The Use of Costal Cartilage in Rhinoplasty

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KEYWORDS

• Rib cartilage • Autologous rib • Cartilage grafting • Revision rhinoplasty reconstruction
• Carving rib cartilage

KEY POINTS

- Autologous rib cartilage can be safely harvested in both male and female patients.
- Rib cartilage harvest is integral to cartilage grafting in revision rhinoplasty cases as it provides adequate quantity of cartilage.
- Rib cartilage can be easily created into grafts for nasal reconstruction.

Video content accompanies this article at http://www.facialplastic.theclinics.com.

PANEL DISCUSSION

Harvest Site/Technique?
Do you perform partial harvest of rib cartilage?
Which are your indications in Primary Rhinoplasty?
What Instruments do you use?
What Cartilage Carving techniques do you use and why?
How have your techniques in this area changed over the last 2 y?

QUESTION 1. HARVEST SITE/TECHNIQUE
Fedok

I have been harvesting costal cartilage for grafting material since the early 90s. Initially, I was doing larger harvests for microtia reconstructions. In those cases, a sizable amount of rib was removed from several ribs. Not infrequently this harvest caused a relative deformity in the area and the harvest was made through a larger incision.

My harvest of rib cartilage for rhinoplasty started out in the same time frame. This was relatively easier than the harvest for microtia. It could be done through a significantly smaller incision. It caused less pain and less of a resultant chest wall deformity. In my practice, the harvesting of costal cartilage for rhinoplasty was frequently for the management of post-traumatic deformity, after severe infection, or post-cancer surgery situations. The rhinoplasty patients were primarily being treated for saddle nose deformity, and those with a significant absence of midline septal support. In these situations, large dorsal grafts were placed to manage those rhinoplasty reconstructive challenges. The noses that were engaged in this fashion were largely those with severe deformity. Thus, most the time the complete cross section of rib was removed to create sizable midline dorsal grafts and central nasal support.

Initially, there was little finesse in these procedures. Larger incisions were made, and the harvest was performed using more traditional rib instruments, such as the Doyen elevator and Matson-Alexander elevators. Typically, the cartilaginous

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rib was removed in its entirety, sometimes going beyond the bony-cartilaginous junction of the rib to harvest a composite graft. The majority of time the perichondrium was stripped on the deep side to limit the potential for violation of the chest cavity. Patients were frequently admitted to the hospital and placed on patient-administered pain pumps to manage the chest wall discomfort after removing the costal cartilage in this manner.

Over time, my harvest technique for obtaining costal cartilage for rhinoplasty has become a more limited endeavor. In general, because I am a right-handed surgeon, I harvest rib from the patient's right side of the chest. The goal is always to obtain an adequate amount of rib cartilage to obtain a sufficient quantity of cartilage grafting material while maintaining the esthetics of the patient's chest wall, whether or not the patient is male or a female.

I design the chest incision at a level and direction that is consistent with the patients relaxed skin tension lines on the chest wall and to take advantage of the inframammary crease where possible. The goal is usually to harvest portions of the sixth rib. The length of the incision depends on the patient's size and amount of subcutaneous fat over the chest wall where the graft harvest is anticipated. In a young thin female where there is less than 1 to 2 cm of overlying of soft tissue between the surface of the skin and the rib, a very small incision is possible that is, 2 cm or less. In the larger, heavier patient where literally one may have to dissect through 5 or 6 cm of adipose to get to the level of the rib, a larger incision is necessary. The incision may even extend to 4 cm or more in length. Skin retraction will be necessary, and some modification of the incision placement may be necessary in larger patients.

Modifications of technique I now use for the rib harvest is a compilation of advice I have received from colleagues over the years. Through their advice, I have learned the utility of retracting the incision and moving its location over several positions on the chest wall. Even a very small incision can be retracted back and forth over the chest wall to get access to different portions of the target rib.[1]

Another adaptation that I have utilized in harvesting rib cartilage was obtained through observation and discussion with thoracic surgeon colleagues. By performing the rib harvest via a "muscle sparing" technique, the patient experiences less incisional harvest pain.[1]

I make my skin incision with either 10 or 15 scalpels. The length of the incision depends on patient characteristics as I mentioned earlier. I will use the bovie electrocautery and blunt dissection to progress through the subcutaneous adipose. I will proceed through Scarpa's fascia in the same manner. At the level of the deep fascia, over the rectus abdominis or external oblique muscles, I will bluntly spread through the fascia and the muscle with a hemostat. Dissection proceeds in the direction of the muscle fibers to minimize trauma to the muscle until the rib periosteum is encountered. Utilizing retractors, one is able to keep the soft tissue out of the way and visualize the perichondrium over the rib. With careful retraction with the use of army-navy and/or Senne retractors, we are able to visualize the whole area of the rib and perichondrium we want to harvest while maintaining the smaller incision.

The instruments I use currently are smaller instruments than what I used in the past. The instruments I commonly use include a 10 or 5 scalpel, an Army-and-Navy retractor, Senne retractor, Freer elevator, and Adson and Cobb elevators. Rarely will I use a Doyen retractor.

My harvest technique continues in the answer to question #2.

Peng

I like to make a very small 1 cm, well placed and hidden incision for rib cartilage harvest. In the preoperative area, with the patient sitting up and facing me, I mark out the inframammary or infrapectoral crease as well as the xiphoid notch (**Fig. 1**). If the patient has larger breasts or pectoralis muscle, I have them hold up the breast/muscle so that I can see the crease. The incision lies within this marked crease, but the placement is finalized once the patient is supine on the operating room table.

With the patient supine, the crease can be easily seen and the incision is marked so that it is medial to the nipple line and approximately 6 to 10 cm from the midline xiphoid marking. I like to prep out the entire chest so that both sides are showing. Many of my female patients have breast implants it allows me to have constant comparison between the 2 sides. The small incision will become a small mobile incision. The goal is to shift the incision so that the small incision can cover a larger area underneath. Younger patients will have tighter skin. The concept of rib cartilage harvest can be likened to that of an inverse funnel (**Fig. 2**).

To get oriented, you have the skin at the top. The second layer is the subcutaneous and fatty tissue. The third layer is Scarpa's fascia which often looks as if it could be the fascia overlying the muscle but in many patients, there is additional, fatty tissue under this layer. The next layer is the true rectus or pectoralis fascia, underneath

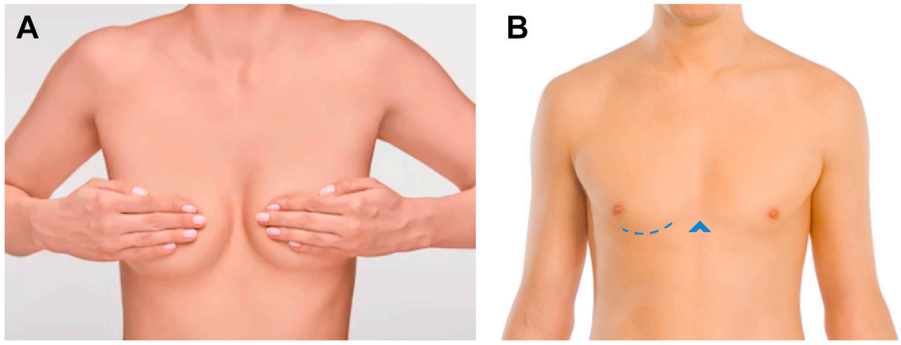

Fig. 1. Marking the inframammary crease and the xiphoid notch with the patient sitting up for the (*A*) female patient and (*B*) male patient. The *blue line* depicts where the inframmary crease is typically located.

which is the muscle. Immediately under the muscle is the rib with the anterior surface of the perichondrium (**Fig. 3**).

I usually make a 1 cm incision and dissect wider at each layer. I then shift the upper layers to allow for maximal exposure at the rib. The 2 landmarks I always look for are the synchondrosis and the bony cartilaginous junction. The incision is placed so that at the extent of the widest dissection the lateral edge is at the bony cartilaginous junction. Usually I am harvesting the sixth rib.

Once I am down to the rib, instead of the traditional H cuts in the perichondrium, I first incise a rectangle, and then make perpendicular cuts to the superior and inferior edge (**Fig. 4**). This way the piece of perichondrium can be used later at the tip or along the dorsum. I dissect the perichondrium off to expose the rib cartilage so that it can be removed en bloc.

Once I have identified the bony cartilaginous junction, I cut through it on the cartilage side with a 15-blade. Then, the focus becomes at the synchondrosis where I elevate with the cottle slightly beneath the rib cartilage and cut through with the 15-blade until I make it through the entire synchondrosis. Once I reach the medial end of the dissection, a cut is made similar to the cut at the bony cartilaginous junction. The superior edge of the rib is dissected free from the posterior perichondrium as is the inferior aspect. The rib is then able to be gently lifted from the posterior aspect.

Once the rib is removed, I always check for any tears and confirm that there are neither leaks nor tears by doing 3 valsava maneuvers to 40 mm Hg.

Finally, it is important to close with maximal eversion at all the layers. I first close the muscle and the fascia together so that the sutures do not rip through the muscle using a 3-0 PDS running locking suture. I close Scarpa's with a 3-0 monocryl. I then close the deep dermal layer with a 4-0 monocryl and a running subcuticular with a 4-0 monocryl.

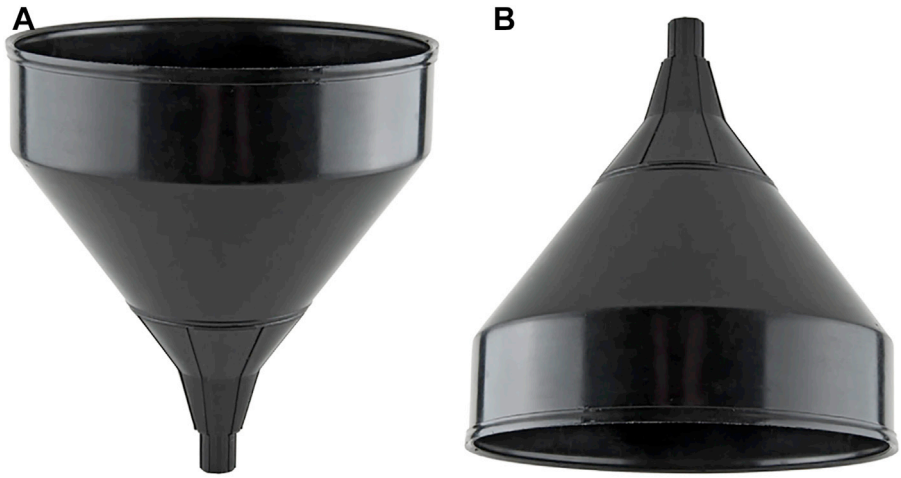

Fig. 2. The concept of rib cartilage harvest through a tiny incision is like that of an inverse funnel. A funnel has a larger opening on top with a small opening on bottom (*A*). An inverse funnel as a small opening on top and a larger, wider opening on the bottom (*B*).

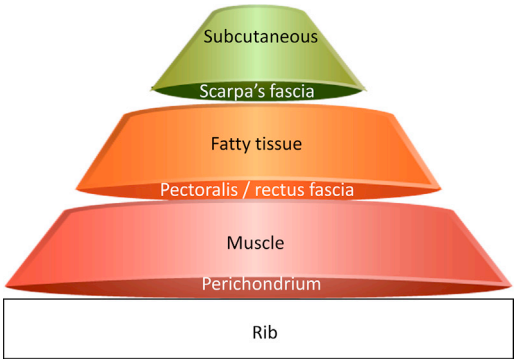

Fig. 3. The schematic of layers when you approach the "inverse funnel" for rib cartilage harvest.

At this time of this writing, I have personally performed over 1100 cases in the last 9 years. The average time is about 36 minutes. The rib lengths range from 2.5 to 6.8 cm and on average is about 4.5 cm.

Overall, rib cartilage can be easily and safely harvested as a reliable source of cartilage in rhinoplasty.

Tastan

Rib cartilage is frequently used by rhinoplasty surgeons in secondary rhinoplasties. Surgeons may be hesitant to harvest and carve rib cartilage because of the risks like pneumothorax, warping problems, scar, and postoperative pain. Surgeons need to be familiar with harvesting and carving of rib cartilage using the appropriate surgical tools and technique.

I always start the surgery with rhinoplasty dissection. I determine the required cartilage graft dimensions and volume, and then proceed to harvest the cartilage graft. Costosternal junction of the seventh rib and costal arch of seventh rib are palpated and marked. Between the sixth and seventh ribs, a 1.5 to 2 cm incision line is located, starting approximately 9 cm laterally from the costosternal junction and extending from lateral to medial. Since medial retraction of tissues is typically easier than lateral retraction at this region, the incision is started from the lateral end of the planned rib harvesting segment. In female patients, it is aesthetically preferred to place the incision along the inframammary crease as much as possible. If inframammarian approach is preferred, as it is relatively far from the target, 25% longer incision is advised. The lateral edge of the incision line which is 5 mm superior to the inframammary crease should align vertically with the lateral end of the planned incision line between the sixth and seventh ribs.

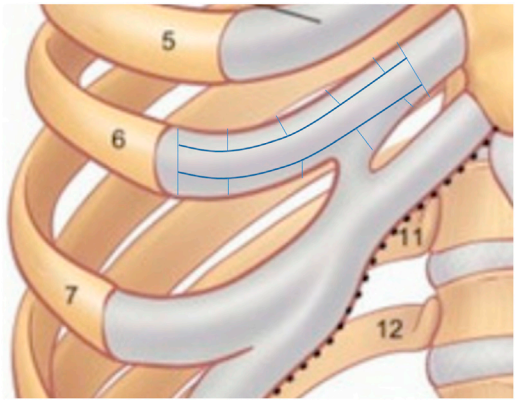

Fig. 4. Anterior rib perichondrium preserving technique while dissecting the rib cartilage from the posterior perichiondrium. Instead of the traditional H cuts, a rectangle is first incised into the perichondrium.

Incision size is often a matter of debate; from the surgeon's point of view, we need enough exposure to the surgical field and enough opening for to take the rib out, from the patient's point of view smaller and even invisible scar. When planning the length of the incision, it is critical to use the smallest incision feasible to ensure surgical exposure, permit rib harvesting, and minimum trauma to the wound edges. To have a better scar, it is necessary to avoid trauma to the wound edges. As the length of incision decreases, the amount of trauma increases. A full rib segment cannot be removed through an incision less than 1 cm. Tissue trauma increases with an incision less than 1.5 cm. If the incision is placed correctly, an incision longer than 3 cm seems unnecessary and usually does not provide additional exposure.

Bimanual working under binocular vision provides best control at the surgical field for to prevent complications. Endoscope is useful only for educational purposes.

The area is infiltrated with 4 cc of local anesthesia (1% lidocaine with 1:100,000 epinephrine), 10 to 15 minutes prior to the incision. After making the incision with a number 15 blade, dissection is carried down to the muscle fascia with a blunt tip scissor. Anterior surface of the fascia is exposed widely, and fascia incision is made with monopolar cautery between the sixth and seventh ribs extending approximately 6 to 8 cm medially. Then, blunt dissection that is parallel to the muscle fibers is performed at the lateral edge of the rib segment, so the anterior surface of the rib is exposed through a window between the intact muscle fibers. Another window opened 3 to 4 cm medially to the first one and the muscle layer is elevated from the anterior surface of the seventh

rib like a muscle bridge. The preservation of muscle fibers is important as it will be helpful to lessen postoperative pain. A wide dissection plane is performed just anterior to the rib perichondrium so the whole rib segment surface is exposed and examined for the cartilage quality and dimensions. If the dimensions are not satisfactory, the neighboring sixth rib can easily be exposed and checked for an available segment.

I usually prefer to harvest the seventh rib, and if it is not suitable, then I harvest the sixth rib. The main differences between the sixth and seventh ribs are based on their anatomic features. The seventh rib has a narrower anteroposterior diameter but a longer, straighter segment. Posteriorly, it is mostly in relation to the abdomen, which makes it safer to harvest and allows for easier dissection since it is relatively mobile. On the other hand, the sixth rib is comparatively shorter but still offers enough length and has a thicker section. The sixth rib is adjacent to the pleura at its posterior border, requiring meticulous dissection.

I plan the perichondrial incision based on whether we need a perichondrial graft or not. If perichondrium is needed as a graft material, it is dissected from the whole anterior surface of the rib segment and the remaining perichondrium is carefully dissected from the inferior and superior borders of the rib without forcing to dissect the posterior surface of the perichondrium. If perichondrium resection is not planned as a graft material, then a longitudinal incision is performed that is 1 cm longer than the medial and lateral edges of the required rib segment.

I am using the "Oblique Split Method" (OSM) as a carving method, so the lateral incision is placed obliquely to provide a longer cross-sectional surface.[2] The rib segment needs to be taken as long as possible because ossification areas or other problems decreasing the cartilage quality can be present. The segment that includes the synchondrosis region has a narrow anteroposterior diameter, which is more appropriate for lateral crural reconstruction and produces more predictable results when modifying the straight OSM graft into a slightly curved one for alar wall support.

The segment to be harvested as a graft is precisely cut using an angled saw at the medial and lateral ends. I use "Tastan saw" that was designed specifically for rib harvesting. The purpose of this specially manufactured tool is to enable controlled incisions using the sensory feedback and pressure sensation in our fingertips, similar to the other saws I designed for use in nasal osteotomies (medial, transverse, and lateral nasal osteotomy microsaws) (**Fig. 5**A–D). Additionally, it is particularly helpful when separating the synchondrosis

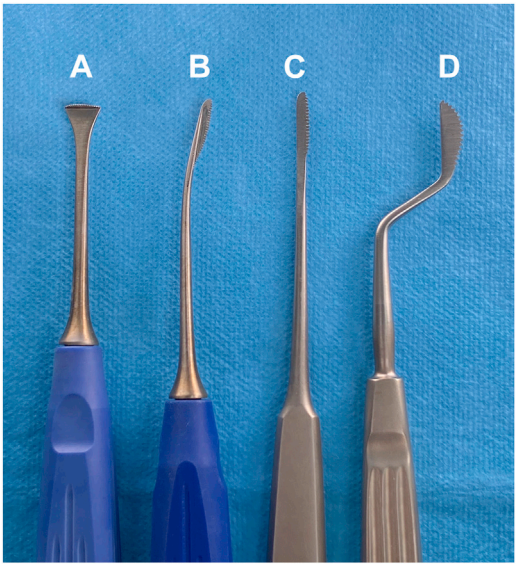

Fig. 5. Tastan saws used for (*A*) Transverse osteotomy, (*B*) Lateral osteotomy, (*C*) Medial osteotomy, and (*D*) Rib harvesting.

regions or when there are ossifications that are hard to cut with a scalpel. Starting rib incision with gentle pressure will allow the teeth to bury themselves in the cartilage tissue, and the incision will be made using back and forth movements. Once the cut is about halfway done, proceed with greater caution and progress in parallel movements with the anterior rib surface until you reach the posterior perichondrium. After both ends are released, the cartilage graft becomes relatively more mobile, making the elevation of the posterior perichondrium easier and safer due to the absence of rib cartilage stability. A blunt tipped, specially designed elevator made of harder steel, which does not bend, is used for the elevation of the posterior perichondrium. In order to reduce the risk of pneumothorax, the aim is therefore to perform posterior perichondrial dissection with less resistance.

The surgical field is filled with saline solution and positive pressure is applied to check pneumothorax (Video 1). Since I do not use a drain, hemostasis should be done carefully. The proper suturing technique is used to repair the perichondrium (4/0 Polydioxanone), muscular fascia (4/0 Polydioxanone), subcutaneous layer (4/0 Polydioxanone), and skin (subcuticular running, 5/0 poliglecaprone 25). The area of the wound is covered with pressure dressing for 3 days. In postoperative follow-up, if you notice any seroma collection, aspirate with an 18-G needle and continue pressure dressing for a few more days.

Robotti

In women, I invariably use an inframammary incision for harvesting rib. Since several years, I moved from the initial concept of looking for the best rib to the decision of always going exactly along the inframammary fold (IMF), then adapting rib selection and exposure to this prerequisite: a least visible access.[3–5] (**Fig. 6**) My technique has essentially been progressively modified from that described by Jack Gunter in 2008.[6] Preliminary palpation will allow the choice of the rib best suited for harvest, corresponding, superior, or inferior to such incision. From personal observation and repeated experience in about 110 to 120 cases per year, I developed and use the following parameters for marking: a vertical line tangential to the medial edge of the areola and carried to the IMF will correspond to the junction between bony and cartilaginous portion of the rib. From that point, the incision is marked extending medially for 2.5 to 3 cm exactly on the fold (**Fig. 7**). It doesn't matter to me which rib that will be: usually it is 5 or 6, depending on the specific anatomy of the rib cage. When a breast implant has been previously placed through the IMF, I will use the same incision, although I usually must extend it a little more medially. My scar will be around 3 cm or even 4 cm on some occasions in heavier patients, but it will hardly be noticeable, especially if 1 or 2 mm of skin at the edges is taken out with a serrated fine scissor at skin closure. This is in fact the portion of skin subject to traction and contusion, and thus more prone to scarring. I understand the benefit of an alternative minimal incision to harvest the seventh rib lower on the chest wall with the additional advantage of preventing the risk of pleural injury, as championed by Toriumi,[7] but, in my perspective, (a) pleural injury should not be a problem if one uses careful technique in harvesting under direct vision, and (b) using such a small access incision will mean considerable traction with retractors as well as a less predictable harvest of the rib segment in continuity with its perichondrium. Such traction may translate in a whitish and wide scar patch, albeit short. The essence is that I want my scar exactly in the IMF. In men, I will look for a native fold in approximately the same position as the IMF in women. In many male patients, especially when you ask them to stand in front of you and relax their posture, you will identify a useable skin crease, and this is where I will place my incision.

Regarding any analysis or diagnostic tool that could address my choice of which rib to take, I do not really find much reason to use any of the multiple described methods, such as walking the needle through the skin to assess calcifications (I actually find this maneuver somewhat perilous) or assessing the correct rib by ultrasound or even by a computed tomography scan. I find these methods unnecessary since I will still go on whatever appropriate rib I find at a reasonable distance from the incision at the fold. Sometimes, this rib will be relatively straight and other times more curved, but I will still use it and then, obviously, laminate it differently. Of course, the rationale of a pre-op analysis is to detect calcifications, but if there are calcifications, they will usually be multiple and essentially unavoidable. My current thinking, stemming from experience, is that they are not necessarily related to the patient's age, at least to a certain degree, while possibly they could be related to the individual's metabolic and nutritional status. If I find calcifications, I will section the rib differently and, in some rare cases, even use a thin-bladed Piezo insert.[8] Calcifications may even become an asset if I want an adequate structure for my L-strut segments. The opposite will hold if I need rib for thin lateral crura struts in rebuilding my lower lateral cartilages. Then, I will try to avoid obviously calcified areas. In those instances, I will also often use composite techniques, in which that part of tip reconstruction is done by the limited quantity of available septum left.

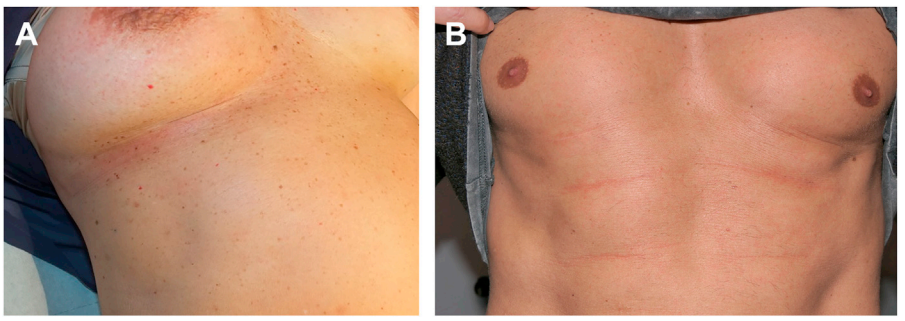

Fig. 6. (*A, B*) The scar following rib harvest at the inframammary fold is usually hardly visible.

Fig. 7. The markings for where to place the incision for rib harvesting are demonstrated.

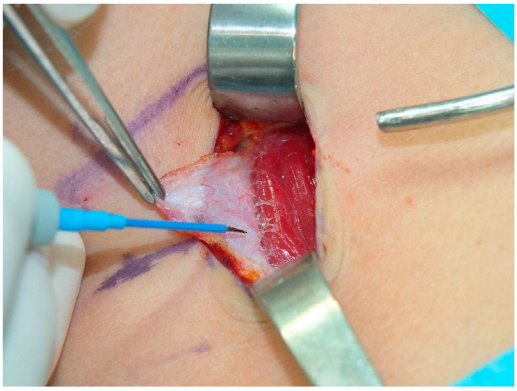

Fig. 8. The rectus muscle is separated along the direction of its fibers to allow rib harvesting, and it is not transected. This essentially respects its integrity.

Technique

After incising dermis and fat, the superficial fascia becomes visible, and I mark it with methylene blue so as to facilitate its later suturing as a separate layer (Video 2). The fat below is readily visualized, and then, with a sweeping motion of a wide, sharp-edged elevator, the rectus fascia is exposed. This dissection is limited to the planned portion of rectus fascia harvest, as described by Cerkes,[9] in the frequent scenario when rectus fascia is needed later for the sandwich of perichondrium and fascia (SPF)-sandwich of perichondrium, rib lamination, and fascia (SPLF) construct. Usually, a 3 × 3 cm segment of rectus fascia is carefully elevated off the underlying rectus muscle by the use of a fine Bovie tip (**Fig. 8**). The fascia is then cleaned of residual muscle fibers, pinned to a silicone block, set aside for later use, and moistened under wet sponges. At this point, bipolar cautery is used to pre-cauterize some rectus muscle fibers along their direction (thus, almost perpendicularly to the skin incision). A gentle spreading motion then allows separation of the muscle without transecting its fibers, and easy subsequent exposure of the chosen rib segment. A full-thickness segment of rib, usually measuring between 3 and 4 cm, is harvested. The anterior perichondrium is left attached, while the posterior perichondrium remains on the chest wall. Specific, small right and left rib elevators, personally developed for this purpose (Marina Medical Instruments, West State Road 84 Davie, Florida, US), are used to carefully separate the harvested rib segment from its posterior perichondrium, while the previously used wide sharp-edged elevator or a thin, straight osteotome usually allows division of the rib medially, just away from the bony junction, as well as laterally. The same instrument will allow transection of synchondroses with adjacent ribs. As described by Gerbault,[8] Piezo can find an indication in the infrequent presence of voluminous calcifications that resist transection by the aforesaid instruments. Residual, sharp, palpable, edges at the periphery of the harvested rib segment are then softened by the use of a double-action rongeur. Then, the wound is filled with saline and a Valsalva maneuver performed by the anesthesiologist so as to confirm pleural integrity. Finally, closure is done in independent layers. A total of 7 to 8 mg of ropivacaine (Naropine) is instilled in the wound through a large-bore IV cannula which had been previously positioned in the residual cavity below the muscle repair, the needle is withdrawn, and the catheter is taped to the skin.[3] The excised rib segment is placed over a soft cutting block on a side table, and its anterior perichondrium is peeled off by a large elevator. Then, lamination begins by the use of a hair transplant blade, as will be described later.

As a final note, I find it interesting that patients invariably have quite little pain following rib harvest. I believe that this occurs because, when employing the technique described earlier, the rectus muscle is not split transversally or cauterized, but is essentially gently separated along its fibers, and then simply resutured (see **Fig. 8**). I find no reason to use pain pumps or other strong analgesics. We use

an IV catheter which is placed at the end of surgery with around 7 or 8 mL of Naropine instilled, with the same dosage repeated the following morning before the catheter is removed at discharge.

QUESTION 2: DO YOU PERFORM A FULL CROSS SECTION OR PARTIAL HARVEST OF RIB CARTILAGE?

Fedok

I usually perform a partial harvest of the rib. To further clarify, I usually allow a portion of the rib, usually along the inferior medial segment to remain in continuity. I do this because it allows me to procure a sufficient amount of rib cartilage to create the appropriate number of grafts, I need to complete a successful rhinoplasty. In addition, because it limits movement of the chest wall, and coupled with the muscle sparing technique, it eliminates much of the chest wall pain for the patient. In fact, in cases where I have had the need to harvest both ear cartilage and rib cartilage, the patient frequently has found the ear to be more painful than his chest wall. If I need a full thickness amount to be harvested to complete my rhinoplasty tasks, I will remove the rest of the cartilage. I leave the posterior perichondrium down. After retrieving the costal cartilage segment, the wound bed is flooded with saline, and the patient undergoes a Valsalva maneuver to confirm the integrity of the parietal pleura.

Occasionally, I will remove the whole cross section of the rib, particularly when I am preparing a large graft for a dorsal replacement of a severe saddle nose deformity, and loss of structural cartilage.

This technique is easier in the younger patient with softer cartilage, where I can actually harvest the graft after cutting through the rib cartilage, on an angle, with a Freer elevator.

Peng

I always perform a full, en bloc harvest of the rib cartilage. I make sure that the dissection down to the rib cartilage allows for adequate exposure and visualization of the bony cartilaginous junction as well as the synchondrosis. With careful dissection of the superior and inferior edges of the perichondrium, I am able to remove the rib without any issues. I always perform 3 Valsalva maneuvers up to 40 mm Hg to confirm that there are no leaks and no violation of the posterior perichondrium.

Tastan

I perform a full cross-section harvest of rib segment because I am using the OSM for carving the rib grafts. As stated in the OSM, the graft obtained from the cross-sectional surface of the rib is in balance in terms of the effecting forces. During partial harvesting of a layer from the anterior surface of the rib, there may be microfractures in the cartilage tissue and may damage the equilibrium of forces. I use the peripheral layer of the rib in onlay tip grafting to support the external nasal valve, for alar rim grafting, or for diced cartilage grafts.

It is better to keep in mind that the structural characteristics of rib cartilage may vary from patient to patient. For example, if there are gaps in the cartilage, the details of carving have to change accordingly (Video 3).

Robotti

The answer to this is never. I don't really understand why this should be done. If the decision is taken to harvest the rib, one should gain the maximum advantage. This means taking a full-thickness portion of rib from which (a) multiple laminations can be derived of different thickness length so as to provide an ample manual of choice, (b) perichondrium can be harvested along the anterior surface, usually for my SPF-SPLF construct[10] (c) the white peripheral portion can be used for deriving a plaster-like substance which we denominated "rib plaster" and which is, once one tries it clinically, immediately, and evidently superior to diced cartilage.[11]

The prerequisite thus becomes having enough material to do what is needed, regarding rebuilding the L-strut in its vertical and horizontal components as well as fashioning lateral crura struts for the tip, using perichondrium for dorsal camouflage or as an ingredient of the SPF-SPLF graft and, not least, having further substance from which to derive "rib plaster". If one performs a partial harvest, be it in a wedge shape or by bisecting the rib anteriorly, one may feel that the approach is safer regarding a possible pneumothorax, but this carries a substantial limitation since one will end up with a few segments which may not be optimal or may not be enough. Specifically regarding the risk of pneumothorax, I think it can be avoided entirely (no instances in all my experience so far) by careful technique, as I detailed earlier. Finally, if one would do a partial rib harvest, the initial steps needed for exposure and the donor site closure would be essentially the same. Not much to be gained, and quite a lot to be lost for a little extra security.

QUESTION 3: WHAT ARE YOUR INDICATIONS IN PRIMARY RHINOPLASTY

Fedok

My indications for the use of rib grafting in primary rhinoplasty are quite limited. The patients where I

would decide to use rib cartilage as the source of donor material are those patients who will require a large amount of cartilage grafting. In addition, it is anticipated that the amount necessary will be beyond what is reasonable to be able to be harvested from their septum and ears. These situations include patients who have suffered a loss in the amount of septal cartilage available because of previous septoplasty, septal perforation, and infection. They may present with saddle nose deformity. If patients have had previous trauma or a severely deviated septum, the septal deformity may preclude the use of septal cartilage, so that another source is necessary. Patients with variations of Binder syndrome or other growth disturbance may prevent there to be an adequate amount of septal cartilage. In some patients of Asian derivation or with markedly platyrrhine noses, there may be insufficient donor sources except for the rib.

In summary, patient who presents with nasal anatomy that requires a large amount of cartilage grafting to be performed, and presentswithout a sufficient amount of septal or ear donor material, I will go immediately to the chess wall. In this way, I prevent harvesting inadequate amounts of grafting materials from the septum and ears and then encountering problems during the procedure.

Peng

I will often use rib cartilage during a primary rhinoplasty when there is insufficient cartilage from the septum itself such as.

- Smaller native septal cartilage as often is the case in Asian, Black, or Hispanic noses
- Need for dorsal augmentation during which I will dice the cartilage very finely and use fibrin glue in order to make a dorsal onlay graft (**Fig. 9**)
- Need to multiple grafts for nasal reconstruction such as internal and external nasal valve collapse or need for a strong caudal septal extension graft

Tastan

The primary reason for using rib cartilage in primary rhinoplasty is the depletion of cartilage. The following patient groups are candidates for rib cartilage grafting: septoplasty or severe trauma history, caudal septum depleted patients, severely crooked nose, short nose, saddle nose, ethnic nose, patients having thick skin and weak cartilage, etc. Also, patients having dynamic alar collapse are prone to have graft material that is inadequate in dimension and resistance.

Fig. 9. Dorsal onlay graft made with ultra-finely diced cartilage with droplets of fibrin glue.

Even though there may be certain indications for rib cartilage harvesting, sometimes predicting this can be challenging. When in doubt, informing the patient about it will help you feel more comfortable during the surgery if you need rib cartilage.

Robotti

Currently, practically none. I touched briefly on this when answering some questions in the other section of this Clinics issue regarding the management of the middle vault in primary rhinoplasty. The reason is my progressive adoption, however, with several modifications, of preservation techniques in managing the dorsum. Even in asymmetric midvaults I can still "play" by preserving the dorsal keystone area (DKA) by my modified dorsal-split cartilaginous pushdown or full letdown approach.[12] If I still need grafting at that point, it would be for very small spreader/s to even out asymmetries between the 2 sides, which will be placed in a pedestal fashion between the upper laterals and the septal border of the septal T. Most patients have far enough cartilage for this. Another important fact is that, since I have adopted the use of long Piezo inserts for harvesting a single piece of septum, usually in a composite fashion, including a portion of the quadrangular plate and perpendicular plate of ethmoid, while

leaving a proper L-strut, I use my harvested septum productively, without waste or piecemeal combination of scarcely useable segments. This makes taking rib usually unnecessary.

Of course, there may still be exceptions, although they are progressively rarer in my current practice.

A different situation is that of the post-traumatic nose, in which saddling can occur if the residual septum is insufficient and heavily distorted. I place these cases conceptually in the realm of secondary rhinoplasties and yes, of course, they will need dorsal reconstruction by extended or staggered spreaders and, oftentimes, need reconstitution of the vertical element of the L-strut. Rib may well be needed in these cases (**Fig. 10**). Usually, bone work will also be required, consisting in osteoplasty and osteotomies, with a combination of Piezo or burr, but at least the tip, although distorted and asymmetric because of the deviated septum, will be per se consisting of native lateral crura to be treated like in a primary rhinoplasty.

QUESTION 4: WHAT INSTRUMENTS DO YOU USE?

Fedok

As stated in the previous section, I use a paucity of instruments to accomplish harvesting of rib cartilage for rhinoplasty. The instruments I commonly use include a 10 or 5 scalpel, an Army-and-Navy retractor, a Senne retractor, a Freer elevator, and Adson and Cobb elevators. Rarely will I use a Doyen retractor.

Peng

I have curated rib tray set that I put together in conjunction with Black and Black surgical (**Fig. 11**). which contain very small instruments to facilitate with a tiny incision. The Senn retractors are 5 mm wide and 22 mm in length. I use a small cottle with round sharp edges. The larger side is 5 mm in diameter and the smaller side is 2.5 mm in diameter. The smaller end can be used to cut through calcifications. I also do all of my dissections with a mosquito to decrease the instrument footprint and allow for a smaller incision.

Tastan

The surgical instruments I use for harvesting rib cartilage and carving cartilage grafts are as follows: specially designed saws, elevators, dermatome blade, No: 15 and 11 blade, forceps, needle holder, retractors, scissors, and monopolar cautery.

The instruments worth discussing are specially designed saws, elevators, and dermatome blade that I have been using for more than 10 years. The purpose of specially designed saws is to harvest rib cartilage with minimal damage to the tissues. Tastan rib harvesting saw enables controlled incisions using the touch and pressure sensation in our fingers similar to the other saws I designed for use in nasal osteotomies. It is easy and safe to cut the rib segment from medial and lateral ends as well as synchondrosis region with this saw under binocular vision, bimanual work. Also, in certain cases where rib cartilage is

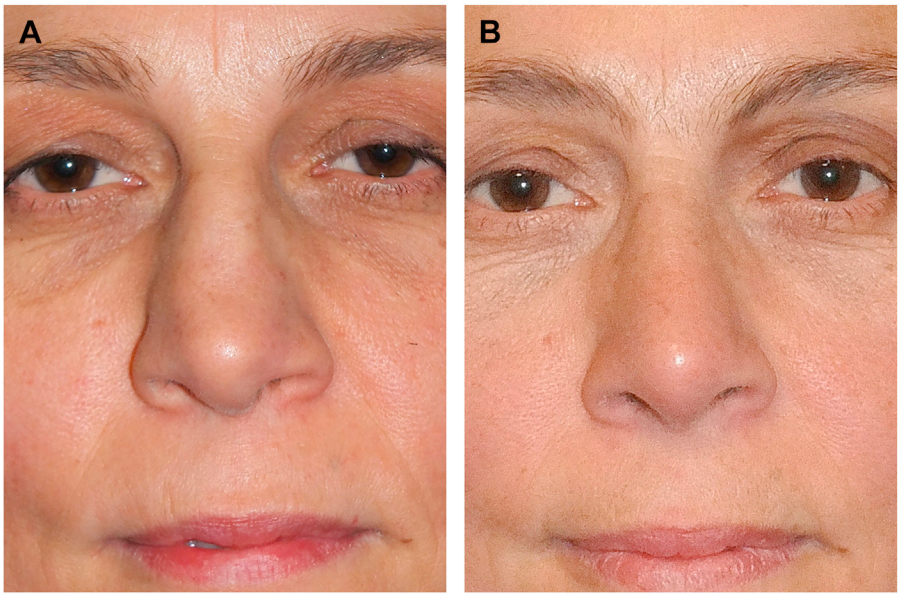

Fig. 10. (*A, B*) Pre-zoomed and post-zoomed frontal view demonstrating reconstitution of the dorsum and aesthetic dorsal lines by L-strut reconstruction by rib grafting in a post-traumatic nose. An SPF graft has reestablished the contour.

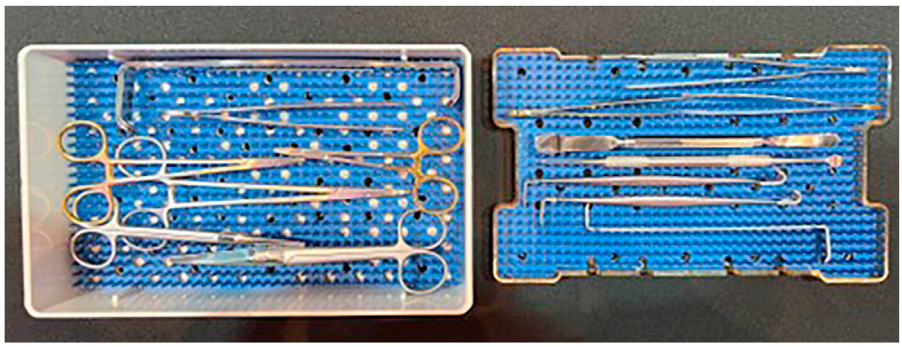

Fig. 11. Peng Rib Tray by Black and Black contains very small sens retractors as well as a small Peng elevator which is a double-sided elevator with 1 tiny oval side and 1 small round side. Both have very sharp edges to help with elevation and cutting through rib cartilage itself.

ossified, it is difficult to incise the cartilage and it would be better to use the saw in these circumstances. After all attachments of the segment are released, it becomes relatively more mobile, making the elevation of the posterior perichondrium safer in order to reduce the risk of pneumothorax.

For the elevators, any kind of blunt tip perichondrium elevator is suitable for anterior surface perichondrium dissection. However, it is necessary to use a blunt-tipped curved elevator to dissect the perichondrium from the posterior surface of the rib segment. In order to prevent unwanted damage to the posterior perichondrium, this elevator needs to be sufficiently strong and rigid (**Fig. 12**A–C).

I recommend using a dermatome blade when preparing cartilage grafts from rib cartilage (Video 4). It is crucial to achieve a smooth graft surface to ensure equilibrium between inner and outer zone forces. Thus, it would be more suitable to use a sharp dermatome blade rather than a scalpel. Grafts prepared with a scalpel often exhibit surface irregularities, affecting the balance of forces and can lead to bending. When using a dermatome blade, it is important to pay attention to the sharp edge and alignment. Specialized handles can be used if necessary.

If there are areas of ossification within the rib cartilage, it may be difficult to use the dermatome blade. In such cases, manual straight micro saw for medial osteotomy, or electric powered saws can be used. If the rib is ossified, shaping the OSM graft with a diamond burr is preferable for dorsal onlay graft preparation.

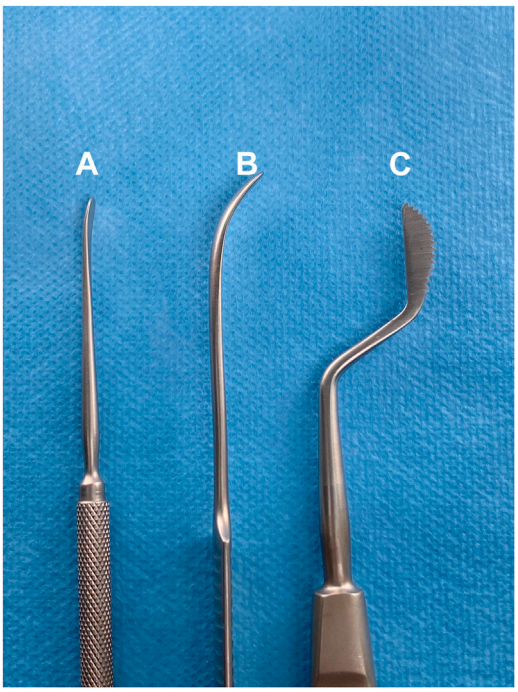

Fig. 12. Surgical instruments for dissection of perichondrium. (*A*) Perichondrium elevator, (*B*) specially designed posterior surface perichondrium elevator, (*C*) Tastan rib harvesting saw.

Robotti

Let us go back to the technique to answer this question. I will highlight the instruments I use in italics:

After skin incision, delineation of the superficial fascia (marked with methylene blue for later resuturing to avoid contour depression), and its transection, the correct plane on the rectus fascia is easily visualized. A wide sharp-edged elevator is used in a sweeping motion to expose the fascia and some perforators are treated by bipolar before they can retract. The rectus fascia is then harvested by a Valleylab Bovie tip. The rectus muscle is exposed and muscle fibers are first pretreated by a nonstick bipolar tip and then gently splayed in a longitudinal direction which follows their anatomy. Once the fibers are split without transecting them, 2 army-navy retractors are used to gain

exposure to the readily seen rib. Then, a sharp-edged wide elevator is used to define the edges of the perichondrium on the anterior surface of the rib and the same elevator is worked laterally on both sides to gain access to the posterior surface of the rib, with the posterior perichondrium is left attached to the chest wall. Customized small right and left rib elevators, personally developed for this purpose (Marina Medical Instruments, West State Road 84 Davie, Florida, US), are then used to dissect the harvested segment from its posterior perichondrium carefully (**Fig. 13**). Finally, the rib will need transection of both ends, usually done by a straight 4-mm osteotome. Only in the occasional cases in which a sizable calcification is encountered, Piezo is used for the same purpose.

QUESTION 5: WHAT CARTILAGE CARVING TECHNIQUES DO YOU USE?

Fedok

I harvest the rib cartilage early in the rhinoplasty procedure so that the rib can be observed for up to 20 to 30 minutes for warping after the initial harvest. In that way, I can be preparing the nose and gain my exposure while the rib is already harvested. I do not wait and watch the rib. I am doing something else while the rib is on the back table. My technique is relatively simple. I use a paucity of instruments for carving. After the rib cartilage is harvested, I place it in saline on the back table. I remove the perichondrium from the entire harvest most of the time since most of the time I will not be using a large thick graft. For the next 10 or 15 minutes, I allow the graft to be subject to some of its internal stresses so I can ascertain in what plane or vector the harvest will warp. I do additional exposure tasks or prepare the recipient sites while the rib is processed.

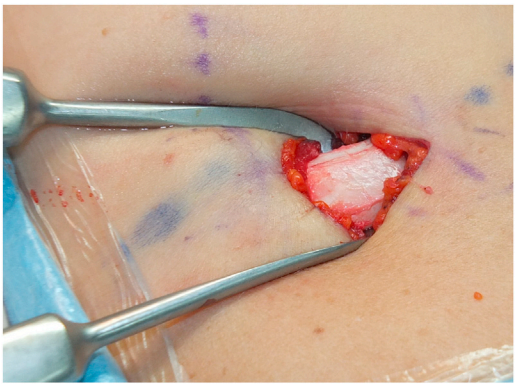

Fig. 13. The Right and Left specific rib elevators are shown. Their curvature serves well to dissect the posterior surface of the rib from its perichondrium, which will be left attached to the chest wall.

I carve the cartilage either on a plastic carving block or on a small stack of blue towels depending on the facility. The cartilage is carved using a sharp, frequently changed #10 scalpel. The cartilage is held with a Kocher clamp and forceps. The cartilage is carved in the plane that takes advantage of the plane the graft is warping in. I usually carve my grafts in stages, so I will first carve the cut the block of cartilage in half along its long axis and let the 2 halves demonstrate how they will warp. I might do that several times. Eventually, I will carve the larger cartilage harvest into the number and dimensions of cartilage grafts that are useful for the procedure. Typically, the grafts are thin, usually no thicker than 1.5 mm to 2 mm. As this is done in stages, I can usually obtain grafts that are suitable and that do not warp in the patient's nose (**Figs. 14** and **15**).

Most the time I am in need of several types of "grafts": spreader grafts, extended spreader grafts, septal extension grafts, septal replacement grafts, dorsal grafts, among others. Even with significant saddles, it is rare for me to use thick grafts anymore. Most of the grafts are the thicknesses described.

Peng

I like to carve cartilage in accordance with the lie of the cartilage using straight blades on a chopping board. There is usually 1 side, either anterior or posterior where the cartilage lies flatter and with less movement on the cutting board (**Fig. 16**). Then, depending on the size of the grafts needed, I will angle my eccentric cuts. The outer portions of cut rib cartilage will always have a higher chance of warping compared to the ones more in the center. The center pieces I always save for caudal septal extension grafts and leave the outer pieces for other grafts.

Tastan

Rhinoplasty is the process of disrupting the current balance of forces and establishing a new balance. To reconstruct a new balance, it is essential to understand the cartilage behavior and equilibrium of effecting forces. Since rib cartilage is a unique tissue by nature, each patient's cartilage is of a distinctive quality; ossification, internal structure, texture, homogeneity, dimension, shape, and other characteristics may vary from patient to patient. In rhinoplasty, straight cartilage grafts of various thicknesses are required. The equilibrium of forces is altered when a rib segment is carved to obtain cartilage grafts.

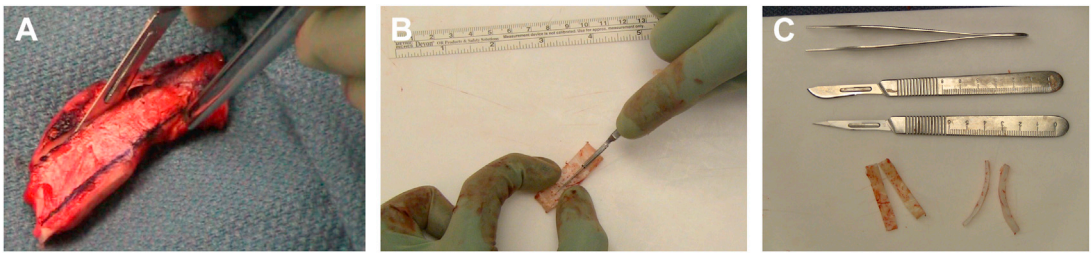

Fig. 14. (*A, B*) Carving of the harvested costal cartilage into large segments devoid of perichondrium. (*C*) Prospective grafts showing tendency to warp, thus noting magnitude and direction. (*From* Fedok FG. Costal Cartilage Grafts in Rhinoplasty. Clin Plast Surg. Jan 2016;43(1):201-212, Figure 11.)

Gibson and Davis reported that the warping of the cartilage is caused by a difference in tension between the outermost layers of cartilage and the inner zone.[13] An intact rib segment has these forces nicely balanced to preserve a stable shape. The matrix tends to expand when cut or carved, whereas the outer stretched layer contracts; therefore, warping occurs.

We can section the rib in 3 different planes; one is parallel to longitudinal axis along superior-inferior direction (SID), other one is parallel to longitudinal axis along anterior-posterior direction (APD), and the last one is crossing the longitudinal axis for to utilize cross section of the rib which is called "Oblique Split Method (OSM)."

The OSM provides a complete rib segment with an intact surface layer in which the diametrically opposed forces are equal and can easily be carved according to the principle of the balanced cross section also.

The cross section of the rib will result in a graft with equal circumferential forces of contracture, and we can also speculate that the cell groups at one cross-sectional surface are in continuous at the other surface, so the forces are balancing each other. Carving the rib at narrower angles to

Fig. 15. (*A–C*) Preoperative images of a patient seen for revision rhinoplasty with insufficient septal cartilage. (*D–F*) Postoperative images of the patient after revision rhinoplasty via open approach and use of sixth rib costal cartilage to place a caudal septal extension graft, bilateral extended spreader grafts, and the placement of bilateral alar contour grafts.

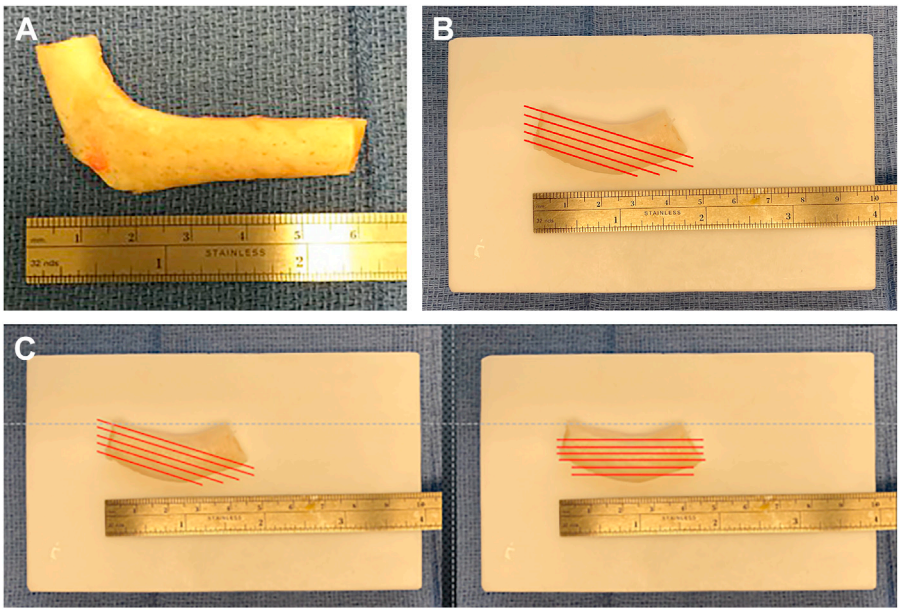

Fig. 16. (*A*) Orientation of rib cartilage. It is either anterior on top and posterior on bottom or anterior on bottom and posterior on top. This depends on how well it lies on the cutting board and the orientation, which will allow less movement while cutting. The goal is for it to lie as flat as possible so that cutting will be more precise. (*B*) Orientation of the cuts depends on the lengths of the grafts you need. (*C*) Other possible orientation.

obtain longer cartilage grafts does not effect the equilibrium of forces.

The elliptical OSM grafts maintain their straight shape even after being transformed into rectangular grafts because the contracting forces are in balance. By considering the equilibrium of forces, it may be possible to carve the grafts asymmetrically or bevel the edges meticulously.

All the frequently used grafts in rhinoplasty (spreader, columellar strut, caudal extension, alar batten, shield and cap grafts, to name a few) can be obtained from a single OSM graft. It is necessary to reconstruct the L-strut segmentally, using both the dorsal and caudal struts. Segmental reconstruction enables fine adjustment of height of the reconstructed septum and provides consistent results.

A dorsal onlay graft can be carved from a single OSM graft in almost all cases. If needed, 2 cartilage grafts can be sutured end to end, side by side, or by overlapping manner after the edges have been modified. Costal perichondrium may be sutured over the dorsal onlay graft to camouflage and for soft tissue padding.

Cartilage grafts used in rhinoplasty are typically straight in shape. If necessary, curved grafts for lateral crural reconstruction can be prepared from a straight OSM graft by beveling the edges.

It presents a challenge to the surgeon to deliver thin, straight grafts in patients with depleted septal cartilage. The OSM is unique in that it provides straight grafts as thin as septal cartilage or even in paper thickness. Additionally, because the OSM graft contains both the central and peripheral rib zones, a significant amount of graft material can be obtained from a given volume of costal cartilage.

I have been using this innovative method for costal cartilage graft carving for the past 17 years, and the OSM consistently produces reliable long-term outcomes.

Costal cartilage grafts carved with the OSM provide grafts that are at the intended thickness, even less than 1 mm, and they preserve their straight form.

Robotti

My concept essentially is that of deriving multiple laminations from a specific full-thickness rib segment, usually measuring 3 to 4 cm in length so that I can have an extensive “rib menu” from which to derive the segments I need for specific applications. Those applications consist of (a) extended or staggered rib spreaders for the horizontal portion of the L-strut, (b) smaller segments which can be used as bilateral splints, for instance, for a septal extension graft or to strengthen the vertical segment of the L-strut, (c) a segment to be used as vertical L-strut in combination with the residual septum, if available, and, lastly, (d)

thin rib laminations to be used as lateral crura struts to splint residual lateral crura segments, or to replace them in toto.

It stands to reason that I need multiple choices and an array of options to derive the best segments for a specific purpose. This is why I never do a segmental rib harvest, as I explained earlier, but I always use a single whole piece. After harvesting, I first remove the perichondrium from the anterior surface, which I will often use as an ingredient of my SPF-SPLF graft, and then lamination begins. As well as making longitudinal segments, I also laminate a few segments perpendicular to the long axis of the rib: those will measure around 1 to 5 cm and can often be used as small splinting elements, for instance, bilateral support for a septal extension graft. For laminating the rib, I use a hair transplant disposable knife, which allows me the benefit of a solid handle and ideal width of the cutting portion of the blade (**Fig. 17**). Notably, a non-slippery rubber or silicone board should be used.

Regarding the direction of subsequent lamination, I have no absolute preference regarding concentric carving or other options.[14,15] What I essentially do is to observe the rib. It may be more or less straight, or curved, or wider on 1 side. After evaluating it, I form the impression of where the straightest segment would lie, and then I proceed with the first cuts. Those will be longitudinal or often obliquely oriented. Cutting obliquely, as described by Tastan,[16] is definitely beneficial in avoiding warping. I deliberately take some thicker and thinner pieces and mark them differently. In the past, I constantly used to try and achieve long rib segments, measuring up to 4 cm, but over the recent years I have often turned to using shorter segments which I will then employ in a staggered fashion for my horizontal L-strut reconstruction (**Fig. 18**). As I said previously, I will also derive some short, transverse laminations, prevalently perpendicular to the axis of the rib (**Fig. 19**). I mark the segments as I cut them with different symbols so as to identify later which options I have for spreaders (which obviously will be wider and more robust, and here calcifications may actually be of help) or, for instance, for lateral crura struts. Obviously, there is a learning curve. There is also a kind personal feel, which will come in time together with experience.

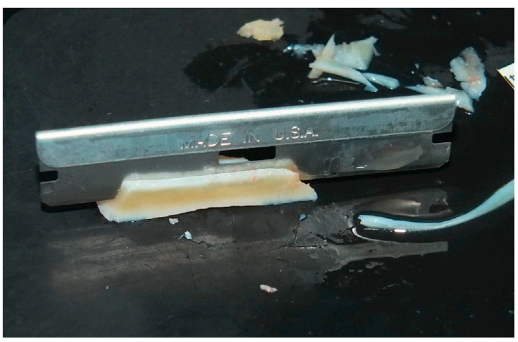

Fig. 17. A hair transplant knife is well-suited for laminating rib.

QUESTION 6: HAVE YOUR TECHNIQUES CHANGED IN THE LAST 2 YEARS?

Fedok

In the last 2 years, my technique has not changed at all. What have changed over the 10 years are the modifications to lessen pain and minimize dissection.

Peng

Have not had any changes over the last 2 years.

Tastan

OSM is a reliable technique we have been using confidently with our colleagues for years.

In the past 2 years, I have not made any changes to my technique for harvesting and carving the rib and preparing cartilage grafts. OSM provides straight grafts in varying thicknesses and the OSM grafts preserve their straight form at long postoperative period (Video 5).

Among the technical details that have changed in the last 5 to 10 years, I can mention that I use intact cartilage grafts instead of diced cartilage to provide more defined dorsal aesthetic lines. Additionally, due to variations in absorption rates, diced cartilage might not provide consistent results. I also prefer the cortex portion of the rib segment as a onlay tip graft due to higher suture security and flexibility.

Robotti

My techniques regarding using rib in secondary rhinoplasty have changed both concerning principles and practice. Also, because of several specific modifications, the premise is that I use rib in over 80% of my secondary cases, which constitute about more than 50% of my exclusively rhinoplasty practice.

Regarding principles, I could say that the major change has been to try and apply finesse concepts in a rib harvesting and application. This means that I take my time in laminating the segment of full-thickness rib, which I have harvested and preplan segments for the applications I will need, considering that I want multiple choices available. In practical terms, it means deriving the thinnest segment which will do its job, meaning that will

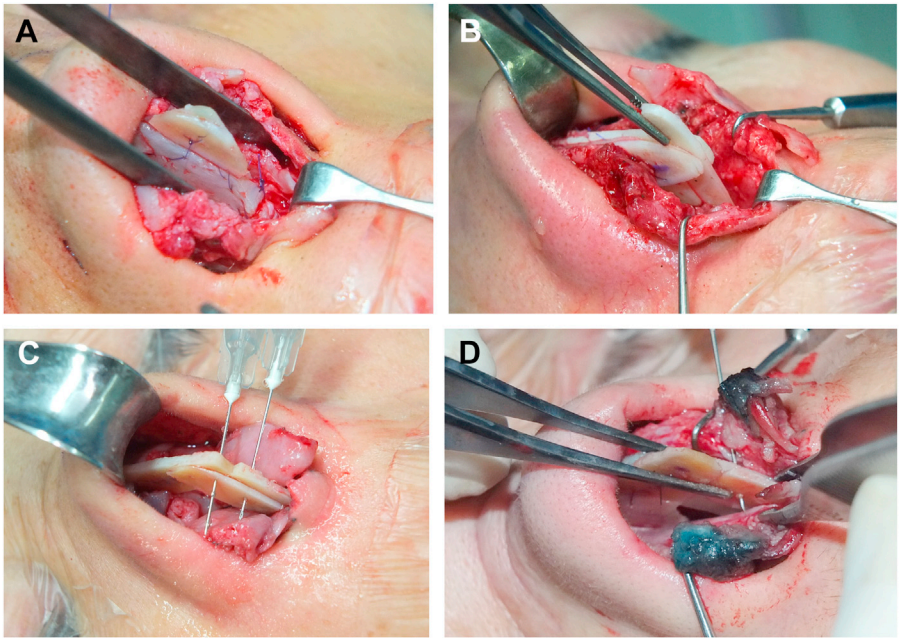

Fig. 18. (*A–D*) Different configurations of L strut reconstruction with rib Laminas of different length and thickness are shown. These are just a few examples of the many combinations possible.

be sturdy enough for the application it should serve. I learned this the hard way over the last years, since initially I was overgrafting and my grafts were essentially rather big. I changed this in time, now striking a proper balance between the function of support and the aesthetics of refined shape that patients desire.

Regarding techniques, I must again go beyond the 2 years stated in the question. The game-changer for me has been the SPF-SPLF graft for dorsal reconstruction graft for dorsal reconstruction. After first progressively tailoring and customizing the DCF (diced cartilage fascia) construct,[4,5] we then abandoned the DCF entirely and started, since 2017, using varying combinations of Perichondrium, Fascia, and rib Laminations.[10]

Fig. 19. Short transverse segments are derived by cutting the rib perpendicularly (or with some obliquity) to its axis.

The acronym SPF means “Sandwich of Perichondrium and Fascia,” and consists of a layer of perichondrium at the bottom (which will be placed on the dorsal plateau in the same orientation as it originally had on the rib) together with a layer rectus fascia at the top, again oriented in the same way as it originally was in the rectus muscle (**Fig. 20**). Precise measurements are again essential.

The acronym SPL F means “Sandwich of Perichondrium, (rib) Lamina and Fascia” and consists of the addition, between the layers of an SPF as described earlier, of a straight or mildly convex, thin, and precisely constructed rib lamina gently beveled at is sides (**Fig. 21**).

The technique’s success depends on the time and care spent on it. The correct lamina has to be chosen and it has to be reshaped to exact desired measurements of length and width. If there is a mild convexity to the shape of the graft, the convexity will be placed facing up. In some instances, its width will be slightly greater between the upper third and distal thirds of the nose, so as to allow a mild trapezoid shape of the dorsum such as desirable in male patients. The lamina has to precisely fit between the perichondrium and fascia juxtaposed layers, like a finger in a glove, without excess. The overlap at each side, where the perichondrium edge meets the rectus fascia’s edge, must be stitched

Fig. 20. (*A–H*) An example of aesthetic dorsal reconstruction with an SPLF graft in a secondary rhinoplasty patient.

precisely (Video 6). This tissue fringe will then serve for fixation to the residual edge of the upper lateral cartilages on either side. A transosseous bony cerclage suture, will then be placed proximally and override the construct without undue compression so as to avoid any lateral shift at the radix. This is the same "transcutaneous transosseous cerclage (TTC) suture" as described by Gubisch and Haack,[17] that I invariably use for solid fixation between rib spreaders

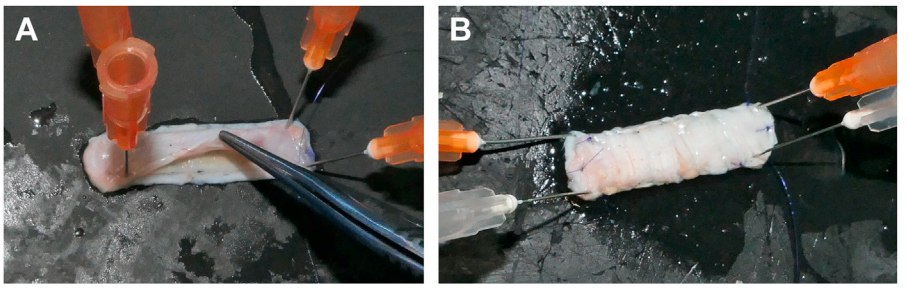

Fig. 21. (*A, B*) The SPLF construct consists of a Sandwich of Perichondrium, rib Lamina, and Fascia.

and proximal bone after custom slots have been configurated by Piezo. Should it be necessary, another lamination can be added, although it is best sutured to the previous one separately on the table. Alternatively, some finely diced cartilage can also be carefully inserted, via the distal edge of the construct left open until final assessment of the augmentation required.

Over the last 2 years, we have, however, substituted diced cartilage with "Rib Plaster" specifically derived by scraping the wide peripheral portion of the remaining rib after the perichondrium is removed and laminations done.[11] This is a putty-like substance with unique properties and can be well compacted into a diced cartilage inserter, smoothly injected, and is easily moldable (Video 7).

However, over the last couple of years, we have also implemented other variations, since we originally in the SPF-SPLF technique. Those consist in a lateral fringe from the fascia to adapt to the lower upper lateral cartilages, in double laminations, when necessary, in addition of rib cartilage plaster, in a fascial extension for the radix to avoid any step off (**Fig. 22**).

I now believe that the SPLF-SPF construct has allowed me to achieve the really natural-looking dorsum, which we had sought for so many years, and which is not equally unachievable by diced cartilage fascia (DCF) construct or, in my opinion, by solid rib. This construct will attach solidly to the underlying dorsal structure by virtue of its perichondrium, and it will resemble a native dorsum if well-crafted and precisely sutured (see **Fig. 20**). On this topic, we are now completing a paper summarizing the possible modifications, but the striking element is that we have observed no warping whatsoever in over 300 cases done at the time of this writing.

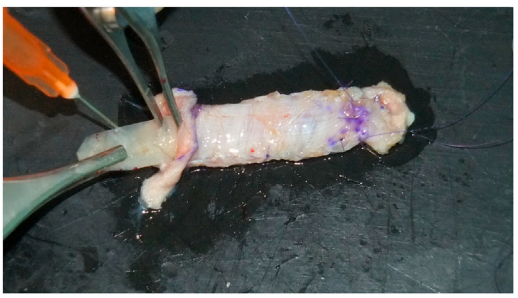

Fig. 22. The double lamina variation of an SPLF graft is shown.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.fsc.2024.06.009.

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