The Diced Cartilage Glue Graft for Nasal Augmentation

Morphometric Evidence of Longevity

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**Background:** A grafting technique that uses diced cartilage without fascia, which improves formability while maintaining long-term stability, would be a welcome addition to the rhinoplasty armamentarium.

**Methods:** A diced cartilage glue graft was recently introduced as the Tasman technique. The technique has been used by one of us (A.-J.T.) in 28 patients who were monitored clinically for 4 to 26 months. Sonographic morphometry of the graft was used in 10 patients with a maximum follow-up of 15 months, and 2 biopsies were obtained for histologic examination.

**Results:** Fashioning the diced cartilage glue graft reduced operating time compared with the diced cartilage fascia graft and allowed for a wide variety of transplant shapes and sizes, depending on the mold used. All grafts were used for augmentation of the nasal dorsum or radix and healed unevenly. Sonographic cross-section measures of the grafts changed between 6% and −29% (median, −5%) in the early postoperative phase and 8% and −7% (median, −2%) between 3 and 15 months after insertion. Histologic examination of the graft biopsies revealed viable cartilage with signs of regeneration.

**Conclusion:** The diced cartilage glue graft may become an attractive alternative to accepted methods for dorsal augmentation, the diced cartilage fascia graft in particular.


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**The Quest for the Ideal**

The quest for the ideal method for augmenting the nasal dorsum has accompanied the development of rhinoplasty techniques since the early days of rhinoplasty and remains a matter of debate. Alloplastic materials, such as Silastic, expanded polytetrafluoroethylene, and porous polyethylene, have been used successfully for dorsal nasal implants and continue to be the material of choice for some surgeons. A meta-analysis on the use of alloplastic materials in rhinoplasty surgery concluded that reliable data for the choice of material are still missing, with an average failure rate of 3.1% for expanded polytetrafluoroethylene (GORE-TEX; W. L. Gore & Associates) and porous polyethylene (Medpor; Stryker) implants and 6.5% for Silastic implants. In a retrospective analysis of 685 GORE-TEX implants, with a follow-up of 1 to 17 years, a low complication rate of 1.9% and excellent long-term stability and biocompatibility were found. Conversely, histologic analysis of 122 explanted GORE-TEX implants that were explanted upon revision between 1 week and 13 years after insertion revealed calcifications of connective tissue in the pores of the implant and foreign body reactions with partial destruction of the implants. The authors concluded that GORE-TEX implants may not be as ideal as previously reported.

More recent trends in dorsal augmentation have strongly favored the use of autologous tissues, each having specific advantages and drawbacks. Optimal biocompatibility and a low risk of infection or extrusion are considered to be the decisive advantages of autologous tissue grafts that must be weighed against the disadvantages of available graft volume, shape, absorption, and donor site morbidity. Solid costal cartilage grafts have been used extensively for dorsal augmentation, but postoperative donor site pain, stiffness, and suboptimal shape of the graft and a high percentage of warping continue to be matters of concern. Homologous irradiated costal cartilage grafts have properties that come close to those of autologous rib grafts, obviate donor site morbidity, and have been proposed as a good alternative on the basis of favorable long-term outcomes in a large patient series. To control warping of costal cartilage en bloc grafts, laminating the cartilage, followed by reconstituting the vol-
By stacking the slices in an alternating orientation and fixation with sutures, has been proposed.\textsuperscript{10} Cyanocrylate glue has been used as an alternative to sutures for the fixation of rib cartilage slices in a porcine model but was found to induce a strong foreign body reaction, resulting in partial resorption of the graft.\textsuperscript{11} Homologous lyophilized bone has been used for dorsal augmentation. Radiographic cephalometry and fluorode positron emission tomography–computed tomography demonstrated neovascularization and patchy osteoneogenesis, with a median loss of projection of 13\% during the first 6 months after insertion.\textsuperscript{12} Processed fascia lata (Tutoplast; Tutogen Medical) has been successfully used for augmentation rhinoplasty.\textsuperscript{13} In a rabbit model, autologous fascia lata and Tutoplast–processed fascia lata showed negligible resorption rates after 6 months, with no significant difference in the degree of inflammation, fibroblast proliferation, and neovascularization. In contrast, autologous fascia and diced cartilage, but not dermis (AlloDerm; LifeCell Corp), had been found to have low resorption rates in rabbits.\textsuperscript{14} The degree of crushing of cartilage is known to have a strong effect on resorption rates, with intact or mildly crushed cartilage faring better in retrospective clinical\textsuperscript{15} and animal\textsuperscript{16} studies. Tutoplast–processed fascia lata had been used successfully in combination with diced cartilage with high patient satisfaction rates and predictable outcomes for dorsal augmentation.\textsuperscript{17}

Experience with diced cartilage dates back to the 1940s, and fusing of transplanted pieces onto a solid mass and the potential role of anatomic localization and the presence of a perichondrial sheeting in the recipient bed have since been reported.\textsuperscript{3} Diced cartilage, which is cleanly cut and not crushed, was known to have very good long-term viability since Young’s description in 1940. Peer first described the use of diced cartilage grafts in 1954. The use of diced cartilage received much attention after the publication\textsuperscript{8} of a large series of patients in whom diced cartilage wrapped in oxidized regenerated cellulose had been used for dorsal augmentation. However, the published impressive long-term success rates of this graft, named “Turkish delight,” were not reproduced by other authors.\textsuperscript{4,5,18-20} who suggested the use of autologous fascia and found clinical and histologic evidence of superior cartilage preservation if oxidized regenerated cellulose was replaced by autologous fascia—temporalis fascia in particular—because of the induction of a foreign body reaction with cartilage absorption by oxidized regenerated cellulose. Wrapping diced cartilage in hyaluronic acid was also found to improve cartilage survival compared with oxidized regenerated cellulose.\textsuperscript{21} Absorption of diced cartilage fascia grafts was found to be clinically insignificant, obviating the need for overcorrection.\textsuperscript{22} The potentially crucial role of the fascial sleeve for cartilage survival\textsuperscript{3} has been questioned recently by 2 studies\textsuperscript{23,24} comparing survival of solid block and diced cartilage wrapped in fascia in rabbits. The degree of resorption of the diced cartilage wrapped in fascia was found to be considerable compared with 1-piece block grafts, most likely because of histologic evidence of fibrosis and inflammatory cell infiltration. Despite these findings, the stability of diced cartilage fascia grafts is generally considered to be good when used for dorsal augmentation. In light of conflicting information on the ideal method of transplanting cartilage for dorsal augmentation and obvious drawbacks of harvesting fascia and preparing a sleeve for the diced cartilage, numerous attempts have been made to simplify the procedure. Autologous temporalis fascia has been replaced by AlloDerm.\textsuperscript{25} Diced cartilage has further been injected over a cartilage framework without a sleeve in cleft nose deformities with a follow-up of more than 6 months.\textsuperscript{26} Cartilage has been replaced by finely diced Medpor implant material wrapped in oxidized regenerated cellulose (Surgicel; Ethicon), and preliminary results were found to be encouraging.\textsuperscript{27} Cartilage dice have been bonded with autologous tissue glue created from platelet-rich plasma (platelet gel) and platelet-poor plasma (fibrin glue) and were injected with the glue into the recipient site.\textsuperscript{28} In that study, 68 patients were found to maintain the dorsal height without complications during a mean follow-up of 15 months. With the ongoing controversy on the optimal substance or scaffold for delivering diced cartilage, there have been calls for new studies.\textsuperscript{8}

This study reports on the morphometric outcome of a technique developed by the first author (A.-J.-T.) that was recently presented as the Tasman technique.\textsuperscript{29} To our knowledge, this is the first report of monitoring nasal dorsum cartilage augmentation by ultrasonography.

### METHODS

**The Diced Cartilage Glue Graft**

Autologous nasal septal, auricular, or costal cartilage pieces are set aside in 3 mg/mL of ciprofloxacin hydrochloride solution (undiluted Ciloxan eyedrops; Alcon Laboratories, Inc.). The antibiotic is known to diffuse into the cartilage, obviating the need for systemic antibiotics.\textsuperscript{8} The cartilage is then diced or cut into fine slivers as demonstrated in the video (http://www.jamafacial.com). A mold is prepared according to the desired shape of the graft, typically made from a 2-mL or 3-mL disposable syringe cut open. The diced cartilage is impregnated with the thrombin component of fibrin glue (Tisseel; Baxter International Inc). This 2-component fibrin sealant consists of virus-inactivated human thrombin and fibrinogen and bovine aprotinin as a fibrinolysis inhibitor; it has been used in Europe since 1972 and in the United States since Food and Drug Administration approval in 1998. Tisseel comes in a frozen 2-component mixture. One syringe contains the sealer proteins (fibrinogen, factor XIII, plasma fibronectin, and aprotinin) and the other syringe contains the thrombin and calcium chloride solution. After the solutions are mixed, a clot is formed similar to the end stage of clotting. Fibroblasts produce collagen and granulocytes slowly degrade the white elastic mass.

The thrombin component is less viscous than the fibrinogen component and is easily identified by a moving air bubble when tilting the syringe. A few drops of thrombin are added to the diced cartilage and allowed to lose volume by spreading on an absorbent surface or spontaneous evaporation. It is important to add the thrombin component first. The diced cartilage is then molded into the desired shape, and care is taken to eliminate any avoidable dead space between the cartilage fragments. These are then bonded by adding a few drops of the fibrinogen-containing component and compressing the graft with 2 fingertips, squeezing out excessive fibrinogen. The graft is then taken from the mold, and the opposite surface may be covered with fibrinogen without compressing the graft. The fingertips leave a ridge on the undersurface of the graft that is trimmed with fine scissors.
PATIENTS TREATED WITH THE DICED CARTILAGE GLUE GRAFT

Between 2009 and 2011, 28 patients have been treated with a diced cartilage glue (DCG) graft. The grafts were used to augment the full length of the nasal dorsum in 16 patients. In 22 patients, the DCG graft was inserted to correct an iatrogenic loss of dorsal height or a posttraumatic saddle nose deformity (Figure 1). In 12 patients, a partial augmentation of the dorsum was required (Figure 2); the DCG graft was used as a radix graft (Figure 3).

Figure 1. A patient with a posttraumatic saddle-nose deformity before (A and C) and 5 months after (B and D) dorsal augmentation. Because significant amounts of septal cartilage had been resected during a previous septoplasty, the diced cartilage glue graft was fashioned using remnants of septal cartilage and auricular cartilage from 1 ear using a 5-mL syringe as a mold (E [measured in centimeters] and F [measured against a Steri-Strip; 3M Nexcare]). The tapering of the graft at the cranial and caudal ends, the concavity of the posterior surface (E), and the convexity of the anterior surface (F) can be seen. Comparing sonographic cross sections of the graft at the sixth postoperative day (G) and 5 months after surgery (H) revealed a reduction in width by 2% and an increase in height by 6%.
in 4 of these patients. In 10 patients, DCG grafting was performed for a primary augmentation rhinoplasty.

Ten patients were available for sonographic morphometric follow-up from 5 to 15 months after surgery and were included in this study. Two of these patients underwent revision under local anesthesia for the correction of minor residual deformity (Figure 4), and the histologic characteristics of resected segments of the DCG graft were analyzed.

SONOGRAPHIC MORPHOMETRY

Sonographic cross sections of DCG grafts were obtained by the first author (A.-J.T.) during postoperative visits between 6 days and 15 months after the operation in the 10 patients included in this study. The method of noncontact sonomorphometry has been described. In brief, a high-resolution sonographic probe is coupled to the nasal dorsum with ultrasound gel filling the irregularly shaped gap between the curved nasal dorsum and the plain surface of the probe. The imaging plane was tilted off the axial plane at a right angle from the nasal dorsum (Figure 5). Individual sonographic landmarks and patterns from the previous scans were used to reproduce identical or very close anatomic planes. Images were analyzed by measuring width and height of the graft on the semiaxial scans with a resolution of 0.1 mm (GE Voluson E8 sonograph; GE Healthcare), with a linear 33.7-mm 7- to 18-MHz transducer (SP10-16-D; GE Healthcare).

HISTOLOGIC ANALYSIS

Two patients underwent revision for minor irregularities after 14 and 20 months, and fragments of the DCG graft were analyzed histologically by one of the authors (P.-A.D.). After fixation in buffered formalin, 4%, and paraffin embedding, slides were stained using hematoxylin-eosin, Alcian blue with periodic acid–Schiff, and Elastica-van Gieson. Immunohistochemical staining was performed with the proliferation marker MIB-1.

RESULTS

SIZES AND FEASIBILITY

Thickness of the grafts ranged from 2.0 mm to 10.1 mm in the midsagittal plane. The length of the grafts ranged from 7.2 mm to 37 mm. The time required to fashion the DCG grafts by impregnating the diced cartilage with thrombin solution, placing cartilage in the mold, adding the fibrinogen solution, and waiting for polymerization was less than 5 minutes in all patients. All grafts were sufficiently mechanically stable for insertion with a bayonet forceps.
FOLLOW-UP: PATIENT SATISFACTION, COMPLICATIONS, AND SONOGRAPHIC MORPHOMETRY

In 24 of the 28 patients treated with a DCG graft, clinical follow-up ranged from 6 to 22 months. Healing was uneventful in all patients. Minor irregularities at the cranial end of the graft were palpable but not visible and not bothersome to the patients in 15 cases. Five patients had visible irregularities that were, for 3 patients, too minor to require a revision and of concern in 2 patients who underwent revision under local anesthesia with subsequent histologic analysis of the trimmed DCG graft. Sonographic cross sections of all DCG grafts were echopenic or hypoechoic and could be well differentiated from the echogenic surrounding tissues (skin, the superficial musculoaponeurotic system, and bone) on sagittal and transverse sonographic sections. The echo pattern was finely granulated and slightly more echogenic than solid cartilage, which has a more echopenic to anechoic pattern. On all cross sections, graft width in the transverse plane and graft thickness in the transverse plane were measured with a 0.1-mm resolution, and changes in measurements were calculated (Table). Changes of cross-sectional measurements between follow-up assessments were documented. Between the first postoperative visit on the sixth postoperative day and the second visit after 3 to 5 months, corresponding measurements in 6 patients changed between 6% and –29% (median, –5%). Between the 3rd and 6th to 13th month after surgery, the changes ranged from 8% to –5% (median, –2%), and in a subsequent additional follow-up period of 4 to 9 months, the changes ranged from 2% to –7% (median, –3%).

HISTOLOGIC ANALYSIS

Histologic examination of DCG graft tissue 14 and 20 months after insertion revealed intact cut edges of the cartilage dices with no or minimal signs of absorption. The dices were embedded in a sleeve of fibrous connective tissue. All chondrocytes appeared to be vital, and formation of small clones consisting of clusters of more than 4 chondrocytes was seen, indicating cartilage regeneration.

COMMENT

The ideal tissue or material for dorsal augmentation has yet to be found. The diced cartilage fascia graft has gained widespread acceptance, with studies strongly suggesting that the cartilage survives well with or without a fascial sleeve. Harvesting of the fascia and sewing a recipient pocket for the diced cartilage adds time to the procedure and necessitates an extension of the procedure to the temple. Although the fascia was found to facilitate cartilage placement, holding the cartilage in place long term, its importance for cartilage survival has been questioned. If temporalis fascia may be helpful for the ease of handling the diced cartilage rather than a prerequisite for cartilage survival, alternatives, such as AlloDerm- or Tutoplast-processed fascia lata or hyaluronic acid membranes, may reduce operating time with equal long-term outcomes. Regardless of the material or tissue that is used for a sleeve, the graft will tend to acquire an oval or kidney-shaped cross section, depend-

Figure 3. A patient requesting correction of a posttraumatic septal deformity. Saddling of the cartilaginous dorsum and a nasal hump (A). Because the patient asked for a minor aesthetic improvement without osteotomies, the septum was rotated and the hump was camouflaged with a diced cartilage glue graft, molded in a 2-mL syringe (C), and placed on the periosteum of the radix (D). Four months after surgery (B), the graft measured 7.2×1.8 mm (E).
ing on the size of the sleeve and the degree of filling. This shape is not anatomic and may cause a visible depression between the transplant and the nasal dorsum as frequently seen in solid rib transplants. Camouflaging may be achieved with diced cartilage between the dorsum and the transplant, but this may add to the complexity of the procedure, reducing its predictability. An ideal transplant should therefore have a crescent-shaped cross section, which is difficult to obtain with a diced cartilage fascia graft and, more so, with a solid rib graft. In an early

Figure 4. A patient with an iatrogenic cartilaginous polybeak deformity and an overresected bony dorsum. Preoperative photographs (A and C). Revision included lowering of the cartilaginous dorsum and augmentation of the bony dorsum with a diced cartilage glue (DCG) graft (E and F). The postoperative photographs taken 15 months after revision (B and D) revealed an irregularity that sonographically could be attributed to the insufficiently tapered caudal end of the graft (asterisk on D, E, and F). Hematoxylin-eosin–stained (G) and Elastica-van Gieson–stained (H) sections of the shaved graft irregularity revealed vital cartilage with smooth contours embedded in sparse fibrous tissue. Vital cartilage with several small clones of regenerating chondrocytes showing basophilia (original magnification x100) (G). Groups of clones are evident in a red collagenous matrix (original magnification x200) (H). This form and chondrocyte clusters are indicative of cartilage regeneration.
report, the resorption rate of septal cartilage graft had been reported to range from 12% to 50%. It is now accepted that this variation may be the result of the degree of crushing, and cartilage survives well compared with other autologous tissues, even if transplanted without a sleeve. This suggests replacing the fascial sleeve by a binder holding the cartilage in place. A prerequisite for the concept of bonding is cartilage survival and graft stability without the resorption seen with oxymethylcellulose sheeting and acrylate glue. The successful use of autologous platelet gel and autologous fibrin glue for this purpose has recently been published. Autologous platelet gel is known to induce wound healing and may be beneficial for the survival of grafted cartilage, but some processing of patient blood is required. Commercially available 2-component fibrin glue is readily available in most clinical settings. The reduction in operating time may more than compensate for the cost of the fibrin glue.

Can fibrin glue be expected to sustain cartilage viability and graft stability? Fibrin as a scaffold for cartilage tissue engineering has received some attention in recent years, with the subsequently cited studies commenting favorably on chondrocyte viability in different fibrin-based carriers both in vitro and in vivo. Earlier cell culture studies using fibrin had shown that chondrocytes proliferate well and produce extracellular matrix components, such as glycosaminoglycans and collagen type II. Chondrocyte proliferation and cartilaginous tissue formation with development of cartilage-specific extracellular matrix components, glycosaminoglycans, and collagen type II increased up to 5-fold, with excellent chondrocyte viability if fibrin was added to hybrid scaffolds. Long-term stable fibrin gels in combination with polyglycolic acid scaffolds were therefore suggested as an interesting option for generating cartilaginous tissue for use in reconstructive surgery. However, an attempt to induce clinically relevant volumes of neocartilage through chondrogenesis by injecting chondrocytes in a fibrin glue carrier was not uniformly successful. The viability of diced cartilage may be improved by adding adipose-derived stem cells. A similar method for the repair of articular cartilage was developed and marketed by Zim-

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Table. Percentage Change of Height and Width of the Diced Cartilage Glue Graft on Sonographic Cross Sections

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Postoperative Change in Sonomorphometric Measurements at Each Follow-up Assessment, % (Postoperative Month)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 d to 2 mo</td>
</tr>
<tr>
<td>1</td>
<td>-29 (5)</td>
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<tr>
<td>2</td>
<td>-5 (3)</td>
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<tr>
<td>3</td>
<td>-2 (6)</td>
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<tr>
<td>4</td>
<td>-2 (6)</td>
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<tr>
<td>5</td>
<td>6 (5)</td>
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<tr>
<td>6</td>
<td>-16 (4)</td>
</tr>
<tr>
<td>Median (range)</td>
<td>-5 (~29 to 6)</td>
</tr>
</tbody>
</table>

**Patients 1 through 6 were available for a first sonographic assessment 6 days after surgery and postoperatively after 3 to 6 months. For patients 7 through 10, the first postoperative visit was after 3 months, with subsequent measurements after 6 to 14 months. Of these, 3 patients came for additional visits after 14 to 16 months.**

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Figure 5. Technique of noncontact sonography. Sonography gel provides acoustic coupling of the straight transducer surface to the curved nasal surface (A). The corresponding sonographic cross section (B) allows identification of the crescent-shaped diced cartilage glue graft (a), the dorsal skin and soft-tissue envelope (b), and the bony dorsum (c), with gel (d) connecting the probe to the nasal dorsum.
In light of this experimental evidence, the good overall survival of the DCG grafts in this study as demonstrated by sonographic morphometry and histologic examination was expected. However, the fate of the varying volumes of fibrin glue added to the diced cartilage in the patient series reported in this article was unclear, with potential complete absorption, transforming into fibrous tissue or cartilage. The largest reductions in sonographic cross sections were seen in an early patient (patient 1), in whom proportionally more fibrin glue was used, whereas excess glue was more rigorously squeezed out of the graft in later patients. Some shrinking of the grafts was seen in all patients between the sixth postoperative day and the second postoperative visit after 3 to 6 months, indicating some absorption of the glue component of the graft. The stability of all grafts between the 3rd and 15th postoperative month indicates that this process takes place only during the early postoperative phase. Histologic examination of 2 graft biopsies harvested 14 and 20 months after the procedure congruently showed sparse fibrous tissue with no traces of the fibrin glue. The DCG graft may therefore be very versatile, with good long-term stability for augmentation of the whole nasal dorsum or parts of it, such as the supratip area or the radix. The DCG graft may also prove to be suitable for augmentation and camouflaging in other anatomic areas of the face.

Several limitations of the DCG graft and the conclusions of this study deserve to be highlighted. First, because of its fragility, the graft is suitable only for augmentation. This, however, is also true for the diced cartilage fascia graft. An important technical aspect is the need for wide surgical access to the recipient bed with a pocket large enough to accommodate the graft without compression by the inserting instrument. An endonasal approach was used for the vast majority of cases treated by the first author (A.-J.T.), reflecting his personal strong preference for endonasal techniques because they were found to provide sufficient access to the dorsum. Of note, squeezing out excess fibrin glue during polymerization makes the graft firm enough to withstand gentle compression by the inserting forceps in contrast to the very soft but solid silicone rubber consistency reported recently. Second, migration of cartilage fragments from the edge of the graft is a potential drawback. Patients have been monitored for migration, but it has not been observed thus far. Third, we report on a small group of patients who were followed up clinically and morphometrically for a short time. Evidence of longevity of DCG grafts is therefore limited. Still, the impressive clinical stability and maintenance of cross-sectional measures of the grafts followed up with sonography speaks in favor of long-term survival. The histologic characteristics of the DCG graft more than 1 year after transplantation are in agreement with this assumption.

In conclusion, the DCG graft has become the method of choice for partial or complete augmentation of the nasal dorsum in our institution. The superior variability of shapes and sizes makes the DCG graft suitable for a wide range of nasal dorsal volume deficits. The clinical outcome has to date been very promising, and published results and the feedback from fellow surgeons from other institutions using the method have been positive.

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