

Crushed Cartilage Grafts for Concealing Irregularities in Rhinoplasty

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Objective: To assess the clinical outcome of crushed cartilage grafts used to conceal contour irregularities in rhinoplasty.

Methods: We reviewed the medical records of 462 patients in whom crushed autogenous cartilage grafts were used, selected from a total of 669 patients in whom rhinoplasty procedures were performed at our institution between June 1, 1999, and June 1, 2006. The grafts were used as slightly, moderately, significantly, or severely crushed.

Results: Eight hundred nine cartilage grafts (41 slightly crushed grafts [5%], 650 moderately crushed grafts [80%], and 118 significantly crushed grafts [15%]) were used in 462 patients. Resorption occurred in 11 of the 462 pa-

tients (2.4%). All of the resorbed grafts (6 moderately crushed grafts and 5 significantly crushed grafts) had been placed in the dorsal area. The resorption rate of those grafts was lower in the moderately crushed cartilage grafts (6 of 284 grafts [2.1%]) than in the significantly crushed grafts (5 of 38 grafts [13.1%]). There was no resorption of slightly crushed grafts.

Conclusions: The degree of crushing applied is important for long-term clinical outcome of autogenous crushed cartilage grafts. Slight or moderate crushing of cartilage creates an outstanding graft material for concealing irregularities and provides both excellent long-term clinical outcome and predictable esthetic results.

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DORSAL CONTOUR IRREGULARITIES caused by various maneuvers such as hump resection or adhesion of the dorsal skin to the nasal bones are among the most common adverse effects that can occur after rhinoplasty. These problems are seen more often in patients with thin skin, frequently develop after revision procedures, and become more prominent after edema has subsided.^{1,2} Dorsal onlay grafts may be used to mask such contour irregularities by filling the defects or preventing the skin from coming into direct contact with the underlying irregular nasal framework. Various graft materials including autografts, alloplasts, and homografts have been used for this purpose.²⁻⁸ However, all grafts have different degrees of risk for rejection, infection, extrusion, later visibility, distortion, and resorption. The search for the perfect graft material continues.

Autogenous cartilage is widely considered ideal for use in all types of grafting in nasal surgery because it survives as living tissue, is seldom resorbed, and does not induce an immune response. As a result, problems with rejection, infection,

and extrusion rarely arise when that material is used.⁹⁻¹² However, when used as a dorsal onlay graft and even carefully shaved before placement, the edges of the solid-carved pieces of autogenous cartilage graft may become apparent and can cause dorsal contour irregularities, especially in patients with thin skin.^{2,9}

Crushed autogenous cartilage grafts may be an option for concealing the irregularities and to achieve a smoother nasal surface. However, the literature contains limited and conflicting information about the clinical outcome of crushed cartilage grafts.^{9,13-22} Thus, most surgeons hesitate to use that material for contour restoration in rhinoplasty. We assessed the clinical outcome in patients in whom crushed cartilage grafts were used to conceal irregularities after rhinoplasty.

METHODS

The medical records of 462 patients (160 men [35%] and 302 women [65%]; age range, 14-72 years [mean age, 36.7 years]) in whom crushed cartilage grafts were used, which had been selected from a total of 669 rhinoplasty procedures performed by one of us (O.C.) between June 1, 1999, and June 1, 2006, were re-

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Figure 1. Moderately crushed cartilage in a Cottle cartilage crusher.



Figure 2. Five grafts with different degrees of crushing. Left to right, Intact, slightly crushed, moderately crushed, significantly crushed, and severely crushed.

viewed. Patients were followed up for 6 to 72 months (mean follow-up, 22 months). Graft data including the source (septal, auricular, or costal), recipient site, and degree of crushing (slightly, moderately, significantly, or severely) were analyzed from a Gunter rhinoplasty diagram (Canfield Scientific Inc, Fairfield, New Jersey) of each patient. For each patient, a standard rhinoplasty series of photographs (a frontal view, 90° side views, 45° oblique views, and a basal view) were obtained preoperatively and postoperatively during each visit after 6 months. Postoperative control visits consisted of inspection and palpation on day 10 after surgery; 1, 3, 6, and 12 months after surgery; and yearly thereafter. Any complication (infection, resorption, rejection, displacement, visible irregularity, or excess graft thickness) associated with a crushed cartilage graft was considered a sign of graft failure.

The crushed cartilage grafts were prepared as follows. The perichondrial layers and the bony attachments were removed and the cartilage was shaped to the desired size with a No. 15 blade. Crushing was performed with a Cottle cartilage crusher (model 523900; Karl Storz GmbH & Co, Tutlingen, Germany) (**Figure 1**). The degree of crushing was defined as follows: slightly crushed, 1 moderate-force hit to soften the surface without reducing the elastic strength of the cartilage; moderately crushed, 2 moderate-force hits to reduce the elastic strength enough to cause minimal bending downward with gravity and twisting with a delicate touch; significantly crushed, 3 to 4 moderate-force hits to cause the graft to bend moderately with gravity without destroying the integrity of the cartilage completely; and severely crushed, 5 to 6 forceful hits to totally destroy the integrity of the cartilage (**Figure 2**). Thick cartilage pieces require greater intensity to be crushed, which

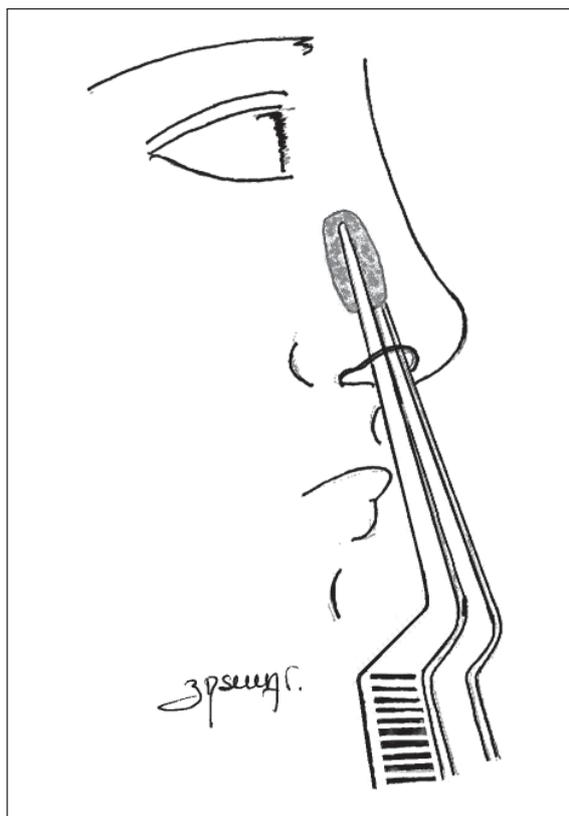


Figure 3. Illustration of a crushed cartilage graft insertion.

may create a blast effect that can cause unintended disintegration. To prevent this, each thick piece of cartilage was shaped with a No. 15 blade to create a graft height of 3 mm or less before crushing was performed. Obtaining a homogenous graft height is also important because disequilibrium of the force exposed can result in overcrushing of some parts of the graft. The autogenous septal cartilage was the first choice for obtaining crushed cartilage whenever available. Autogenous auricular and costal cartilages were used in patients who were depleted of autogenous septal cartilage. The desired degree of crushing for septal and ear cartilage can be achieved via the methods described. However, rib cartilage usually does not crush well and may shatter. After the cartilage was crushed, the graft was carefully shaped to fit the size of the defect and was placed in the recipient area with bayonette forceps (**Figure 3**).

Autogenous crushed cartilage grafts were used for the following purposes: (1) to cover the sharp edges of an irregular nasal framework after hump resection (**Figure 4**), (2) to serve as an underlying padding material to prevent skin adhesion (**Figures 5, 6, and 7**), (3) to fill pit holes and, thus, mask irregularities (Figure 6 and Figure 7), (4) as a filler to mask asymmetries and depressions on the side walls (Figure 6 and Figure 7), (5) for tip grafting (Figure 6 and Figure 7), (6) to camouflage the edges of solid onlay grafts (Figure 6 and Figure 7), (7) to supply minor dorsal augmentation for the correction of an overresected dorsum, and (8) to increase the thickness and natural color of the overlying skin where skin atrophy had occurred.

The primary areas of graft insertion were the nasal dorsum, side walls, radix, supratip, and tip. The grafts were placed as a monolayer or in multilayers, depending on the depth of the defect. If the defect was too deep, the crushed cartilage was placed on or around the intact cartilage graft to soften the con-



Figure 4. A and B, Preoperative views of a patient before primary rhinoplasty. A significantly crushed septal cartilage dorsal onlay graft was used to camouflage the sharp edges of nasal skeleton caused by hump resection. C and D, Postoperative views after 12 months show smooth nasal dorsum.



Figure 5. A and B, Preoperative views of a patient who had undergone 3 previous rhinoplasty procedures. A thin layer of moderately crushed septal cartilage dorsal onlay graft was placed. C and D, Postoperative views after 24 months show smoother dorsal surface with better skin quality.

tours of the intact graft. If the patient had thick skin, intact cartilage grafts rather than crushed cartilage grafts were preferred for tip grafting to obtain sharp-edged tip contours. The crushed grafts were not fixed or sutured when they were placed in the nasal dorsum, side walls, supratip, or radix; however, the grafts placed in the tip were fixed with a 5.0 polydioxanone suture. After major grafting had been performed, the columellar incision was sutured and the final contour of the nose was carefully evaluated. Very small pieces of crushed cartilage grafts were subsequently placed via remaining incisions as necessary. Over-correction was not performed in any patient. During the early postoperative period, after edema had subsided, any bulging areas were treated with delicate regular finger massage. That maneuver, which was seldom required, was successful for 4 to 6 weeks postoperatively. The evaluation for revision surgery was made 6 months to 1 year after surgery.

RESULTS

Crushed cartilage grafts were used in 462 of 669 patients (69%) who underwent rhinoplasty. Although 353 of the 462 patients (76%) had undergone primary rhinoplasty and 83 patients (18%) had undergone secondary rhinoplasty, 26 patients (6%) had undergone previous multiple nasal corrections (range, 3-7 previous rhinoplasty procedures). Four hundred thirty of the 462 patients (93%) received grafts by means of an open rhinoplasty approach and the remaining 32 patients (7%) were treated with a

closed approach. The crushed cartilage grafts were harvested from the septum in 375 patients (81%), from the auricula in 77 patients (17%), and from the costa in 10 patients (2%). Only 1 form of crushed graft was used in 420 patients (91%), but more than 1 form of crushed graft was used simultaneously in 42 patients (9%). A total of 809 crushed cartilage grafts (41 slightly crushed grafts [5%], 650 moderately crushed grafts [80%], and 118 significantly crushed grafts [15%]) were used in 462 patients (**Table**). The severely crushed cartilage grafts were used in only 4 patients to correct negligible irregularities caused by atrophic skin. Because the number is small, severely crushed grafts were excluded in the evaluation. The primary areas of crushed cartilage graft placement included the dorsum in 338 patients (73%), the lateral side walls in 277 patients (60%), the radix in 36 patients (8%), the supratip in 45 patients (10%), and the tip region in 113 patients (24%) (**Table**). Revision surgery necessitated because of failure of the crushed cartilage was performed in 14 patients (3%). Graft infection, rejection, and extrusion did not occur in any patient studied. The graft failure was caused by resorption, which occurred only in grafts placed in the dorsal area, in 11 of 462 patients (2.4%), by graft displacement in 3 patients (0.6%), and by excess graft thickness in 2 patients (0.4%). Resorption occurred in 6 of 284 moderately crushed grafts (2.1%) and in 5 of 38 significantly crushed grafts (13.1%). There was no resorption of



Figure 6. A and B, Preoperative views of a patient who had undergone 3 previous corrective attempts. The moderately crushed auricular cartilage grafts were placed on dorsum, side walls, and tip regions. C and D, Postoperative views after 24 months show straight, natural appearance of the nose.

the slightly crushed grafts. The severely crushed form of cartilage graft was used only to correct localized depressions caused by atrophic skin at various sites in selected patients. An improved, smoother skin surface resulted in all cases. Each patient in whom graft failure occurred underwent revision via touch-up surgery, resection of excessive tissue, or regrafting with a moderately crushed graft, depending on the cause of failure, and all of those patients were satisfied with the results of revision.

COMMENT

The search for the best method for concealing irregularities of the nasal vault and achieving smoother contours remains a major concern of surgeons who perform rhinoplasty. Some authors have stated that autogenous soft tissue grafts, such as dermal grafts³ or temporalis fascia grafts,⁵ are satisfactory for covering underlying dorsal irregularities. However, those materials have disadvantages of possible partial resorption and donor-site morbidity. Although some authors have suggested that temporalis fascia grafts are among the most reliable materials and are associated with reasonably low resorption rates,^{5,8,23} those grafts are difficult to manipulate because they are thin and slippery.^{23,24} Alloplastic materials, such as gelatin film,⁴ polyglactin 910 (Vicryl suture; Johnson



Figure 7. A and B, Preoperative views of a patient who had undergone 7 rhinoplasty procedures. The asymmetries, depressions, and skin adhesions were concealed with moderately crushed auricular cartilage grafts. C and D, Postoperative views after 36 months show improved nasal contours with better skin quality.

Table. Graft Recipient Sites and Types

Recipient Site	Degree of Crushing ^a			Total
	Slight	Moderate	Significant	
Dorsum	16	284 ^b	38 ^c	338
Radix	4	31	1	36
Supratip	5	34	6	45
Lateral side wall	8	232	37	277
Tip	8	69	36	113
Total	41	650	118	809

^aBecause the number of severely crushed grafts was small, they were excluded from the evaluation.

^bResorption occurred in 6 of the 284 moderately crushed grafts (2.1%) in the dorsal area.

^cResorption occurred in 5 of the 38 significantly crushed grafts (13.1%) in the dorsal area.

& Johnson Gateway LLC, Piscataway, New Jersey),⁶ and Gore-Tex (W. L. Gore & Associates Inc, Newark, Delaware),⁷ have also been advocated for that purpose. However, absorbable synthetics do not last long, and of all graft materials, nonabsorbable synthetics are associated with the highest rates of infection and extrusion.^{2,11} A soft-tissue filler, AlloDerm (LifeCell Corp, Branchburg, New Jersey), which is derived from cadaveric skin, is another material frequently used to achieve a smoother nasal dorsum. However, AlloDerm has the definite disadvantage of

partial graft resorption, especially when it is positioned over the dorsum in patients with thin skin.²⁵

In contrast to these options, autogenous cartilage is widely accepted as the ideal graft material for use in rhinoplasty. However, when solid-carved pieces of cartilage are used to conceal residual deformities or to eliminate adhesions between nasal bones and overlying skin, the edges of the onlay graft may cause unsightly irregularities with time, especially in patients with thin nasal skin or scars. Various authors^{2,9,13-18,24,26-30} have suggested modifying autogenous cartilage, by thinning, dicing, or crushing, to manage this situation. McKinney et al² popularized the use of cartilaginous autogenous thin septal grafts that measured 35 × 8 mm and were less than 1 mm thick to mask residual deformities. However, it is not always possible to obtain an intact cartilage graft that large, especially in patients undergoing revision surgery.

Diced cartilage is excellent for filling, but it is difficult to introduce and to retain in tissue.^{9,26,28,29} Erol²⁶ recently popularized the use of a diced cartilage graft wrapped in a piece of absorbable knitted fabric (Surgicel [Turkish Delight]; Johnson & Johnson Gateway LLC) and reported substantial success with that technique. However, Daniel and Calvert²⁸ reported clinical failure in the form of the ultimate graft absorption of all diced cartilage grafts wrapped in Surgicel in their series. Our experimental study in rabbits⁹ supported those results and showed that Surgicel inhibits cartilage proliferation and decreases cartilage viability. Thus, we suggest that wrapping diced cartilage with Surgicel reduces the long-term viability of grafts. As a modification, some authors^{28,29} have advocated using diced cartilage wrapped in temporalis fascia. Although the maintenance of typical cartilage viability and a high graft survival rate have been reported with the use of this material, harvesting the temporalis fascia adversely affects the donor site, where either permanent or transient alopecia can develop after surgery.

Many authors^{9,14-18,24,30} have used a crushed cartilage graft to conceal dorsal irregularities and to achieve a smoother nasal surface. However, no standardization has been established for the crushing methods used in clinical reports. To our knowledge, with the exception of 1 study,¹⁸ the crushing technique and the intensity applied have not been defined and clinical results with this material have not been documented properly.^{14-16,24,30}

Guyuron and Friedman^{18(p255)} defined crushed cartilage as “altered in the crusher to become more pliable and less rigid, yet allowed to maintain its integrity.” Those authors used 136 crushed autogenous cartilage grafts and reported surgical success in 119 of 136 patients (87.5%). The long-term results of crushed cartilage grafts have also been investigated in several experimental studies^{9,13,17,19-22} that yielded contradictory results about the viability of those grafts. Although some experimental studies have shown that crushed cartilage remained viable and retained its volume even after severe crushing,^{17,20} other investigations have demonstrated that crushing led to extensive necrosis^{21,22} or at least diminished graft viability.¹⁹

Recently, we attempted to resolve the conflicting results in those reports by assessing the influence of the degree of crushing on the cartilage of rabbit ears.⁹ Our

assessment showed that the mean percentage of viable cartilage decreased as the degree of crushing increased (70% in slightly crushed grafts, 50% in moderately crushed grafts, 30% in significantly crushed grafts, and 10% in severely crushed grafts), whereas 90% of intact cartilage grafts were viable. In addition, slight crushing of the cartilage induced variable amounts of chondrocyte proliferation and metaplastic bone formation while preserving viability; this may help to soften the contours of the nasal dorsum and to balance any resorption that occurs. We then investigated the effects of the degree of crushing on the viability of human nasal septum chondrocytes in adherent cell cultures.¹³ The results agreed with those of our animal study in rabbits and demonstrated that, although slight or moderate crushing of cartilage grafts enabled good chondrocyte viability and proliferation at levels comparable to those of intact cartilage, significant or severe crushing reduced chondrocyte viability and proliferation and could result in an unpredictable degree of graft volume loss. We subsequently customized our clinical conception and more often chose moderately crushed cartilage grafts.

Our current clinical series confirmed our previous animal⁹ and human cell culture¹³ studies that the degree of crushing applied is important to the long-term clinical outcome of crushed cartilage grafts used in rhinoplasty. The results showed a correlation between the degree of crushing applied and the resorption rate of the crushed graft, especially in grafts applied at the dorsum. The resorption rate was zero in slightly crushed grafts, 2.1% in moderately crushed grafts, and 13.1% in significantly crushed grafts. Our results show that slight or moderate crushing of the autogenous cartilage produces an outstanding graft material that is effective in concealing irregularities, filling defects, and creating a smoother surface, with excellent long-term clinical outcome and predictable esthetic result. We suggest that intact cartilage should be used to correct major deformities and that moderately crushed grafts should be used for smaller depressions to minimize resorption. The severely crushed form of cartilage should not be used as filler except to correct negligible depressions in atrophic skin. The edges of solid onlay grafts might be softened by placing small pieces of moderately crushed grafts on or around the solid graft. The tiny pieces of moderately or significantly crushed grafts might be successfully used in final contouring at the conclusion of surgery. In patients with thin skin or in whom revision is required, a thin layer of moderately or significantly crushed cartilage would be the proper option as a padding material to prevent the adhesion of skin and to camouflage the sharp edges of the nasal skeleton that might be visible after edema has subsided.

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