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REVIEW

Biomaterials in rhinoplasty

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The surgical goal of rhinoplasty is a nasal skeleton with balanced individual components, which allows optimal function while dictating a shape to the skin-soft tissue envelope which is in pleasing harmony with the rest of the face. To reach this goal, modern rhinoplasty principles emphasize restructuring, including relocation and augmentation, rather than reduction.[1TM4] The practical importance of this philosophy is illustrated in Table l, depicting the relative frequency of selec-ted procedures, such as regional augmentation and alar suture relocation, applied in primary and secondary rhinoplasty. Although these modern principles are well accepted, the selection of biomaterials for restructuring remains an area of controversy. Biomaterials include autografts, homografts, xenografts and alloplasts (Table 2). From these biomaterials, autogenous cartilage has the longest record and is the most frequently used material for nasal augmentation.[5] At times, however, adequate autogenous cartilage is not readily available and a suitable substitute is needed. Over the years various alternatives have been proposed, such as autogenous bone,[6] homografts,[7] and various alloplasts.[8 n]

This paper aims to review the various biomaterials currently *en vogue* and discuss their selection and application in individual nasal components.

Table 1. Approximate frequency of selected restructuring techniques regionally applied in primary and secondary rhinoplasty

Nasal region	Primary rhinoplasty (%)	Secondary rhinoplasty (%)
Premaxilla augmentation	5	15
Columella strut	90	85
Tip graft	35	60
Middle third spreader (Vuyk)[94]	30	30
Dorsal augmentation	35	50
Lateral wall graft	15	20
Alar graft	15	30
Alar suture relocation (Vuyk)[4]	90	75

Table 2. Classification of biomaterials

Form	Source
Autografts	Same organism
Allo (homo) grafts	Same species
Xenografts	Different species
Alloplasts	Synthetic

General considerations

The broadest possible definition of a biomaterial includes any substance used for tissue augmentation and replacement, whether natural or synthetic.[12] The ideal biomaterial would have a wide range of macroscopic and microscopic properties including those listed in Table 3.[12 r4]

However, every biomaterial available falls short of the ideal and lacks a number of the listed properties. The pros and cons of each biomaterial should be carefully weighed, making selection a major task. To improve this selection process, some of the properties which are not self-evident can be elucidated.

Ideally the macroscopic physical properties of the implants should match the tissues which are to be replaced or augmented. For example, the lower two-thirds of the nose, including the septum and upper and lower lateral cartilages, is characterized by flexibility, as opposed to the rigid upper third, the bony pyramid. Grafting of the septum or nasal dorsum using strong, stiff biomaterial, including bone, may lend an unnatural stiffness to the lower two-thirds of the nose. Moreover, stiff material in this flexible area risks fracture, while mechanical shearing forces may induce necrosis of overlying tissues.[15] Thus, soft, flexible biomaterials such as

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Table 3. Ideal implant characteristics*

Macroscopic	Microscopic
Compatible physical properties	N o/minimal inflammatory response
Retains constant shape and volume	No/minimal surface contamination
Non-resorbable	Infection resistant
Easily removed	Non-degradable
Retains stable position, does not migrate	No disease transmission
Exchangable	Non-carcinogenic
Modifiable	
Easily available	
Cost-effective	

* After Constantino,[12] Holt[13] and Scalis.[14]

autogenous cartilage or temporalis fascia are to be preferred for the columella, nasal tip, supratip and septum.

Regarding other macroscopic properties, it should be noted that some biomaterials do not maintain their own original volume because they are resorbable, but are replaced by living tissues over time. This may be permissible and sometimes even advantageous as long as the reconstruction remains to fulfil the functional and aesthetic goal. Ease of removal is important in order to reverse the surgical steps in case of infection or sub-optimal result. Moreover, the short history of biomaterials does show that problems may occur with every type of implant material, sometimes not until years later. This implies that, specifically for non-autogenous materials, future exchangeability is important.

Apart from matching macroscopic physical properties of the implant and the implant site one should realise that the success of implantation is largely determined on a microscopic level at the biomaterial-tissue interface. Optima! soft tissue compatibility is characterized either by limited inflammatory reaction with thin fibrous encapsulation or mesenchymal ingrowth with minimal, macrophage activity.[16]

If the inflammatory response which appears to be associated with every biomaterial is not resolved, the elevated macrophage activity with enhanced vascularity may induce skin redness, possibly resulting in skin slough and extrusion. The degree and duration of inflammation occurring at the interface depends on a number of microscopic factors, including the degree of porocity, biostability and contamination. Fibrovascular permeation of the implant by host tissue allows locally active immune defense and implant fixation. Soft tissue ingrowth is largely dependent on pore size.[17] A minimum pore size of 20—30 *i* is a prerequisite for some degree of peripheral ingrowth, possibly increasing over time.[1718] Pore size of 40-150 *i* allows extensive infiltration by host tissues, both increasing resistance to infection and implant fixation. However, extensive tissue ingrowth will decrease the chances of easy removal if necessary.[19] Smooth, non-porous materials (silicone) are more likely to elicit dense capsule formation than the porous materials because of failure to develop invading fibrous bonds that secure it in place.[13] Limited fixation does allow micromotion inducing an ongoing inflammatory response. Mechanical forces will increase capsule dimensions with dead space formation while risking subsequent extrusion. Fragmentation of particles may precipitate a chronic inflammatory response. Furthermore, harmful substances can be released because of degeneration of a biomaterial.[20] The degree of inflammation is also related to surface contamination, possibly occurring during processing and handling. Surface contamination diminishes the compatibility and may pose a bigger risk for non-autogenous materials, especially alloplasts which are less resistant to infection, necessitating special handling precautions.

N ever should the advantage of any biomaterial outway the risk of contagious diseases. In conclusion, the success of biomaterial implants is largely determined by macroscopic and microscopic characteristics of the biomaterial which must be tailored to the specific recipiënt site.

Specific biomaterials

AUTOGENOUS CARTILAGE

Autogenous cartilage grafts are the most frequently used materials for nasal augmentation.[5] Cartilage grafts are the standard to which most other biomaterials are compared because of their long-term successful application.[21*22] Autogenous cartilage is manipulated with ease while its inherent resilience lends support to the reconstruction. Infection and resorption of autogenous cartilage grafts in the nose is extremely rare.[2223] Unlike bone or alloplastic material, autogenous cartilage may be positioned in areas of little soft tissue coverage. The following proximal or distant donor sites may be considered in order of preference: septum, auricle and rib.

Autogenous septal cartilage can be harvested from the same operative field with little increase in morbidity. Depending on the size of the nose and the age of the patiënt, the length of the cartilaginous portion of the septum will vary from 25 to

40 mm. A piece of cartilage can be harvested, keeping a caudal and dorsal strut of at least 1-1.5 cm intact in order to maintain the structural integrity of the nose. Harvested septal cartilage is often straight and strong. It does not warp or curl if the surfaces are not unilaterally scored or cut. It can be easily sculptured and/or very lightly crushed to a variety of thicknesses. These characteristics make septal cartilage available for support, contouring or filling. Thin pieces of cartilage may be *very* lightly crushed to increase flexibility and adaptation, while possibly avoiding the cartilage cell loss associated with more aggressive crushing.[24] One may consider harvesting cartilage including a part of the perpendicular plate of the ethmoid attached to it, if additional length is required. However, the attached bone does decrease the degree of possible sculpting. Septal bone grafts harvested from the ethmoid and vomer have limited applicability because of their rigidity and difficulty in shaping and fixing. They are mainly used for additional septal support.[25 26]

If not enough septal cartilage can be obtained, the auricle is the second donor site to be considered. Auricular cartilage grafts are harvested through an anterior or posterior approach, but generally the anterior approach is pre-ferred.[19,21,27] The anterior incision is sited deep to and medial to the crest of the antihelical fold. To enhance scar camouflage, the incision line may be broken in the midportion. A significant portion of the concha can be removed, without deforming the donor area.[28] A variation involves harvesting both cymba and concha separately, while maintaining a bridge of cartilage for cosmetic purposes.[29] If only a smal] piece of ear-cartilage is to be harvested, a small posterior incision may be preferred. Harvested ear cartilage has a multi-curved shape, is not as strong as, and is more brittle than septal cartilage. There is a large inter-individual variability in size and thick-ness of auricular cartilage. lts thickness determines its stiffness and pliability. Preserving attached perichondrium is not obligatory, but it may enhance rapid fixation of the auricular cartilage graft.

COSTAL CARTILAGE

Costal cartilage is available in large quantities, but involves greater morbidity at the donor site. Either a submammary incision is used to harvest the fifth or sixth rib, or a more lateral, lower incision is used to harvest the distal segments of the ninth and tenth ribs. Care is taken to dissect the perichondrium off the cartilage and avoid damaging the intra-costal nerves and vessels (lying just. below and somewhat medial to the rib) and pleura.[30] To prevent warping, the graft must consist of a complete or minimally manipulated segment or one which has been carved in such a way that the stresses released are symmetrically distributed about the long axis.[31,32] In most situations, this involves symmetrical removal from both sides and using the central part of the cartilage only.[31] Plates formed from this central cartilage are ideal for septal reconstruction.[26] Although rarely indicated, costal cartilage struts are strong enough to extend from the premaxillary spine into the subdomal region to enhance tip support and projection. For total dorsal nasal augmentation costal cartilage is recommended only by a small number of authors.[31,33,34] One must be aware that in order to conform the cartilage implant to the dorsum it must be asymmetrically shaped, increasing the tendency to warp. Alternatively, screw fixed osseocartilaginous rib grafts incorporating a minimally manipulated short cartilaginous element may be used. These are associated with a decreased risk of warping.[35] It should be noted that in older patients there may be less tendency for warping but progressive calcification renders costal cartilage more difricult to sculpture.

AUTOGENOUS BONE GRAFTS

Compared to autogenous cartilage, autogenous bone grafting is a second choice. Adequate vascularity of the recipiënt bed and adequate soft tissue coverage are prerequisites. In most cases bone to bone contact is essential for the graft to survive.[6] The graft must be immobilized for 8-12 weeks to allow fixation to surrounding bone. Although bone grafts, used in either the dorsum or septum, may give support to the nose, they may lend an unnatural rigidity to the normally mobile lower two-thirds of the nose and risk fracture. Moreover, bone is difricult to shape and conform to the recipiënt site.[1935,36] Endochondral bone grafts, such as rib and iliac crest, have long been used in reconstructive surgery. In the last decade calvarial bone grafts have become increasingly popular.[37] Ani-mal studies suggest that membranous bone, such as cranial bone grafts, is significantly less resorbed compared to endo-chondral bone.[38] Still, resorption rates of calvarial bone grafts have been estimated at 20-30%.[39] Studies with over 10 years follow-up proving the reliability of membranous bone for nasal dorsal augmentation are still lacking. The possible advantages of a split-cranial bone graft must be weighed in each individual patiënt against difficulties in adapting the bone to the nasal dorsum, its limited thickness[35] and the slight but potentially serious risk of cerebral injury associated with harvesting.[40,41]

TEMPORALIS FASCIA GRAFT

Fascia from the temporal region is easily harvested within the head and neck operative field with minimal postoperative discomfort and negligible scar deformities.[42] After incising the skin and subcutaneous tissue one immediately encounters the superficial temporal fascia which is in close contact with the subcutaneous tissues. Subsequently there is a. layer of loose aureolar tissue is encountered separating the superficial temporal fascia from the superficial layer of the deep temporal fascia, which covers the temporalis muscle.[40] The superficial temporal fascia varies in thickness from 2-3 mm.[43] The aur-

eolar tissue is extremely thin. The superficial part of the deep temporalis fascia is dense and sturdy and about l mm thick. Temporalis fascial grafts are used to cover the osteo-cartilaginous framework (including cartilage or bone grafts) aiming to prevent possible irregularities or sharp edges.[44] They may also be used to fill small lateral bony or cartilaginous deficiencies. Patients with thin or traumatized skin in primary or secondary rhinoplasty may benefit from temporalis fascia interposition grafts.[45,46] Temporalis fascia grafting does not replace, but rather augments precise sculpting of the nasal skeleton. These grafts demonstrate temporary swelling in the immediate l to 2 months after operation, and with subsequent shrinkage maintain 80% of their original volume.[47] For enhanced cosmesis the nasal tip may be cushioned by peri-chondrium from the ear or septum, rather than fascial grafts, aiming to circumvent the initial swelling associated with fascial grafts. Although the usefulness of temporalis fascia grafts for significant dorsal augmentations in rhinoplasty remains debated,[48] animal studies[49]as well as long-term clinical follow-up[44,45] pro vide evidence of their stability.

The other indication for temporalis fascial grafts in rhino-plasty is scaffolding support of mucoperichondrium suture lines in septal perforation closure.[50,51] The author prefers two thin temporalis fascia grafts on either side of the septum overlapping the cartilaginous perforation, which additionally is filled with autogenous cartilage graft.[52] Intranasal muc-operichondrium/periosteal flaps are advanced, rotated or transposed asymmetrically on both sides of the perforation, covering the fascial grafts, while preventing opposing suture lines. This two-sided, non-tension mucosal closure of septal perforations which includes three layers of autogenous tissue grafts has proved to be highly reliable.

HOMOGRAFTS

Homologous cartilage seems an attractive alternative to autogenous cartilage grafts, mainly because of its apparent similarity to autogenous cartilage. Moreover, homologous grafts are not limited in quantity and eliminate donor site morbidity. Irrespective of the method of harvesting and preser-vation, the homograft matrix is invaded and replaced by adjacent connective tissue and may show reduction in volume over time.[12] Cialit preserved cartilage shows a considerable infection and resorption rate, strongly arguing against its use 53,54 Krïdei[55] suggested that irradiated cartilage in the nasal dorsum, being a relatively immobile area, does not show as much evidence of resorption as in other facial regions.[56] Because of long-term unpredictability, relatively high infection rate and the possibility of warping, homograft materials are not commonly used.[5,56,57] Ultimately, the fear of disease transmission despite rigorous precautions is also a major drawback.

XENOGRAFTS

Xenografts are also subject to resorption and are unpre-dictable in terms of volume consistency,[58] probably even more than homografts. Xenografts are not replaced by autogenous host tissue but seem to be resorbed with a variable disposition of fibrous tissue.[12]

ALLOPLASTICS

Solid silicone

This was the first alloplast to achieve widespread use in facial * plastic surgery.[59] Solid silicone is not porous and tissue ingrowth does not occur. The material exists as a relatively non-reactive inert 'space' within a fibrous capsule. On the •* nasal dorsum, the stiffincompressible silicone implant remains slightly mobile, while a dead space exists between the implant and the capsule surface, increasing the risk of infection and extrusion. Most of the silicone nasal dorsal implants have been used in oriental patients[11] and rarely used in Caucasian patients. Arguably, the thicker skin in Orientals provides better covering compared to the thinner Caucasian nasal skin. In spite of widespread successful use of silicone in Asian patients in the Oriënt, Western thought is that solid silicone implants are not recommended in rhinoplasty. Even years after surgery they may extrude.[60,61]

Mersilene

Until recently mersilene (polyethylene terephthalate) has been propagated by a selected number of rhinoplasty surgeons for dorsal augmentation.[36,62,63] Mersilene is a polyester fibre mesh which is chemically inert and shows limited susceptibility to resorption. It is not known to be subject to degradation. Mersilene mesh can be folded, sutured, and shaped with rela-tive ease, providing a natural feel and early stability, but no structural support. It has been used in the nasal dorsum with infection rates of up to 4%, necessitating removal in 2%.[36] Because of extensive fibroblast ingrowth, total removal after the initial healing phase may be extremely difficult and even impossible, posing a potentially significant problem even years after implantation. Nowadays mersilene has been largely abandoned in favour of Gore-tex® S AM.

Gore-tex(K) SAM (Subcutaneous Augmentation Material) facial implant

Gore-tex® is an expanded polytetrafluoroethylene (PTFE) polymer composed of solid nodes connected by very fine fibres oriented in a grid pattern. Depending on the fibril length, the pore size varies from 0.5-30 jti, averaging 22 ^u.[64,65] These pores permit limited soft tissue infiltratlon and cellular attachment with minimal capsule formation.[18,66] It is biocompatible, as histiocytic and foreign body giant cell reactions in the sur-rounding tissues is minimal.[17,18] The limited connective tissue

ingrowth balances sufficient stability of the implant with ease of removal.[64,67]

The soft pliable Gore-tex® PTFE sheeting used for subcutaneous augmentation is provided in patches of l-, 2- and 4-mm thickness. Gore-tex® is easily cut, carved and sculptured using scissors or scalpel and has a long record of tissue compatibility by virtue of its use in vascular surgery.[68] More recently Gore-tex® SAM facial implant has been used in facial plastic surgery for a wide range of procedures including rhinoplasty.[12,69,72] A compilation of the literature of over 300 Gore-tex® dorsal implants with maximum reported follow-up of 6 years[73] demonstrated less than 1% extrusion and less than 2% infection rate.[10,67,73,77] Remarkably, the majority of the problems occurred in one study of 24 patients.[77]

Regarding the chemical properties and tissue ingrowth characteristics, Gore-tex® sheeting is a promising synthetic material for nasal dorsal augmentation.[12,63] One of the drawbacks of the Gore-tex® for nasal dorsal augmentation is its lack of structural support. Furthermore, convincing long-term (10 years) success, with morbidity and complications com-parable to autogenous cartilage grafts, is still lacking.[78] Obvi-ously, if used at all, it should be used cautiously and selectively.

Recipiënt site

GENERAL CONSIDERATIONS

Apart from factors affecting biocompatibility, specific characteristics of the implantation site are major variables involved in the selection of augmentation material (Table 4). If complications involving the use of a biomaterial are critically reviewed, the vast majority can be traced to errors relating to one of these factors.

It must be clear that adequate soft tissue coverage is a prerequisite for optimal long-term implantation. Therefore elevating the soft tissues in a dissection plane immediately above the perichondrium and deep to the periosteum is of utmost importance. This deep dissection plane not only creates less eventual scarring, but also enhances augmentation by cushioning the edges or slight irregularities of the augmentation material.[1] Implants that are too large for the space in which they are placed put pressure on the overlying tissues and blood vessels, risking ischaemia, necrosis and possible implant failure. For the same reasons implants should be shaped according to the defect to be filled while aiming to prevent sharp and irregular edges. Post-implantation mobility may cause continuing tissue injury leading to chronic inflammation. Recipiënt tissues should, of course, be handled gently and every effort should be made to avoid haematoma formation.

Table 4. Implantation site factors influencing wound healing

Bacterial contamination
Soft tissue coverage
Wound tension Tissue
mobility Vascular supply

When non-autogenous materials are used special precautions are recommended. Utmost care must be taken to prevent contamination. The patiënt is given prophylactic antibiotics, starting l h before the operation. The implant is prepared in a clean field using previously unused instruments and new gloves, while avoiding contact between the implant and the skin. The implant is not removed from its sterile packaging, until the wound has been fully prepared. Before insertion the pocket is irrigated and the implant is soaked in antibiotic solution.

It is a basic precaution, especially with alloplasts, for all incisions to be as far away as possible to reduce the amount of bacterial contamination.[8] The transcolumellar incision of the external approach.[3,79] lies most distant to the nasal dorsal area to be augmented. Furthermore, the external approach offers ample opportunity to fix the implant with sutures if necessary. To decrease the risk of contamination of alloplastic material, the upper lateral cartilages preferably are kept attached to the septum and no medial osteotomies are performed. If it is necessary to separate the upper lateral cartilage from the septum, it is important to keep the mucosa intact. A pocket that has been exposed to the lining of the nasal mucosa (i.e. intercartilaginous incision or mucosal laceration) increases the chance of infection.[36] In a scarred, previously operated recipiënt site vascular supply is decreased suggesting the consideration of autogenous materials only. Cartilage and fascia are possibly the most reliable in these unfavourable situations.

PREMAXILLA

Premaxillary nasolabial augmentation may be indicated after iatrogenic shortening of the inferior aspect of the caudal septum or excision of the premaxillary spine and/or traumatic or congenital retrusion of the premaxilla.[80] Precise premaxillary subperiosteal pockets are made to accommodate the implant material. Autogenous cartilage or temporalis fascia are satisfactory, but the volume available is often not sufficient to produce significant change. Soft alloplastic material like Gore-tex® may be preferred.[64] The premaxilla probably tolerates a maximum of 4 mm augmentation. A greater volume increases the risk of unnatural feel and extrusion. The implant may also be used as a pedestal for a suture fixed columellar strut.

SEPTUM

Only autogenous cartilage should be used to reconstruct the septum. The thin mucoperichondrium covering does not tolerate any foreign material including homografts. Autogen-

ous cartilage from the septum, ear or even rib is preferred, with perpendicular bone grafts as second choice. Septal reconstruction may involve reinforcement using batten type grafts[26,81] or extensive replacement.[27,82] Relatively conservative surgery, maintaining caudal and dorsal struts in combination with batten grafts is recommended in most cases. Thin, strong batten type grafts may be applied onto the remaining dorsal strut[83] or caudal strut[25] or both. Especially in the nasal valve region care is taken not to impinge on the airway by the volume of the graft. If batten grafts are placed along the dorsal aspect of the septum in between the septum and the upper lateral cartilages, these grafts act as a spreader graft, by pushing the lateral nasal wall outwards enhancing the nasal airway. To straighten or strengthen the remaining caudal septal strut a graft is applied in the anterior most septal part only.[25]

For extreme septal deformities some authors have proposed partial or complete excision of a significant portion or even complete excision of the cartilaginous septum, extracorporal correction and replacement as an autograft.[82,84,85] Graft survival is good while infection is rare, but potentially dangerous. This technique is characterized by extreme mobilization (taking out the septum), and is associated with an aesthetic dorsal revision rate, of up to 8%,[84] testifying to the difficulties involved in exact replacement. Ideally, septum correction is based on the particular anatomy while surgically inducing incremental changes, each subsequent step being not more aggressive than necessary.

THE NASAL TIP

To restructure the nasal tip, including columella, lobule and ala, a variety of cartilage grafts may be applied. Autogenous cartilage should be used exclusively. Alloplasts are known to extrude[86] and bone grafts will lend an unnatural stiffness to the columella and nasal tip. The open approach is ideal for precise graft fixation and sculpting.[2,87]

A columella strut may be inserted in between the medial crurae to extend just above the nasal spine to strengthen and lengthen the medial crural complex so as to control projection.[88] Batten type grafts are helpful to fill in a retracted columella. Grafting the nasal lobule with either shield type grafts[89] or onlay grafts[90] or a combination of both[2] is one of the most powerful methods to increase tip projection[88] and shape the domal region. The added structure does help support the nasal soft tissues inducing predictable long-term changes.[29,87] As complete blending into the existing nasal anatomy may be impossible, thin skinned patients risk unaesthetic graft visibility. Cushioning of the graft with temporalis fascia or perichondrium may help.

Lateral alar cartilages may be reinforced or even replaced, preferably using cymba cartilage grafts for their inherent convex shape. These replacement or onlay type grafts aim to improve the nasal airway by reinforcing the lateral nasal wall.[21,91] To correct severe herniation of the most lateral aspect of the lower lateral cartilage in the nasal vestibule, relatively thin and straight septal cartilage grafts may be applied at the undersurface of the alar cartilage (after dissecting off the vestibular lining) while reaching out onto the piriform aperture[27,92] to provide lateralization and stabilization. Regardless of the type of graft required, the ultimate goal is always a normal anatomical structure with functional and aesthetic integrity.

MIDDLE NASAL THIRD

Autogenous cartilage grafts may be used to widen the middle nasal third for both functional and aesthetic purposes. These spreader-type grafts, originally described by Sheen[93] are most often placed between the dorsal aspects of the nasal septum and the upper lateral cartilages.[94] These grafts consist of a flat rectangular piece of cartilage averaging 10-25 mm in length, 3-5 mm in vertical height and 1-2.5 mm in thickness. One should err on the conservative side to prevent overwidening of the middle nasal third. Subtle widening can be obtained by using the cephalic portion of the lower lateral cartilages. Horizontal mattress suture fixation allows subsequent dorsal refinement. Spreader grafts can be extended up in between the nasal bones in the case of an open roof deformity or to support collapsed nasal bones.[63] With this type of nasal valve surgery a significant subjective and objective functional improvement may be obtained.[94 %]

Similar but more subtle aesthetic and functional changes may be obtained by placing spreader grafts endonasally as high as possible in the nasal vault against the intact septal/ upper lateral cartilage junction. These grafts are held in place by precise pocket formation or alternatively by a trans-cutaneous suture through the apex of the nasal valve and external skin. These grafts function similarly to a wedge. A unilateral middle third dorsal concavity caused by a septal curve or upper lateral cartilage deformity can be aesthetically improved by placing a spreader graft along the concave side, with concomitant improvement of function. Alternatively onlay grafts can be used to fill the concavity without re-positioning the upper lateral cartilages. Bone grafts from the perpendicular plate do not seem to survive when used in the lateral nasal wall.[97]

NASAL DORSUM

Most often only part of the nasal dorsum is in need of augmentation. For regional augmentation, such as in the supratip region and nasal frontal angle, cartilage grafts either from the septum or the ear are preferred because they are easily manipulated. Preferably a pocket the exact size of the implant is made, thus preventing displacement during the initial heal-ing process. The implants which are to be applied after wide field dissection are either fixed with suture or external paper tape or fibrin glue. As partial dorsal augmentation risks a

postoperative step deformity, the bony-cartilaginous dorsum may be taken down to a uniform level and subsequently raised to the appropriate height with a graft, thus converting a partial dorsal augmentation to a complete dorsal augmentation.[73,98]

More common reasons for autogenous cartilage grafting of the whole nasal dorsum are profile enhancement, as well as camouflaging irregularities and residual twists of the septum." Furthermore, onlay grafting closes an open roof in patients with a narrow bony pyramid in whom infracture of the nasal bones is contra-indicated.

Total nasal dorsum augmentation taxes the surgeon's ingenuity with regard to technique and choice of implant material. Composition of pieces of cartilage is often necessary to conform the graft to the length of the nasal dorsum and obtain a certain height, which technically is a cumbersome task.[100] Depending on the thickness of the skin-soft tissue covering, the edges of the cartilage grafts must be feathered and/or the graft may be *lightly* crushed to increase blending into the existing nasal skeleton. Extreme crushing is ill-advised as it damages viable chondrocytes, increases surface area and increases the risk of resorption. Alternatively, an additional layer of temporalis fascia to cover the graft may smooth the contour to a certain extent but necessitates a second donor site.

How well the nasal dorsum tolerates allografts remains controversial. However, in the patiënt with a lack of autogenous donor material who declines donor site morbidity and presents with a favourable nasal dorsal recipiënt site, it appears reasonable to use alloplasts such as Gore-tex.[R] These implants may be shaped from one block or layered. Care should be taken to prevent ridges and step-off deformities, especially if significant augmentation is performed. Additional localized dorsal augmentation of the nasal frontal angle or supratip region may be performed using either autogenous materials or additional layers of Gore-tex.[R] It must be emphasized that the external approach with incisions distant from the implant site is generally considered one of the pre-requisites for success.

Reflecting the advances in biotechnology, an increasing number of materials will be developed in the future. Apart from new synthetic materials, research into micro-encapsulation of autogenous chondroplasts and subsequent *in vitro* cell proliferation aiming to engineer autogenous tissue is of particular interest.[101] These exciting developments will necessi-tate even greater selectivity by the surgeon for proper implant selection.

Conclusion

Successful reconstruction of the three-dimensional shape of the nose largely depends on the type and availability of the material used for augmentation. In view of the large number of biomaterials available together with differences in nasal graft sites, appropriate material selection is a considerable undertaking.

Autogenous cartilage grafts are the mainstay of treatment because of their versatility and long-term survival. Arguments against autogenous material, such as increased surgical time and morbidity of the donor site, are only relative and should be weighed against the possibly promising but not yet proven advantages of alternatives.

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