	• Dorsal onlay • Nasal tip • Strut/caudal septum replacement • Bilateral nasal valves		• PDS • Prolene	2 mo	• 9.5 mo • 10% Resorption of nasal tip
3	• Nasal surgery×2	• Nasal tip • Columellar strut • Right alar rim	• 3 Pieces of nasal septal cartilage • 1 Piece of ear cartilage	• PDS • Prolene	2 wk	• 1 y • No resorption
4	• Nasal surgery×1 • Sinus infections	• Dorsal onlay • Columellar strut • Bilateral alar rims • Bilateral alar battens	• Acellular dermis (over dorsal onlay made of IHCC)	• PDS • Prolene	?	• 8 wk • Minimal resorption of dorsal onlay
5	• Nasal surgery×2	• Dorsal onlay • Nasal tip • Spreaders×2	• Acellular dermis over dorsal onlay • Composite ear cartilage×2	• PDS • Prolene	7 wk	
6	• Nasal surgery×3	• Dorsal onlay • Nasal tip • Spreaders×2 • Right alar rim	• Acellular dermis over dorsal onlay	• PDS • Prolene	2 wk	• 10 mo • Minimal resorption of dorsal onlay
7	• Nasal surgery×4 • Septal perforation • Sinus infection	• Nasal tip • Strut/caudal septum replacement • Bilateral alar batten • Right onlay	• Acellular dermis (over dorsal onlay and alar batten)	• PDS • Prolene	4 wk	• 2.53 y • No resorption
8	• Multiple nasal traumas	• Nasal tip • Columellar strut	• Septal cartilage • Mersilene mesh	• PDS • Prolene	2.5 y	• 9 mo After surgery • No resorption
9	• Nasal surgery×2	• Dorsal onlay • Strut/caudal septum replacement	• Nylamid • Temporalis fascia	• PDS • Prolene	1 mo	• 6 y After surgery • Resorption of strut/caudal replacement

**Figure 4.** Infection and infective resorption of irradiated homograft costal cartilage (IHCC) grafts in 9 (cases 1-9) and 5 (cases 1, 2, 4, 6, and 9) cases, respectively. A question mark indicates that the timing was not clear. Mersilene and Nylamid are manufactured by Johnson & Johnson Gateway (Piscataway, New Jersey) and S. Jackson Inc (Alexandria, Virginia), respectively.

vious nasal operations, recurrent sinus infections, septal perforation, or nasal trauma.

### Infective Resorption

As shown in Table 5, 5 of 9 cases that became infected underwent resultant resorption 2 months to 4.08 years after graft placement. As discussed in the “Methods” section, the rate of infective resorption was 0.48%, which was calculated based on 1025 IHCC grafts. The rates of resorption measured by the immersion method intraoperatively in 2 cases were 10% and 100%. The amount of

infective resorption in 3 cases was determined by palpation and was moderate. The types of IHCC graft that underwent infective resorption included nasal valve, dorsal onlay, nasal tip, and strut/caudal septum. Only 1 of 5 infected-resorbed grafts was replaced, and no further complications were observed 2.5 years after replacement.

### Noninfective Resorption

Noninfective resorption by definition indicates resorption of a graft that is not a result of active infection following IHCC rhinoplasty. The rate of noninfective resorp-

**Table 6. Noninfective Resorption of Irradiated Homograft Costal Cartilage (IHCC) Grafts<sup>a</sup>**

Existing Preoperative Risk Factors	Postoperative Year When Resorption Was Noticed	Type of IHCC Graft	Amount of Resorption, % <sup>b</sup>	Replacement of Graft	Findings at Follow-up	No. of Resorbed Graft/No. of Graft Type <sup>c</sup> (%)
Nasal trauma and sinus infection	15.25	Columellar strut	100	+	No complication 1 y after replacement	1/212 (0.47)
Multiple rhinoplasties and sinus infection	9.91	Nasal tip	40	+	No complication 1.83 y after replacement	1/190 (0.52)
Multiple rhinoplasties and sinus infection	9.91	Strut/caudal septum	10	+	No complication 1.83 y after replacement	1/97 (1.03)
Trauma, septal perforation, and sinus infection	6	Dorsal onlay	Moderate	-	-	1/201 (0.49)
Septal perforation and sinus infection	5	Nasal valve	Minimal	-	-	1/79 (1.26)

Abbreviations: -, no follow-up; +, a follow-up was performed.

<sup>a</sup>Noninfective resorption of IHCC grafts was detected 5 to 15.25 years after placement of grafts. All 5 cases of noninfective resorption had a common preoperative history of sinus infections, which could sensitize nasal tissue to homografts. Two of 5 cases did not need replacement because the patients were satisfied with cosmetic outcomes; perhaps fibrous replacement of the grafts provided the cosmetic result noted.

<sup>b</sup>The amounts of resorption for 2 grafts that were not replaced and were estimated by palpation were defined as moderate and minimal.

<sup>c</sup>See Table 4.

tion in the current study was 0.53%, which was calculated based on 941 palpable IHCC grafts. To avoid bias, noninfective resorption of IHCC grafts in patients with progressive autoimmune diseases or as a result of postoperative nasal trauma were not included in **Table 6**. One of 2 patients with minimal noninfective resorption of a dorsal onlay graft, which was reported in our earlier investigation,<sup>42</sup> was excluded in the present study because the patient had an active progressive autoimmune disease that was assumed to be the cause of resorption of IHCC graft.

According to these criteria, 5 cases of noninfective resorption of IHCC grafts are reported in detail in Table 6 and include the following: Total noninfective resorption of a columellar strut was seen in 1 patient who previously had nasal trauma and recurrent sinus infections. In 2 patients, 40% resorption of a nasal tip graft and 10% resorption of strut/caudal/septal replacement graft, respectively, were detected 9.91 years after placement of these 2 grafts in the same patient. It is notable that this patient had already undergone 3 unsuccessful rhinoplasties elsewhere and had a history of recurrent sinus infections. There was abundant granulation tissue in the subcutaneous and submucosal areas in this patient. In the fourth case, progressive noninfective resorption of dorsal onlay graft made of IHCC was estimated to be 20% (or minimal) at the fourth postoperative year, 25% (or moderate) at the fifth postoperative year, and 50% (or near-complete) at the sixth postoperative year. This patient had a history of preoperative nasal trauma and nasal bone fracture in childhood. Later, this patient developed a severe nasal allergy and a septal perforation with recurrent nasal bleeding, sinus infections, severe nasal breathing difficulty, and dorsal saddling. At 2.41 years after nasal and septal reconstruction, a minimal depression was noticed over her dorsum. This depression was covered with acellular dermis. At 4.33 years after this revision, resorption of the acellular dermis was observed, and an additional revision was performed using 4 layers of GORE-TEX. Three months after the GORE-TEX application, the patient was fully satisfied with her nasal

appearance and breathing. The fifth case of noninfective resorption was noted in a patient who had undergone previous septal surgery that led to a septal perforation, nasal infection, and nasal breathing difficulty. In this patient, 5 IHCC grafts (dorsal onlay, strut/caudal septum, and 2 nasal valves) were used. Only the left external nasal valve underwent minimal noninfective resorption 5 years after nasal surgery. The patient was still satisfied with her nasal function and appearance; therefore, no replacement procedure was performed. Since these 5 cases of noninfective resorption occurred in 77 patients with follow-up periods of 5 to 24 years (Figure 2), the rate of noninfective resorption within 5 to 24 years and per patient is estimated as 5 of 77 (6.49%) with respect to the follow-up time period. Note that all 5 patients had multiple preoperative dire nasal conditions, and they expressed satisfaction with the structural and functional improvements of their nose after IHCC rhinoplasty. Only 1 of the 201 dorsal onlay grafts (0.49%) underwent moderate resorption, without need of replacement.

One case of noninfective resorption of a dorsal onlay IHCC graft that underwent resorption (most likely as a result of advanced and progressive autoimmune disease such as vasculitis, polymyalgia arteritica, or renal focal sclerosis) was not included in Table 6. In this patient, complete noninfective resorption of the dorsal onlay IHCC graft was detected 8 years after rhinoplasty, which is a long time considering that she had a devastating autoimmune disease that was later fatal.

#### COMPLICATIONS ASSOCIATED WITH AC GRAFTS USED WITH IHCC

During the course of this study, some complications related to the use of 5 AC grafts were detected. Two of these 5 grafts were not included in statistics: 1 graft made of autogenous rib cartilage, which underwent warping after rhinoplasty was performed elsewhere, and 1 nasal tip graft made of septal cartilage that underwent moderate nonin-

**Table 7. Resorption of Autogenous Cartilage (AC) Grafts Used in Association With Irradiated Homograft Costal Cartilage (IHCC) Grafts<sup>a</sup>**

Amount of Resorption	Type of Graft	Grafts, No.	Years After Surgery
Minimal	Ear cartilage (nasal valves)	2	9.33
Minimal	Septal cartilage (onlay)	1	15.58

<sup>a</sup>Number of noninfective resorption of AC per number of AC grafts: 3 of 218 (1.37%). Compare 1.37% noninfective resorption of AC grafts with 1.01% combined noninfective and infective resorption of IHCC grafts (see Figure 4 for additional information).

fective resorption (case 2). Three cases of noninfective resorption of AC cases that were considered as true-positive (not as a result of trauma or autoimmune diseases) were included in **Table 7**. Noninfective resorption of AC was detected in 2 external nasal valve grafts and in 1 onlay graft in the supratip area made of ear cartilage. Regarding the 218 AC grafts used with IHCC graft (Table 4) and 3 noninfective resorption of AC grafts that were detected in the present study, the rate of noninfective resorption of AC was 1.37%, which was 2.58-fold higher than the overall 0.53% noninfective resorption rate of IHCC graphically shown in Figure 4. We counsel all of our patients about potential resorption of any cartilage grafts we use, whether they are autogenous or homologous.

#### USE OF IHCC AND AC GRAFTS IN CONJUNCTION WITH SEPTAL PERFORATION CASES

**Table 8** presents comprehensive information about the concomitant use of IHCC in 53 cases of septal perforation. Temporalis fascia, acellular dermis, septal cartilage, and mastoid periosteum were used as the interposition graft for repair of 27, 21, 2, and 1 cases of septal perforations, respectively. In total, 162 IHCC grafts were used to correct other nasal anomalies in conjunction with septal perforation repair. Septal perforations are seen commonly after previous septal surgery. Sometimes, overzealous removal of the caudal septum caused nasal tip underprojection or derotation requiring either caudal septal replacement or a strut often composed of IHCC. If such septal surgery was performed at the same time as a rhinoplasty and a perforation ensued, often a revision rhinoplasty was also necessary and required IHCC grafts. Sometimes, the process that caused the perforation, the progressive nature of the perforation itself, or the loss of support of the dorsum secondary to the size of the perforation would cause nasal dorsal saddling.

Complications related to the use of 162 IHCC grafts in septal perforation cases were rare and consisted of 4 cases (2.46%) as follows: 1 case of infection (0.61%), which occurred 1.8 months postoperatively and was treated promptly with full satisfaction as noted 2.58 years after repair; 1 case of minor mobility of a dorsal augmentation onlay graft that occurred 7 months postoperatively without a need for repair (0.61%); 1 case of

minor warping of a dorsal onlay graft that was noticed 1.66 months postoperatively without patient complaint or need for repair (0.61%); and 1 case of 100% infective resorption of a strut/caudal septal replacement graft that was replaced and at the 6-year postoperative follow-up yielded no complication (0.61%). Of interest is that the total complication rate for the use of IHCC grafts in conjunction with septal perforation repair is lower than in those cases of just IHCC grafts and/or AC grafts when no perforation was present. Such a finding strongly suggests that a concomitant septal perforation repair does not increase the complication rate when IHCC grafts are also used.

Complications related to the use of 25 AC grafts in septal perforation cases included 2 cases of resorption of external nasal valve grafts of a total of 25 AC grafts (8%), which were noted an average of 9.33 years after placement, and no replacement was performed. Compared with IHCC, AC was associated with a 3.25-fold higher complication rate in conjunction with septal perforation cases, for unknown reasons.

#### COMPARISON BETWEEN THE RESULTS OF THE 1993 STUDY AND THOSE OF THE PRESENT STUDY

**Table 9** shows a comparison between some of the parameters discussed in the previous report in 1993<sup>42</sup> and the present study. Despite an increase in the number of patients (from 117 to 357), the number of rhinoplasties (from 122 to 386), and the number of IHCC grafts (from 306 to 1025), total complications dropped by 1.05%, from 4.3% in the previous report to 3.25% in the present report. Perhaps our techniques improved as we gained greater experience.

#### USE OF IHCC IN PATIENTS WITH AUTOIMMUNE DISEASE

Irradiated homograft costal cartilage grafts were used in 3 cases of nasal deformity caused by progressive autoimmune diseases. By definition, the immune systems of these patients attack their own soft tissues, including cartilaginous tissue. These patients are poor candidates for cartilage grafting because any such grafts can be absorbed when the disease progress is active.

In 1 case of a patient with an autoimmune disease (case 7), IHCC was used as dorsal onlay, nasal tip, and strut/caudal septum replacement grafts in a 31-year-old white woman with chondritis, which had caused her nasal deformity, septal perforation, epistaxis, and nasal breathing difficulty. At 2.08 years after her rhinoplasty, the patient was satisfied with the outcome of her nasal reconstruction.

In the second case (data not shown), IHCC was used as a dorsal onlay and for strut/caudal septum replacement grafts in a 27-year-old woman with a nasal deformity and nasal breathing difficulty, a history of Epstein-Barr virus, nasal infection, polychondritis, and arthritis. Ten years after surgery, the patient was satisfied with her nasal breathing and nasal appearance and had experienced no complication.

**Table 8. Complications Associated with Septal Perforation Cases**

Type of Outcome Complication	Type of Graft	Grafts, No.	Postoperative Period	Replacement Status	Period of Follow-up After Replacement, y	Outcome After Replacement
<b>Complications Associated With the Use of 162 IHCC Grafts Used in 53 Septal Perforation Cases</b>						
Infection complication	Strut	1	1.8 mo	+	2.58	No complication
Minor mobility	Dorsal onlay	1	7 mo	-	-	-
Minor warping	Dorsal onlay	1	1.66 mo	-	-	-
100% Infective resorption	Strut/caudal septum	1	NA	+	6	No complication
<b>Complications of IHCC: 4 of 162 (2.46%)</b>						
<b>Complications Associated With the Use of 25 AC Grafts Used in 53 Septal Perforation Cases<sup>a</sup></b>						
Noninfective resorption	Nasal valves	2	9.33 y	-	NA	NA
<b>Complications of AC: 2 of 25 (8%)</b>						

Abbreviations: AC, autogenous cartilage; IHCC, irradiated homograft costal cartilage; NA, not applicable; -, no; +, yes.

<sup>a</sup>Complications of autogenous cartilage (AC): 2 of 25 (8%); AC showed 3.25 times higher rate of complications than IHCC in association with septal perforation repairs.

**Table 9. Comparison Between Various Parameters From the Previous (1993) and Present Reports<sup>a</sup>**

Parameters	1993 Report by Kridel and Konior <sup>42, b</sup>	Present Report <sup>b</sup>
Patients, No.	117	357
Rhinoplasties, No.	122	386
IHCC grafts, No.	306	1025
Palpable IHCC grafts, No.	295	941
Dorsal onlay grafts, No.	74	201
Mean duration of follow-up, y	1.25	13.45
Warping rate per No. of palpable IHCC grafts	2/295 (0.67)	10/941 (1.06)
Noninfective resorption rate per No. of palpable IHCC grafts	2/295 (0.67)	5/941 (0.53)
Mobility rate per No. of palpable IHCC grafts	3/295 (1.01)	3/941 (0.31)
Extrusion rate per No. of palpable IHCC grafts	0	0
Infection rate per total No. of IHCC grafts	4/306 (1.30)	9/1025 (0.87)
Infective resorption rate per total No. of IHCC grafts	2/306 (0.65)	5/1025 (0.48)
Total, % <sup>c</sup>	4.3	3.25

Abbreviation: IHCC, irradiated homograft costal cartilage grafts.

<sup>a</sup>Despite the marked increase in numbers of patients, rhinoplasties, and IHCC grafts in the present study, complications in the present study decreased markedly compared with the previous study. Unless otherwise indicated, data are given as No./total No. (%).

<sup>b</sup>Complication rates are given in parentheses.

<sup>c</sup>Mean sum of complication rates.

In the third case (data not shown), IHCC was used as dorsal onlay and as strut/caudal septum replacement grafts in a 42-year-old woman with a nasal deformity and nasal breathing difficulty with history of vasculitis, polymyalgia arteritica, and renal focal sclerosis. Eight years after IHCC rhinoplasty with a progression of her disease, her IHCC grafts were resorbed, and the patient later died of her disease.

### PATIENT SATISFACTION

We were able to access retrospectively patient satisfaction data in 42 patients with an mean (SD) follow-up period of

**Table 10. Patient Satisfaction Based on a 5-Point Likert Scale Questionnaire<sup>a</sup>**

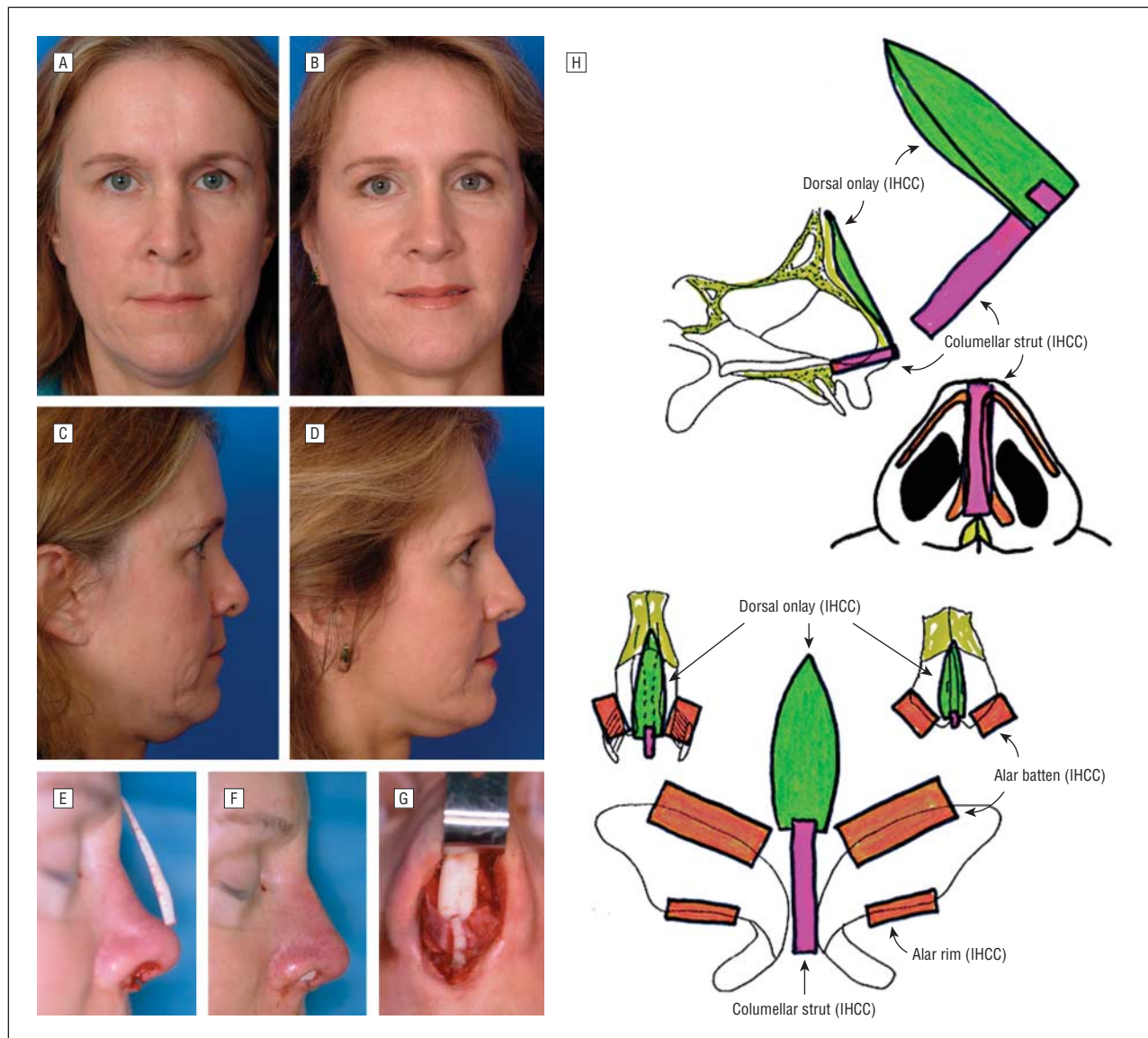
Parameters	Short-term Satisfaction, %	Long-term Satisfaction, %
Nasal appearance	96.43	98.78
Nasal breathing	90.27	91.66
Nasal symptoms	83.33	90.00
Quality of life	95.23	97.61
Average satisfaction	91.31	94.18

<sup>a</sup>Short-term satisfaction (2-3 months after rhinoplasty after the early healing process was accomplished) and long-term satisfaction (>3 months after last rhinoplasty) are expressed as percentages. Comparison was performed according to preoperative status. N=42; mean (SD) follow-up period, 7.87 (5.64) years. Marked short-term and long-term satisfactions were obtained in all categories. See the "Follow-up" subsection in the "Methods" section.

7.87 (5.64) years using a 5-point Likert scale<sup>51</sup> (Table 10). The questionnaire was completed to compare short-term (2-3 months after rhinoplasty) and long-term (> 3 months after rhinoplasty) satisfaction with nasal appearance, nasal breathing, nasal symptoms, and quality of life. Both short-term and long-term satisfaction was seen in all aspects with overall satisfaction, increasing by 2.87% from 91.31% (short-term) to 94.18% (long-term).

### REPORT OF CASES

Because dorsal onlay augmentation graft was the most superficial, voluminous, and therefore most easily inspectable IHCC graft used in our patients, 14 cases in which IHCC was used as dorsal onlay are presented from the shortest (3 months) to the longest (20 years) postoperative follow-up periods. Due to space limitations, only 3 of the 14 cases are described herein. The reader is directed to the journal Web site for other cases and expanded comments (<http://www.archfacial.com>). Irradiated homograft costal cartilage was not used as a dorsal onlay in the patient with the longest follow-up period (24 years) in the current report; therefore, this patient is not presented in our case studies. Both successful and complicated cases are discussed in brief and systematic style supplemented with operative sketches and methodologic information.



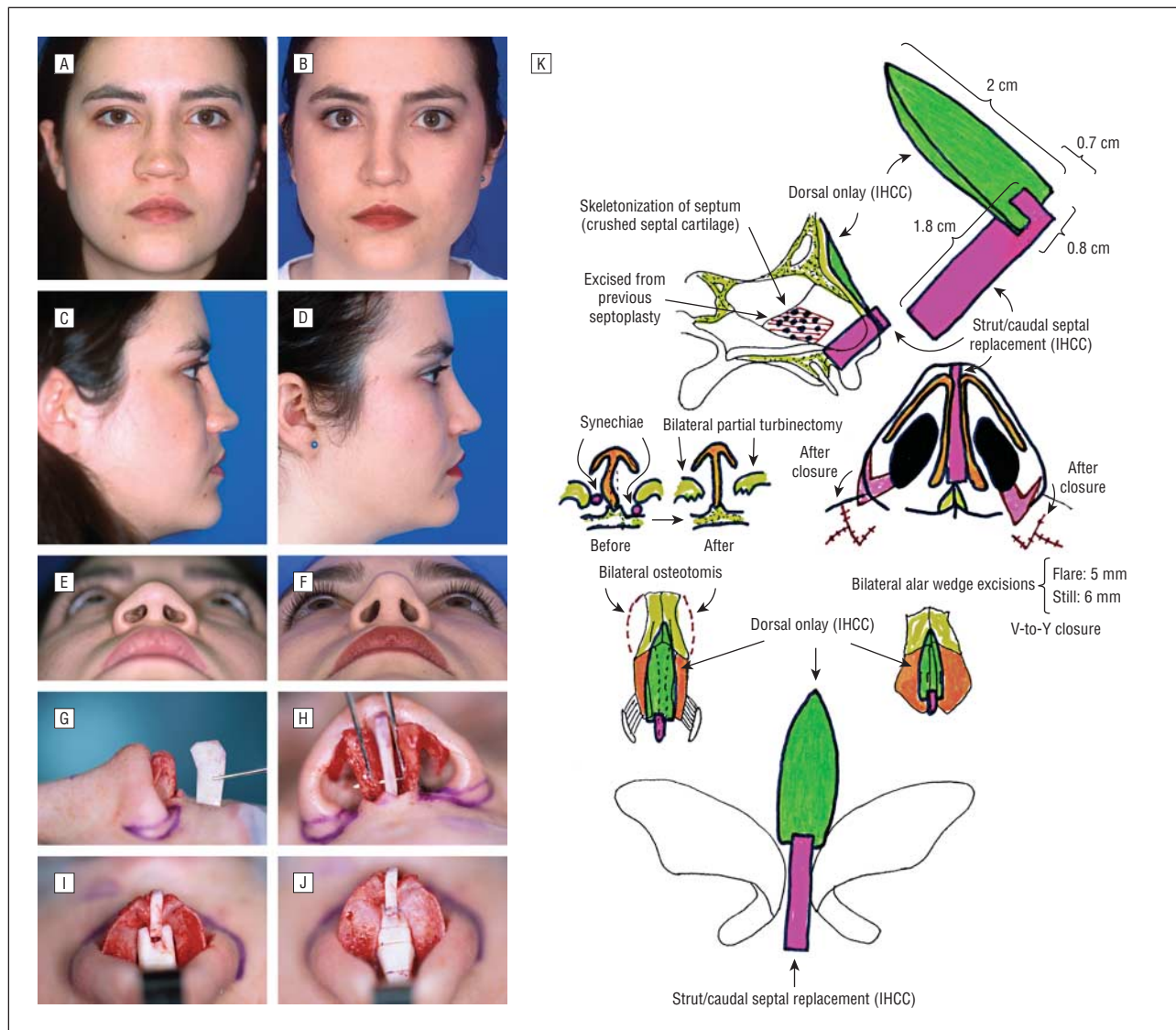
**Figure 5.** Case 3. A and C, preoperative views of a patient who had undergone 2 previous rhinoplasties elsewhere. Findings from the physical examination revealed an irregular dorsum, amorphous nasal tip, nasal valve collapse bilaterally during inspiration, and alar notching. B and D, Views 10 months after the operation. The patient was fully satisfied with improvement of her nasal appearance. The irradiated homograft costal cartilage grafts (IHCC) included dorsal onlay, septal columellar graft, bilateral alar batten grafts that were placed directly between the upper lateral cartilages and lower lateral crura to provide better support in this region and correct the underlying external valve collapse, and 2 alar rim grafts that were located in the alar rim region to correct notching. E, Intraoperative view shows the dorsal onlay graft that is placed over the saddle-nose deformity for alignment. F, Intraoperative view after placement of the grafts. G, The dorsal onlay graft was interdigitated with a large columellar strut in form of dado-rabbit form that was sewn between the medial crura and extended posteriorly to provide nasal tip support and to help stabilize the entire nasal base complex. H, Operative sketch showing the types and locations of the grafts.

### CASE 3

A 42-year-old woman presented with a history of 2 previous nasal surgical procedures performed elsewhere with postoperative undesirable nasal disproportion (**Figure 5A** and **C**). Major physical and surgical findings were nasal disproportion, dorsal saddling, nasal valve collapse, and vestibular stenosis. The summary of operative procedures and grafts included (1) repair of vestibular stenosis; (2) revision rhinoseptal reconstruction; and (3) IHCC grafts that included dorsal onlay, columellar strut, 2 alar rim notching grafts, and 2 alar batten grafts (**Figure 5E-H**). Ten months after surgery, the patient was fully satisfied with her nasal appearance without incidence of any complication (**Figure 5B** and **D**).

### CASE 5

Following an accident, a 20-year-old woman underwent 2 rhinoplasties elsewhere and postoperatively developed a nasal deformity, nasal breathing difficulty, recurrent headaches, and recurrent sinus infections. The major physical and surgical findings included saddle-nose deformity, wide nasal dorsum owing to the loss of height, broad and amorphous nasal tip, wide nostrils and alae, retracted columella, acute nasolabial angle, absence of caudal septum, left inferior turbinate hypertrophy, fixed right-sided nasal obstruction due to the deviation of the nasal septum to the right and adhesion to the right inferior turbinate, adhesion of left inferior turbinate to the nasal floor, and intranasal synechiae



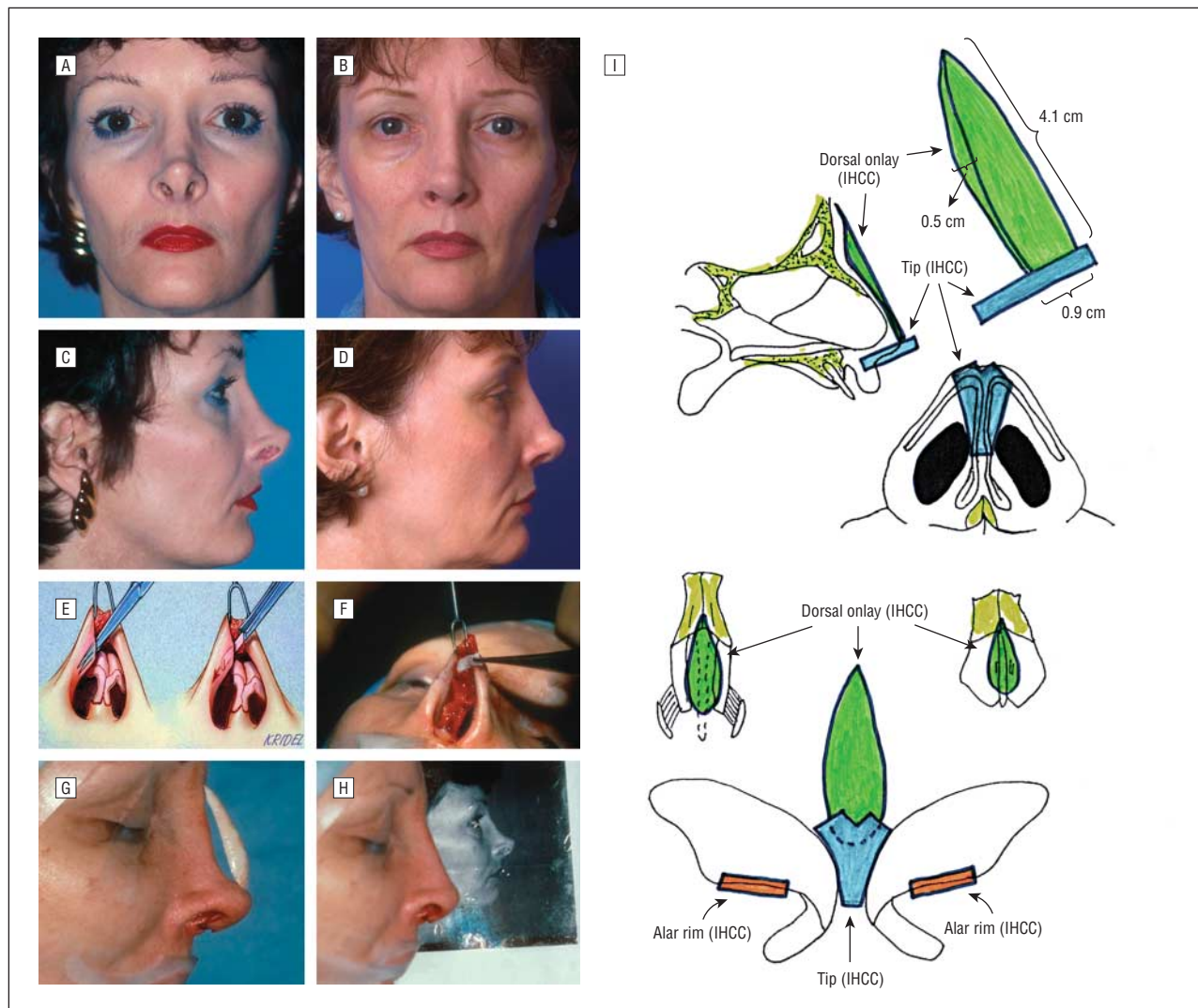
**Figure 6.** Case 5. A, C, and E, Preoperative views of a patient with history of nasal trauma and 2 previous rhinoplasties performed elsewhere. She had a saddle-nose deformity, deviated septum, bilateral intranasal adhesions, and inferior turbinate hypertrophy. B, D, and F, One-year postoperative views without any complication. Irradiated homograft costal cartilage (IHCC) was used as dorsal onlay and strut/caudal septum replacement grafts. G and H, Strut/caudal septum replacement graft before and after insertion into a pocket created between the medial crura and posterior to the caudal end of septal cartilage. Plain 5-0 suture on a Keith needle was used to sew the graft in place to the medial crura. I and J, Dorsal onlay made of IHCC was sewn into place with multiple 6-0 PDS sutures. 6-0 Prolene sutures were then used to sew the dorsal augmentation graft to the strut/caudal septum replacement graft in the form of a dado-rabbit interdigitation. K, Operative sketch showing the types and locations of the grafts.

(**Figure 6A, C, E, and K**). The summary of operative procedures and grafts is as follows: revision rhinoplasty was performed using IHCC grafts, including a dorsal onlay with a size of  $2.0 \times 0.8$  cm and a strut/caudal septum replacement  $1.8 \times 0.7 \times 0.2$  cm in size. The height of the dorsal augmentation graft was tapered and measured 0.1 cm at its shortest height, gradually increasing to its greatest height of 0.5 cm inferiorly. This graft was sewn into place with multiple 6-0 PDS sutures. The dorsal onlay was sewn to the strut/caudal septum using Prolene (6-0) sutures. A strut/caudal septum replacement graft was placed within the pocket developed between the medial crura and the caudal membranous septum. This allowed for an excellent replacement of the deficient caudal septum in addition to providing a strut and further increasing the nasal tip support. Other operative procedures included reskeletonization of the septum using crushed residual septal carti-

lage, bilateral partial resection of the inferior turbinates, lysis of intranasal synechiae, bilateral alar wedge excisions, including sill and flare, and their closure in a V-to-Y fashion in order to medialize the nasal alae (Figure 6G, H, I, and J). Results from the 1-year follow-up (Figure 6B, D, and F) and 6.16-year follow-up (no photograph) indicated that the patient was free from any preoperative symptoms and that the grafts were intact and in place.

### CASE 13

A 42-year-old woman presented with a history of severe nasal breathing difficulty following a rhinoplasty performed elsewhere. Major physical and surgical findings are as follows: dorsal saddling as a result of overresection of nasal dorsum; overrotated and overprojected nasal tip; alar rim notching; nasal septum deviated to the right; and bi-



**Figure 7.** Case 13. A and C, Preoperative views of a patient with a history of severe nasal breathing difficulty, saddle-nose deformity, overrotated and overprojected nasal tip, alar rim notching, and deviated nasal septum following a rhinoplasty performed elsewhere. B and D, Views 9.41 years after surgery. The patient was fully satisfied with her nasal breathing and the result of her irradiated homograft costal cartilage (IHCC) rhinoplasty. Minor depression in supratip area could be the result of the aging process. E, The method of making pockets for alar rim notching grafts using a sharp dissection scissors. F, Insertion of right alar rim notching graft made of IHCC. G, The dorsal onlay graft was placed over the dorsum for final adjustment. H, Intraoperative comparison of reconstructed nose with preoperative photograph. I, Operative sketch showing the types and locations of the grafts.

lateral hypertrophy of the inferior turbinates (**Figure 7A** and **C**). The summary of the operative procedures and grafts are as follows: septoplasty; revision open rhinoplasty using IHCC as dorsal onlay, nasal tip, and 2 alar rim notching grafts; and bilateral and partial inferior turbinate resection (Figure 7E-I). At follow-up after 9.41 years, all IHCC grafts remained intact and in place, and the patient was fully satisfied with her nasal breathing and appearance (Figure 7B and **D**).

Cases 1, 2, 4, 6, 7, 8, 9, 10, 11, 12, and 14 are presented in detail in the Web-only appendix available at <http://www.archfacial.com>.

#### COMMENT

The search for the ideal nasal implant remains an ongoing effort. We desire a substance that is readily available in large quantities; resists infection and absorption; is com-

pletely integrated into host tissues; causes little patient morbidity; and can be molded, shaped, or carved with ease. Irradiated homograft costal cartilage satisfies many of these ideal parameters because it is easy to carve, is available in large sizes and therefore capable of providing multiple grafts from 1 piece, remains inert, and has a firm yet not overly stiff quality that provides a strong structure.<sup>20</sup> Regardless of several reports indicating that IHCC is equal and even superior to autogenous costal cartilage for rhinoplasty, some still anecdotally question the use of IHCC because of the lack of a long-term study with a large sample size regarding its usage in the nose (rather than other parts of the face) to validate its merits. The present evidence-based report fulfills these goals in support of the use of IHCC grafts for rhinoplasty. Compared with our previous report,<sup>42</sup> the sample size increased from 117 to 357 patients, the number of IHCC grafts increased from 306 to 1025, and the fol-

low-up period increased from an average of 1.25 years to a mean (SD) of 13.45 (2.83) years (Table 9). Moreover, the following factors consolidate the data presented: (1) All the operations were performed by 1 surgeon (R.W.H.K.), using the same protocol and providing consistency. (2) Data evaluation was performed by independent sources (F.A. and C.G.H.), who were not involved in the clinical care of the patients. (3) A supplemental standardized patient questionnaire (Likert scale)<sup>31</sup> was completed by patients to evaluate the subjective outcome of the rhinoplasties. (4) Detailed and comprehensive information, mostly in the form of multiple tables and supplemented with diverse cases, is provided to compare various parameters from different perspectives. (5) Finally, the present data are compared with our previous data and multiple other reports related to infection and resorption rates of IHCC and AC grafts, after an extensive literature review.

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**Author Contributions:** *Study concept and design:* Kridel. *Acquisition of data:* Kridel, Liu, Ashoori, and Hart. *Analysis and interpretation of data:* Kridel, Liu, Ashoori, and Hart. *Drafting of the manuscript:* Kridel, Liu, Ashoori, and Hart. *Critical revision of the manuscript for important intellectual content:* Kridel. *Statistical analysis:* Kridel, Liu, Ashoori, and Hart. *Administrative, technical, and material support:* Kridel. *Study supervision:* Kridel.

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**Additional Information:** A Web-only appendix with 13 eFigures and 2 eTables is available at <http://www.archfacial.com>.

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