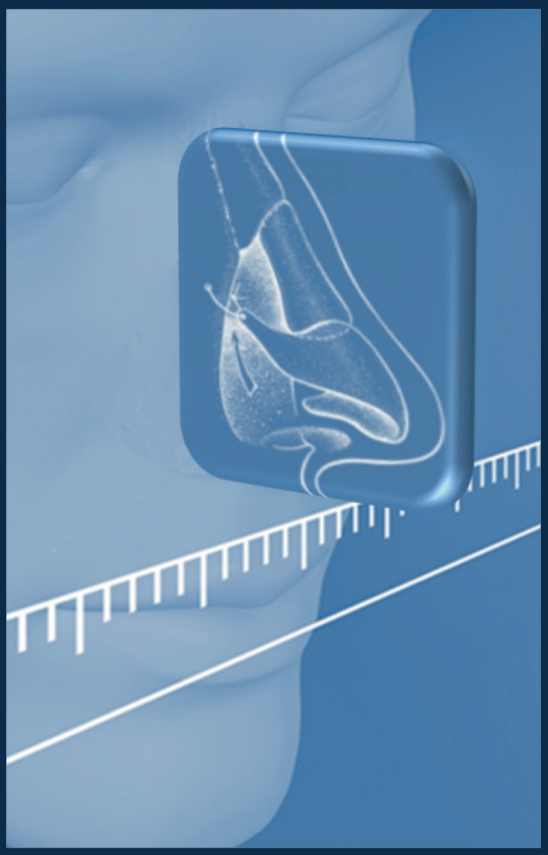
The Nasal Valve:
New Methods for Reconstruction, Suspension and Objective Measurements



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The nasal valve:
New Methods for Reconstruction, Suspension and Objective measurements

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(met een samenvatting in het Nederlands)

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Chapter 1
Introduction

Introduction

The internal nasal valve is the narrowest area of the upper airway and was first described by Mink almost a century ago.[1] Today, there is consensus that the nasal valve is divided into two distinct components, which are defined as the internal- and the external nasal valve, together the nasal valve region. This thesis deals with different aspects of the nasal valve region, which is formed and stabilized predominantly by the cartilaginous nasal skeleton. The cartilaginous nasal septum together with the upper laterals and the lower lateral cartilages are therefore closely related to the nasal valve. Consequently, patients that require reconstruction of the cattilaginous nasal skeleton often complain of impaired nasal breathing due to collapse or insufficiency of the nasal valve region.

Development of the nasal skeleton

The nose of a child is smaller compared to the nose of an adult, the nasal dorsum is shorter, there is less projection of the nasal tip and columella, rounder nostrils and a larger nasolabial angle.[2, 3] The nasal skeleton of an infant is mainly cartilaginous. The major supporting mechanism of the nose is the nasal septum, which forms a T-bar-shaped structure with the upper laterals. In adults, these upper lateral cartilages extend cephalically underneath the nasal bones, but in children they extend further to reach the anterior skull base.[4, 5]

The nasal septum is initially cartilaginous and develops due to the formation of new cartilage. Within the first postnatal year an endochondral ossification process starts in the region of the anterior skull base with the formation of the perpendicular plate. In a later stage the perpendicular plate extends due to progressive ossification of nasal septal cartilage.[6, 7] Due to this ossification process most of the cartilaginous part of the nasal septum loses contact with the sphenoid. In adults, only a small remnant of septal cartilage, the “sphenoid tail”, can be found between the cartilaginous nasal septum and the sphenoid separating the perpendicular plate from the vomer.

Nasal growth was observed to be completed earlier in females (16 to 18 years) compared to males (18-20 years). [8] The growth of the nose is not gradually but has two growth spurts, the first two postnatal years and during puberty. In this development the cartilaginous nasal septum has been demonstrated to have a morphogenetic function for midfacial growth. The cartilaginous part of the nasal septum has a 3D organization with two thicker areas with different mitotic activity and histological maturation.[9] These thicker areas, or growth zones, are approximately 3 mm thick whereas the thinner area between these zones has a transverse diameter of approximately 0.4 mm. Both zones extend from the sphenoid. The “sphenodorsal” zone is located between the sphenoid and the nasal dorsum and appears to be primarily responsible for the normal increase in length and height of the nasal dorsum.[10] The “sphenospinal” zone is located between the sphenoid and the anterior nasal spine and is the driving force in forward outgrowth of the maxilla. The thinner area of septal cartilage, in between the two growth zones, does not influence nasal development and midfacial growth.[10]

Reconstruction of the nasal skeleton in children

Both clinical observations [11-14] and experimental studies [15-22] have shown that destruction of the growth zones during childhood result in underdevelopment of both the nose and the maxilla. Destruction of these zones can be the result of septal hematomas or nasal septal abscess formation due to nasal trauma or surgery. The effect of destruction of the nasal septum on midfacial growth was found to be age related; in younger children the outcome was more severe compared with older children.[11, 12] A young child with complete destruction of the nasal septum will end up with an underdeveloped nose with saddle deformity, retraction of the columella, an over-rotation of the nasal tip and a retroposition of the maxilla.

The aim to perform septorhinoplasty in children therefore is to restore the nasal septum to promote normal development and outgrowth of the nose. For every indication the expected benefits of intervention should be weighed against the possible adverse outcomes on nasal and midfacial growth. In the ideal situation surgery should be postponed until after the pubertal growth spurt. However, there are indications for immediate intervention like in destruction of the nasal skeleton due to a nasal septal abscesses or severe nasal trauma. Reconstruction of partial or completely destructed septal cartilage in which the growth zones are involved, is essential for the normal development of the nose and the maxilla. Different types of reconstruction materials have been described in literature. The nasal septum has been reconstructed with homologous cartilage implants but both clinical evidence and animal models have shown conflicting results. [23-27] At present, autologous cartilage is the implant material of choice in adults, which is consistent with the objectives of optimal long-term postoperative results with limited risk of resorption, infection, or extrusion. [28-31] However, there is lack of evidence in terms of prospective studies, that reconstruction of the nasal septum with autologous cartilage grafts promotes the normal development of the nose in children and prevents the sequels as mentioned above.

Reconstruction of the nasal skeleton in adults

In adults, reconstruction of the nasal skeleton can be indicated for patients with functional- and aesthetic problems due to collapse or insufficiency of the nasal valve region; for example after trauma, previous rhinoplasty, congenital disorders or mucosal diseases like Wegener's granulomatosis, sarcoidosis or leprosy.

In reconstruction of the nasal skeleton different types of grafs or implant materials can be used; autogenous cartilage and -bone grafts, synthetic alloplasts such as silicones, Teflon and expanded polytetrafluoroethylene (Gore-tex®) or homologous cartilage grafts such as irradiated homologous rib grafts (IHRGs). The most frequently used grafts for nasal reconstruction are autogenous cartilage grafts, either from donor sites of the nasal septum, auricular concha or costal cartilage. [28] Autogenous cartilage is successful in the long term, and infection or resorption in the nose is rare. [32-34] Autogenous bone grafts, on the other hand, have higher resorption rates, are more difficult to shape and sculpture to the recipient site and their biomechanical features are

less tolerated in the natural flexibility of the nasal tip area. [35-39] Alloplasts are attractive because of their relative ease of use and availability in unlimited supplies but they have the disadvantage of a relatively high incidence of infection and extrusion. [40-45] Irradiated homologous rib grafts (IHRGs) can be a good alternative for autologous rib grafts with less morbidity and the advantage of their availability in unlimited supplies and ease of use. IHRGs have low complication and resorption rates. [46-49] The rate of resorption varies in different studies and some reports mention that the original grafts may be replacement by fibrous scar tissue. [46-54] However, there are still no reports about resorption rates for specific nasal recipient sites concerning the long-term efficacy of IHRGs for both augmentation and support function.

In modern rhinoplasty, autogenous cartilage is still the material of choice for the reconstruction of the nasal skeleton. [41, 55-58] However, there is lack of evidence how autologous cartilage grafts behave in recipient sites with poor conditions, like in leprosy patients. Leprosy-related saddle-nose deformities are challenging and difficult to reconstruct with the techniques that have been proposed in the past. The literature concerning saddle-nose deformities in leprosy describes a variety of reconstruction techniques and graft materials. Bone grafts, nasolabial skin flaps, forehead flaps, postnasal inlay of split-skin grafts, auricular and costal rib cartilage grafts and alloplasts are the most widely used in leprosy-induced nasal deformities. [55, 59-64]

Reconstruction of the nasal valve using suspension sutures

Collapse of the lateral sidewall of the nasal valve region during inspiration is a frequently encountered symptom of impaired nasal breathing. In addition to the use of cartilage grafts many techniques have been described to improve the nasal patency in these patients. The goal of most procedures in nasal valve surgery is to widen the cross-sectional area and/or strengthen the lateral sidewall. Until now, different surgical methods to deal with nasal valve collapse have been described; they can be divided into four groups. The first group consists of cartilage grafts such as the spreader graft, [65] the upper lateral splay graft, [66] the butterfly graft, [67] and the alar batten graft. [68] The second group includes repositioning and reallocation techniques like the upward rotation of the lateral crura of the lower lateral cartilages[69] or an alar base Z-plasty to widen the external nasal valve. The third group comprises alloplast implants such as titanium implants to widen and strengthen the nasal valves (aWengen, [Breathe-implant, Heinz Korz GmbH, Dusslingen, Germany]) or polyethylene implants to reverse the collapse of the midnasal third. [70] The fourth group consists of suspension suture techniques, methods in which sutures are used to lateralize or strengthen the lateral component of the nasal valve region. There are three major suspension techniques described in the literature: nasal valve suspension in the direction of the orbital rim; spanning sutures across the nasal dorsum; and the suspension and rotation of the lower laterals toward the piriform aperture. [71-81] In most suspension suture techniques, the suture is placed at the site of maximum collapse through the upper or lower lateral cartilage and fixed to a rigid anchor point located laterally to the nasal valve. Often, this rigid point is through a hole in the bone at the site of the orbital rim or nasal bone. The surgical approach, the site of incisions, the

type of suture material and whether they are located submucosal or exposed to the outside world is different in the current techniques. So far, there is not a single endonasal technique that uses of a permanent submucosal suspension suture that exclusively widens the external nasal valve. Moreover, there is little evidence that suspension suture techniques improve the subjective nasal patency using validated instruments or objective tests to evaluate nasal patency.

Objective measurements in nasal valve surgery

Today, there is still no consensus regarding the value of objective measurements in the evaluation of nasal patency. Rhinomanometry, acoustic rhinometry and Peak Nasal Inspiratory Flow (PNIF) correlate poorly with the individual subjective sensation of breathing. This correlation however, is greater when each nostril is evaluated individually and in the presence of breathing problems but results are conflicting and the role of these techniques in current medical practice is limited. [82, 83] In most of these studies the subjective complaints of patients were often not defined or were measured with non-validated instruments. Today there are validated patient reported outcome measures (PROMs) such as the SinoNasal Outcome Test (SNOT-22) and the Nasal Obstruction Symptom Evaluation score (NOSE) that have been developed to be good and validated assessment tools in both clinical and research setting. [84-89] There is however, no evidence that functional septorhinoplasty provides improvement the nasal passage in validated PROMs for adults with an anatomical obstruction of the nasal valve. In the current objective measurements that use computed tomography (CT) to calculate the cross-sectional area of the nasal passage do not determine the true Minimum Cross-sectional Area (MCA). [90-93] In search for an objective, quantifiable test that correlates with the subjective complaints of the patient objective measurement of the MCA on CT might be helpful in the diagnosis, as well as the choice and evaluation of surgical treatment for nasal valve insufficiency.

Postoperative care of nasal valve surgery

Several studies have shown that adequate postoperative care greatly influences final results after surgery of the nasal valve. [94-98] Recurrence of narrowing of the nasal valve is a well-known problem after rhinoplastic surgery and is predominantly caused by scar tissue retraction. This is the problem, in particular, in patients with internal nasal valve pathology, in case of stenosis this region is susceptible to impaired nasal breathing. [99] The cause of wound contraction is the inward movement of the intact edges of the injured tissue, which occurs during wound healing. The effect of this physiological phenomenon is to decrease the dimension of the area of trauma to its smallest possible extent and is due to the action of fibroblastic differentiation into myofibroblasts. [100] These myofibroblasts have ultrastructural characteristics of smooth muscle cells and are maximally present in the wound from the 10th until the 21st day. To avoid re-stenosis, it is necessary to maintain the contour of the nasal valve area during wound contraction. [94, 101] To reach this goal and to prevent re-stenosis of the valve region, many reports proposed the use of some kind of nasal stenting in the postoperative period. [97, 102-106] Most of these splints are commercially available and made of elastic silicone or acrylic resin. However, there is no evidence that the use of a (custom made) device in the post-operative period may help reduce the chance of developing re-stenosis or improve nasal patency or the aesthetics of the nose.

All of the before mentioned nasal valve related issues are discussed in this thesis, as well as research of new concepts and techniques, in the following chapters.
In **chapter 2**, several issues relating to the use of different types of homologous- and autologous cartilage grafts for the reconstruction of the nasal valve region and nasal skeleton are dealt with. The question is raised whether irradiated homologous rib grafts (IHRGs) are safe and provide a stable long-term reconstruction of the nasal skeleton. Do IHRGs resorp, how is resorption characterized and is there a difference between recipient sites in the nose. The long-term efficacy of IHRGs for both augmentation and support function was studied retrospectively. Another question dealt with severe saddle nose deformities in leprosy patients. Reconstruction of these deformities is complicated by the quantity and the poor quality of the remaining nasal mucosa and requires new surgical techniques. What are the preferred surgical techniques and which types of autologous cartilage grafts are needed for the reconstruction of different grades of leprosy induced saddle-nose deformities. In this study we provide a grading system for leprosy-induced deformities of the nose and guidelines for nasal reconstruction based on this grading system.

Finally the question is raised how to promote a normal development of the nose and the maxilla in children with near complete- or total loss of septal cartilage after a hematoma or abscess of the nasal septum. In this prospective study we introduce a new surgical technique to reconstruct the nasal septum with the use of autologous cartilage grafts affixed to polydioxanone (PDS) plate.

In **chapter 3**, a new surgical technique for external nasal valve insufficiency is described, the "lateral crus pull-up". With the use of this method the lateral crus of the lower lateral cartilage is rotated upward and affixed to the piriform aperture with a permanent submucosal suspension suture though a modified delivery approach. This chapter also describes a new method to objectively determine the minimum cross-sectional area of the nasal passage on computed tomography (CT-MCA). To evaluate CT-MCA we performed a prospective study in patients that underwent a lateral crus pull-up procedure and compared pre- and postoperative outcomes of CT-MCA in relation to other objective tests. Finally the question is raised whether functional septorhinoplasty provide improvement of the nasal passage in validated patient reported outcome measures (PROMs) for adults with an anatomical obstruction of the nasal valve.

In **chapter 4**, the postoperative care of nasal valve surgery in patients with stenosis of the nasal vestibule is studied using a new custom made vestibular device. We performed a retrospective study to evaluate the effect of this custom-made device on the occurrence and severity of re-stenosis.

In **chapter 5**, the discussion and conclusions of this thesis are to be found. A summary of the presented research in this thesis is given in English and in Dutch in **chapter 6**.

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Chapter 2

Cartilage grafts and reconstruction of the nasal valve

Chapter 2.1

Irradiated homologous rib grafts in nasal reconstruction

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Abstract

Objective: To assess the long-term efficacy of irradiated homologous rib grafts (IHRGs) for both augmentation and support function in rhinoplasty in general and for specific recipient sites within the nose.

Design: A retrospective study was conducted at an academic medical center to evaluate the loss of volume and support function of IHRGs in 9 specific recipient sites in the nose.

Results: We studied 66 patients, with a total of 177 IHRGs, dating back 9 years, with an average follow-up of 51 months. The rate of resorption increased with duration of follow-up. Complete resorption was found in 1 IHRG, and moderate resorption was observed in 55 IHRGs (31%). Resorption was characterized by a loss of support function rather than a loss of volume. Moderate resorption had a negative clinical outcome for shield grafts only.

Conclusions: Irradiated homologous rib grafts were safe to use in rhinoplasty. In cases requiring a shield graft, IHRGs should be avoided.

Introduction

Controversy persists about the resorption and complication rates for irradiated homologous rib grafts (IHRGs) in rhinoplasty and facial plastic and reconstructive surgery. In general, IHRGs can be used to augment and/or to provide structural support in a recipient site. The accepted advantages of this material are the elimination of additional incisions for graft harvesting and donor site morbidity as well as ready availability. Nevertheless, there are conflicting reports regarding the resorption rate, the resistance to infection and extrusion, and the threat of introducing infections with viruses or prions.

The first publication relating to the use of IHRGs in the human face dates back almost half a century.[1] Since that study, multiple clinical reports have been published, often with low complication and resorption rates.[2,3,4,5] However, both animal studies and long-term follow-up series have shown that the incidence of resorption increases with the duration of follow-up to rates in excess of 75%.[6,7,8] In addition to the time factor, the recipient site also seems to affect the rate of resorption.[2,9,10] This could be explained by 2 factors. The first involves the vascularity of the implant in the recipient bed. Relatively low vascularity is thought to be associated with higher resorption rates.[8,10] The second involves trauma or microtrauma due to muscle activity and stresses that may be associated with higher resorption rates.[9] The IHRGs that were used to reconstruct the auricle, for example, were more susceptible to graft failure than nasal grafts.[10] Previous studies have shown that the resorption of IHRGs can be characterized by a loss of volume and/or a loss of support function. The latter can be explained by the replacement of the original IHRGs by fibrous scar tissue.[2,8,9] In rhinoplasty, however, there are still no reports (to our knowledge) about resorption rates for specific nasal recipient sites.[2] The aim of this study was to assess the long-term resorption and complication rates for IHRGs in rhinoplasty, with special emphasis on particular nasal recipient sites. We hoped to identify the nasal regions where IHRGs are safe to use and to determine whether they achieve a stable long-term result in terms of the structural support function and volume preservation.

Methods

This study included all patients undergoing nasal surgery with IHRGs between November 1998 and August 2005 in the Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands.

Surgical management and implants

All IHRGs were obtained from Tutoplast (Tutogen Medical GmbH, Neunkirchen am Brand, Germany). The rib implants were selected according to stringent specifications with respect to donor selection and serologic study results to minimize the risk of transmitting infectious disease. After the removal of the rib cartilage, the process started with several cycles of alternating baths in deionized water and 10% sodium chloride. The cartilage was then soaked in 3% hydrogen peroxide for 24 hours, after which the material was placed in pure acetone

several times followed by evaporation under vacuum. Final packaging consisted of placing the cartilage in sterile screw-cap vials and adding sterile normal saline. The grafts were then sterilized by gamma irradiation with a minimum dose of 1780 krad (to convert to grays, multiply by 10) and a maximum dose of 2010 krad.

During surgery, the grafts were aseptically removed from the container and rinsed 3 times in 500 mL of sterile saline solution. To prevent warping, the outer layers were removed, including the perichondrium, leaving only the central portion of the donor cartilage for reconstruction material. Graft implants were shaped, sculptured, and beveled with fresh scalpels. In most cases, the procedure consisted of an open approach through a broken columellar incision. An open approach was not technically necessary in all cases, but it was used to prevent postoperative infection by minimizing intranasal incisions and taking advantage of the elongated distance between the graft implants and the outer world. Amoxicillin (1500 mg in 3 doses for 7 days) was administered orally to all patients to prevent postoperative infection.

Evaluation of the postoperative results

To evaluate the postoperative results, we analyzed the rate of resorption, infection, extrusion, and warping and the condition of the overlying soft-tissue envelope. We also assessed and classified the resorption rates for each individual graft. This evaluation took into account the amount of volume or augmentation, graft integrity, and support function. The amount of volume or augmentation of each implant was studied by comparing postoperative photographs 3 months after surgery with those taken at the time of evaluation. Also, each implant was palpated to assess graft integrity and support function. We developed 3 levels of resorption. The first level, N (none, 0%-25%), was classified as no loss of graft volume and no changes in graft integrity or support function. The second level, M (moderate, 25%-50%), was classified as an evident loss of graft volume and/or evident loss of graft integrity or support function. The third level, C (complete, >50%), was classified as a complete loss of volume and/or a complete loss of graft integrity and support function. This third level was characterized by the necessity for revision surgery.

The rate of postoperative infections was based on the need for local or systemic antibiotic therapy, the localization of the infection, and the need for surgical removal or extrusion of the implant. We evaluated the functionality of the alar batten grafts by comparing the patients' subjective nasal passages with their condition 3 months after surgery. Finally, we assessed the rate of warping, the reactions in the overlying soft-tissue envelope, and the mobility of the implants. The patients were divided into 3 groups depending on the duration of follow-up: the first group (group 1) was followed up for 18 to 44 months; the second group (group 2) was followed up for 45 to 70 months; and the third group (group 3) was followed up for 71 to 96 months.

Results

Between February 1999 and August 2005, a total of 90 patients underwent reconstructive rhinoplastic surgery with IHRGs. We were unable to evaluate 24 patients (27%). Fourteen of the 24 patients were untraceable: 6 patients were satisfied with the functional and aesthetic result but did not want to participate in the study; 3 patients underwent revision surgery with autogenous cartilage grafts owing to persistent functional or aesthetic problems that were not related to the resorption of the grafts or other IHRG-related complication; and 1 patient died during follow-up as a result of causes that were not related to his nasal surgery.

Sixty-six patients (73%) were evaluated in this study (29 men and 37 women) during a follow-up period ranging from 18 to 96 months (average follow-up, 51 months). The patients' ages on the date of surgery ranged from 15 to 68 years, with an average of 39 years. A total of 177 IHRGs were implanted in these 66 patients (Table). Ten of the 66 patients underwent primary rhinoplasty, and 56 underwent a revision procedure. Fifty-two of the 56 patients had undergone previous surgery elsewhere, and 4 had undergone previous surgery in our clinic: 2 with IHRGs and 2 without IHRGs. The endonasal approach was used in 8 of the 66 patients, with 58 patients undergoing an external approach. The indication for nasal surgery in 27 patients was a saddle nose deformity without recent infection; 21 patients had functional-aesthetic problems requiring nasal grafts; 15 patients had a unilateral cleft lip; 2 patients had extrusion of a silicone implant; and 1 patient had a septal perforation.

Table. Resorption of Irradiated Homologous Rib Grafts

		Resorption											
		Group 1[a] (n=29)			Group 2[b] (n=24)			Group 3[c] (n=13)			All 3 Groups, No. (%) (N=66)		
Type of Implant	No.	N	M	C	N	M	C	N	M	C	N	M	C
Columellar strut	42	16	4	0	9	6	0	3	4	0	28 (67)	14 (33)	0
Caudal septal replacement	24	9	2	0	2	5	0	2	4	0	13 (54)	11 (46)	0
Shield or tip graft	27	12	2	0	3	4	1	2	3	0	17 (63)	9 (33)	1 (4)
Dorsal or nasofrontal onlay	40	16	3	0	10	5	0	3	3	0	29 (72)	11 (28)	0
Alar batten	30	7	0	0	7	0	0	9	7	0	23 (77)	7 (23)	0
Spreader graft	4	0	0	0	2	0	0	2	0	0	4 (100)	0	0
Side wall onlay	3	1	0	0	0	2	0	0	0	0	1 (33)	2 (67)	0
Alar rim graft	2	2	0	0	0	0	0	0	0	0	2 (100)	0	0
Columellar onlay	4	1	0	0	1	1	0	1	0	0	3 (75)	1 (25)	0
Maxilla augmentation graft	1	0	0	0	1	0	0	0	0	0	1 (100)	0	0
Total, No. (%)	**177** (100)	**64** (85)	**11** (15)	0	**35** (59)	**23** (39)	**1** (2)	**22** (51)	**21** (49)	0	**121** (68)	**55** (31)	**1** (1)

Abbreviations: C, complete (>50%); M, moderate (25%-50%); N, none (0%-25%).
[a] Follow-up, 18 to 44 months.
[b] Follow-up, 45 to 70 months.
[c] Follow-up, 71 to 96 months.

The resorption rate of the IHRG implants was evaluated as described in the "Methods" section. Among the group as a whole (66 patients, 177 nasal grafts), 121 of the grafts (68%) had no signs of graft resorption and 55 (31%) had moderate resorption (Table). One graft had complete resorption, which required revision surgery. In group 1 (29 patients, 75 nasal implants), 64 implants (85%) showed no signs of resorption, and 11 (15%) showed moderate resorption. In group 2 (24 patients, 59 nasal implants), 35 implants (59%) showed no signs of resorption, 23 (39%) showed moderate resorption, and 1 (2%), a shield graft, showed complete resorption. In group 3 (13 patients, 43 nasal implants), 22 implants (51%) showed no resorption, and 21 (49%) showed moderate resorption. Complete resorption was not observed in this group. After the use of alar batten grafts (n = 40), functional improvement in nasal breathing was observed in 37 cases (92%).

In 15 of the 66 patients (23%), 17 complications other than resorption were observed.

Complication	No.
Infection	6
Extrusion / removal implant	0
Warping	2
Reaction soft tissue envelope	8
Mobility	2
Total	17

A postoperative inflammatory response was noticed in 6 patients (9%) who had undergone revision surgery through an external approach. In all cases, the response was characterized by localized erythema and edema of the soft-tissue envelope without purulent discharge or fever. Five of the 6 patients were treated with oral systemic broad-spectrum antibiotics (amoxicillin/clavulanic acid, 500/125 mg every 6 hours). The other patient was treated with a topical antibiotic ointment. None of the implants needed to be removed, and no recurrent or chronic infections were observed. The onset of the inflammation occurred within 1 month after implantation in all cases. On average, the clinical signs started on the 13th day. The inflammation was localized in the nasal tip in 1 patient, in the dorsum in 1 patient, and in the columella in 3 patients. The erythema was located in the tip and columella region in 1 patient. No association was found between inflammation and a higher resorption rate. There was no extrusion of implants. Minimal warping of a dorsal onlay graft was observed in 2 of 40 cases (5%). In 2 other cases (5%), also with dorsal onlay grafts, the patients complained of mobility in the cranial part of the implant at the site of the frontonasal groove during palpation. In 7 of the 66 patients (11%), reactions were observed in the overlying soft-tissue envelope. Diffuse chronic redness of the skin was detected in 3 patients (5%), 2 of whom had an inflammatory response in the postoperative period (2 of 6 patients [33%]). In 4 of the 66 patients (6%), there were signs of telangiectasia of the soft-tissue envelope overlying a dorsal onlay graft (4 of 40 patients [10%]).

Comment

Our data showed that the incidence of graft resorption of IHRGs increased with the duration of follow-up. Clinically, the most important finding was that resorption of IHRGs was characterized by a loss of support function rather than by a reduction of volume. These findings were in agreement with other long-term follow-up studies[8,10] and animal data.[6,7,9] In the literature, it has been suggested that the original grafts are replaced in time by fibrous tissue, resulting in a loss of support function without a loss of volume.[8] This phenomenon, and relatively short follow-up periods, may also explain the more favorable outcomes regarding the rate of resorption in some other studies.[1,2,4,5,11,12,13,14,15,16,17]

More specifically for rhinoplasty, Kridel and Konior[2] described the largest series so far, with 122 rhinoplastic procedures in which 306 IHRGs were used. In their study, the follow-up ranged from 1 to 84 months, with an average of 15 months. Complete resorption was noted for 2 grafts (both in the same patient). This total resorption was found early in the postoperative phase and resulted from a localized infection at the graft site. Partial resorption (0%-25%) was seen in 2 patients, both cases involving a dorsal onlay graft. Murakami et al[4] described a series of 18 patients with saddle nose deformities. Reconstruction was performed using IHRGs, a dorsal onlay graft attached to a collumelar strut. Follow-up ranged from 1 to 6 years (mean, 2.8 years), and none of the IHRGs showed infection, extrusion, or noticeable resorption. Burke et al[10] studied 118 patients who had undergone nasal reconstruction in which a total of 177 IHRGs were used. Four of 13 patients (30%) with follow-up of 5 to 10 years had severe to complete loss of graft volume (51%-100% resorption), whereas 2 of 3 patients (66%) with follow-up of more than 10 years showed this volume reduction. Loss of structural support with compromised nasal function or aesthetics for the same follow-up periods occurred in 3 of 14 patients (21%) and in 1 of 3 patients (33%), respectively. Burke and colleagues[10] also studied the long-term outcome of IHRGs for auricular reconstruction and found resorption in 5 of 7 patients (71%). The typical appearance was an amorphous mass, which was probably due to the replacement of the original grafts by fibrous tissue. The IHRGs from our series were obtained from Tutoplast. Because these grafts were chemically processed with peroxide and acetone before irradiation, they might not behave the same as nonchemically processed irradiated rib grafts. Irradiated homologous rib grafts from the same manufacturer were used to augment the nasal dorsum as dorsal onlay grafts, or they were diced and wrapped in oxidized cellulose (Surgicel; Johnson & Johnson, New Brunswick, New Jersey). With a mean follow-up of 36 months, recurrence of dorsal depression was observed in 5 of 23 patients (22%). This recurrence was probably attributable to partial resorption.[18] Song et al[19] noted partial resorption of dorsal onlay grafts in 6 of 35 cases (17%). Our study was intended to assess which types of nasal grafts were reliable for a favorable long-term functional and aesthetic outcome. In the evaluation of the resorption rate, the amount of volume and support function were taken into account. Both parameters were evaluated in a subjective manner, but with the use of the classification system described in the “Methods” section, we studied and analyzed the results as objectively as possible. As we stated earlier, the rate of complete resorption in our

series was low. Only a shield graft was completely resorbed. In that case, palpation confirmed the presence of graft tissue underneath the overlying soft-tissue envelope, with a reduction of tissue consistency compared with the original IHRG graft. The incidence of moderate resorption, on the other hand, increased with duration of follow-up to levels of 49% in patients with follow-up of 71 to 96 months. However, the clinical consequences of resorption were different for the distinct types of nasal IHRGs used. Nasal IHRGs with a need for structural support were more likely to lose their function. Shield grafts for increasing nasal tip projection were most at risk. In cases of moderate resorption, these grafts showed less tissue consistency during palpation. Clinically, the nasal tip in these cases showed a loss of tip definition and refinement and became more bulbous in comparison with the situation 3 months after surgery. Consequently, there was minimal loss of nasal tip projection. Columellar struts and caudal septal replacement grafts were clearly less rigid on palpation, but, in general, there was little to no loss of projection. In time, IHRG dorsal onlay grafts were also found to have lost tissue consistency on palpation, but the contour was generally well preserved. In all cases involving alar batten grafts, the implants were palpable and showed some reduction of tissue consistency. However, improvement of nasal breathing was achieved in 37 of 40 cases (92%). Improved nasal passage with spreader grafts was found in 4 of 4 cases (100%).

In our study, we found that nasal IHRGs underwent no or minimal reduction in volume, but it is possible that some structural support might be lost over time. For most types of grafts, this loss in tissue consistency did not negatively influence the functional or aesthetic result. However, with the use of IHRG shield grafts, tip definition and refinement were at risk in the long term. For shield grafts, therefore, we recommend the use of autologous cartilage grafts such as auricular or costal cartilage. In a previous study involving patients with leprosy,[20] autogenous costal cartilage shield grafts underwent more resorption (55%) than auricular grafts (23%). The lower resorption rate and more favorable physical properties owing to the natural flexibility of auricular cartilage made this the material of first choice in the lower nasal third in cases in which shield grafts were needed. Auricular cartilage is probably more resistant to resorption caused by microtrauma and stresses from the overlying soft-tissue envelope in the nasal tip area than irradiated and autogenous costal cartilage. Localized erythema and edema of the skin in the postoperative phase was the most frequently noted complication (6 of 66 cases [9%]). This symptom, however, completely disappeared with the use of orally and/or locally administered antibiotics. Frequent postoperative assessments after surgery with IHRGs are therefore essential to avoid progression of the inflammation response and/or infection. At the site of the inflammatory response, however, 2 of the 6 patients developed a diffuse chronic redness of the skin. In our series, minimal warping was observed in 2 of 40 dorsal onlay grafts (5%). Warping can be prevented by using only the centrally cut pieces of rib cartilage. In a controlled experimental study, the rate of warping in irradiated and nonirradiated costal cartilage proved to be similar for at least 4 weeks.[21] Two patients in our series had undergone previous surgery elsewhere involving a silicone implant. Both patients developed a chronic infection that did not respond to antibiotic

therapy. In these patients, immediate reconstruction with IHRGs was performed. Immediate reconstruction has advantages over reconstruction at a later date after a period of resolution of the inflammation.[22] When reconstruction is performed immediately, patients need not wait for a secondary reconstruction, and this is emotionally beneficial. Also, there will be less change caused by retraction of the pocket underneath the soft-tissue envelope as a result of scar tissue formation. In both patients, there were no complications in the postoperative period and, in particular, no signs of infection or extrusion. These findings were in line with similar observations in a series of 18 patients described by Clark and Cook.[23] Impregnation of the IHRGs with antibiotics could conceivably result in a further reduction of the risk of postoperative infection in cases in which the implant bed is already infected.[24]

In conclusion, in our study, the use of IHRGs in rhinoplasty resulted in relatively low complication rates. The resorption rate increased with duration of follow-up. Resorption was characterized by a loss of structural support rather than by a loss of volume. This phenomenon was probably the result of the replacement of the original grafts by fibrous scar tissue. Complete resorption requiring revision surgery was uncommon. There was moderate resorption in half of the cases with a follow-up period of 71 to 96 months. For most types of nasal grafts, moderate resorption did not negatively influence the functional or aesthetic result. However, in cases of moderate resorption of IHRG shield grafts, there was loss of nasal tip definition and nasal tip projection. In cases in which a shield graft is a clinical necessity, we recommend the use of autogenous auricular cartilage grafts.

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Chapter 2.2

Reconstructive surgery of the leprosy nose: a new approach

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Summary

There has still been no reduction in the detection rate worldwide for leprosy, despite supervised multi-drug therapy. In time, leprosy can result in a severe saddle-nose deformity leading to functional problems, disfiguration and stigmatization. In severe cases, only the nasal skin tissue and the lower lateral cartilages are preserved. In such cases, the ideal would be to restore the cartilaginous skeleton but, by contrast with other causes of saddle-nose deformities, this is complicated by the quantity and the poor quality of the remaining nasal mucosa. Leprosy-related saddle-nose deformities are therefore challenging and difficult to reconstruct with the techniques that have been proposed in the past. In this study, 24 patients underwent rhinoplastic surgery involving the use of autogenous costal and/or auricular cartilage or composite grafts. The nasal septum, the upper laterals and the anterior nasal spine were reconstructed with a dorsal onlay attached to a columellar strut with an extension on the proximal side. Before surgery, the saddle-nose deformities were classified according to severity with a new system based on clinical symptoms and signs. Postoperative evaluation was performed at least two years after surgery (N = 17). Functional and aesthetic improvement, resorption rate, warping, infection and extrusion were analysed. Functional and aesthetic improvements were achieved in 15/17 patients. None of the patients developed an infection and extrusion or warping of the implants was not observed. The resorption rate depended on the localization and the type of cartilage implant. In general, auricular conchal cartilage implant grafts resulted in less resorption than costal cartilage. Least resorption (4/17 patients) was observed in the dorsal onlay grafts of both conchal (1/6) and costal cartilage grafts (3/11). Resorption of columellar strut implants and shield grafts was observed in 7/17 patients. No resorption was seen of composite grafts (0/4) and alar battens (0/7). Autogenous cartilage implants can be used to reconstruct saddle-nose deformities in leprosy with a minimum risk of complications. The preoperative grade of severity was used as a basis for the development of guidelines for optimal long-term functional and aesthetic outcome.

Keywords:

Saddle nose; Leprosy; Reconstruction; Costal rib cartilage; Implants

Introduction

Leprosy, or Hansen's disease is a chronic granulomatous infection of skin tissue and peripheral nerves caused by Mycobacterium leprae, an intracellular bacterium. In the past this disease was widespread. However, at present, it is mainly seen in tropical regions such as Africa, South America and Asia. The widespread implementation of supervised multi-drug therapy has been associated with a fall in the prevalence of leprosy but there has not yet been any reduction in the case detection rate worldwide. Nevertheless, 107 of the 122 countries endemic for leprosy in 1985 have achieved the WHO elimination target of a reduction in the prevalence of leprosy patients receiving antimicrobial therapy to less than one per 10 000 population. At present, 83% of recorded cases are concentrated in only six countries: India, Brazil, Burma, Indonesia, Madagascar

and Nepal.[1] Although many classifications have been proposed, Ridley and Jopling's spectrum of disease model[2] is still widely used. It combines clinical and histological findings into five groups expressing patient immunity. These five groups are indeterminate (I), tuberculoid (TT), borderline tuberculoid (BT), borderline borderline (BB) and the most severe stage, lepromatous disease (LL). The port of entry is considered to be the respiratory tract, with the nose playing a central role [3,4] in spreading the disease through nasal secretions.[5,6] The clinical symptoms include skin lesions, nerve damage, blindness, hair loss of the eyebrows and systemic features like testicular atrophy and involvement of bone, the renal system and the nasal mucosa.

Destruction of the nasal lining and saddle-nose deformity

One sequel of leprosy is visible in the middle of the face and cannot be concealed by the patient: the development of a severe saddle-nose deformity caused by the destruction of the nasal skeleton. This process is probably induced by damage to the mucosal lining of the nose. These changes to the mucosa are only visible microscopically in indeterminate (I) and tuberculoid (TT) conditions with signs of cellular infiltration and vasculitis. However, in time, mucosal disintegration occurs and severe damage can also be seen macroscopically in lepromatous disease (LL).[7] At this stage of disease, this lining is destroyed and the underlying cartilage is exposed, resulting in secondary infection and necrosis of the nasal septum and subsequently a septal perforation. Together with resorption of the nasal spine, a saddle-nose deformity can develop with an acute nasolabial angle and lack of columellar show. The causes of the destruction of the nasal mucosa are still not fully understood but the fact that this is mainly a feature in lepromatous patients (LL) suggests that non-mechanical factors such as secondary infections – rather than nose picking and sensitivity disorders – are the main reason. The process can extend to involve the nasal bones, with flattening of the nasal bridge and complete destruction of all nasal turbinates. As the disease progresses, typical vertical alar grooves and vestibular stenosis may develop due to scar tissue retraction. The final result, a severe saddle-nose deformity, not only causes functional difficulties such as impaired nasal breathing and crusts, but also aesthetic problems, and particularly stigmatization. The ideal solution would be to restore the normal cartilaginous skeleton but, in saddle-nose deformities caused by leprosy, this is precluded by the quality and the quantity of the nasal mucosa. The nasal mucosa is of poor quality, causing the destruction of the nasal septum and upper laterals, but there is also damage to the lateral wall of the nasal cavity. As with the resorption of the nasal septum, the turbinates also disappear completely. The remaining mucosa is prone to inflammation, chronic infections and excessive crust formations. These conditions make the reconstruction of the nasal septum with the use of local mucosal flaps impossible and inadequate for a good functional and aesthetic result in the long term. Severe saddle-nose deformities caused by leprosy therefore require reconstruction techniques that are outside the scope of the techniques required when only the septum has disappeared, for instance after a septal abscess.

Materials and methods

Between 1995 and 2000, we performed rhinoplastic surgery on 24 Brazilian lepromatous leprosy (LL) patients, 19 men and 5 women, average age 40 years (range 16–63). All patients had a severe saddle-nose deformity. They had completed multi- or monotherapy and were being treated in the leprosy centre in Bauru, Instituto Lauro de Souza Lima. A standardized history was taken and ENT examination was performed in all patients. The questions focused on the history and functional symptoms such as impaired nasal breathing and the formation of nasal crusts. Nasendoscopy and nasopharyngoscopy, including intranasal photography, were performed on every patient using a Storz 30° and 70° optic scope (Fig. 1). Resorption of the anterior nasal spine and cartilaginous septum was diagnosed by palpation and standard sinus X-rays. Standardized photographs of the face of all patients (frontal, lateral, oblique and basal view) were taken preoperatively and in the immediate postoperative stage.

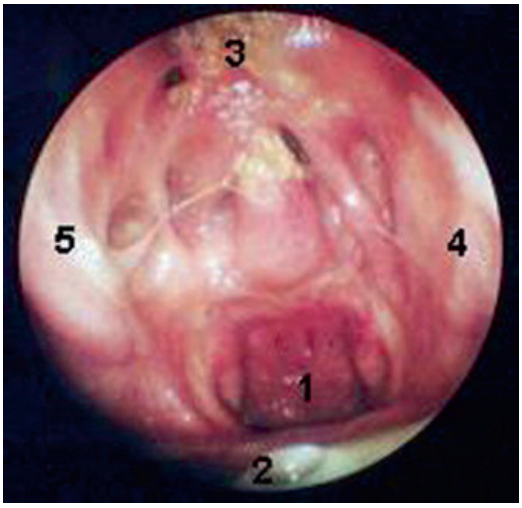

Figure 1. Endoscopic view of the nasal cavity. The nasal septum has completely disappeared due to leprosy. (1) Nasopharynx, (2) floor of the nasal cavity, (3) roof of the nasal cavity, skull base, (4) lateral wall, left side, (5) lateral wall, right side. On both sides there is complete destruction of the inferior and middle turbinates.

Definitions: severity of the saddle-nose deformity

On the basis of the history and examination, we classified the saddle-nose deformities into four grades of severity (Table 1). The first grade (I) consisted of mild saddle-nose deformities on clinical grounds, a partly destroyed cartilaginous framework with a septal perforation and absence of the anterior part of the anterior nasal spine (Fig. 2). The second grade (II) consisted of moderate saddle-nose deformities, subtotal destruction of the cartilaginous framework with a large septal perforation and partial destruction of the turbinates, absence of the entire anterior nasal spine and retraction of the columella (Fig. 3). The third grade (III) consisted of severe saddle deformities with total destruction of the cartilaginous framework and complete loss of the nasal septum, subtotal destruction of the turbinates and absence of the entire nasal spine (Fig. 4). The fourth grade (IV)

consisted of severe saddle deformities with absence of both the cartilaginous framework and the anterior nasal spine, a complete loss of the nasal septum and turbinates, the presence of vertical alar grooves with vestibular stenosis and flattening of the bony nasal bridge (Fig. 5).

Table 1. Grade of Severity of Saddle-Nose Deformities in Leprosy

	Grade of saddle-nose deformity			
	I	**II**	**III**	**IV**
Saddle deformity				
mild	x			
moderate		x		
severe			x	x
Cartilaginous framework*				
partly destructed	x			
subtotal destruction		x		
total destruction			x	x
Nasal cavity				
Septal perforation	x	x		
Complete loss of septum			x	x
Complete loss of turbinates				x
Nasal spine				
absent anterior part	x			
absent entire spine		x	x	x
Alar grooves				x
Vestibular stenosis				x
Columella retraction		x	x	x

* includes the nasal septum and the upper laterals.

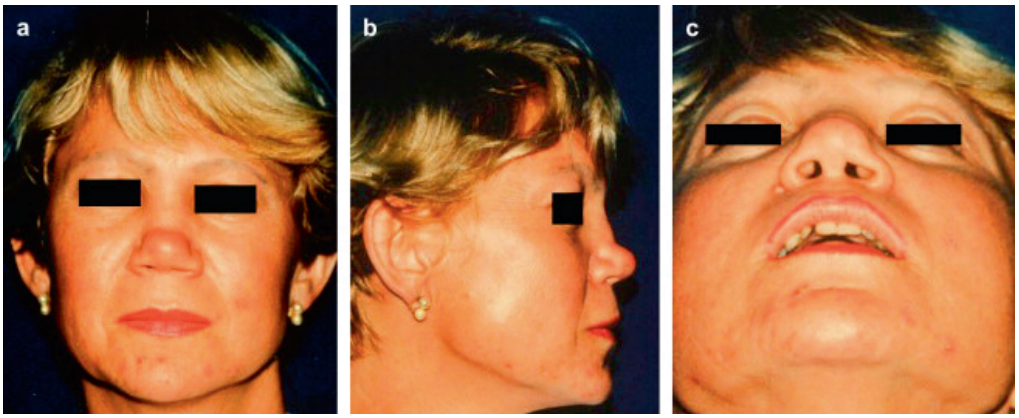

Figure 2. (a–c) Preoperative views of a patient with a grade I saddle-nose deformity. There is partial destruction of the cartilaginous framework, resulting in a mild saddle-nose deformity.

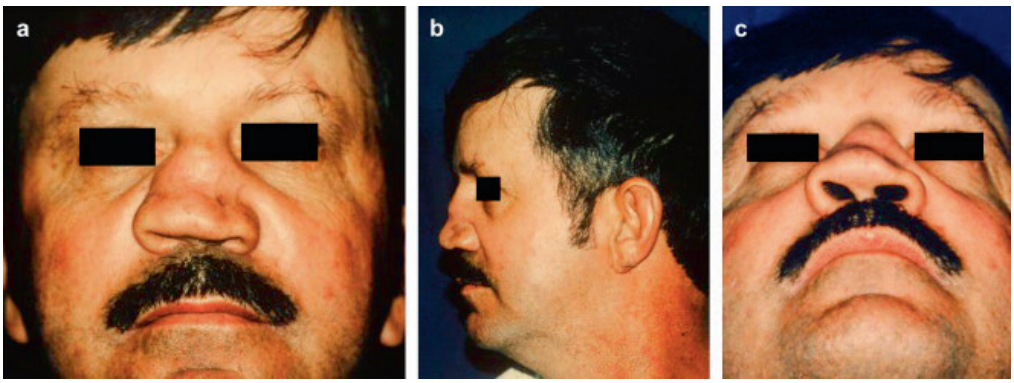

Figure 3. (a–c) Preoperative views of a patient with a grade II saddle-nose deformity. There is a moderate saddle-nose deformity, subtotal destruction of the cartilaginous framework, absence of the entire anterior nasal spine and retraction of the columella.

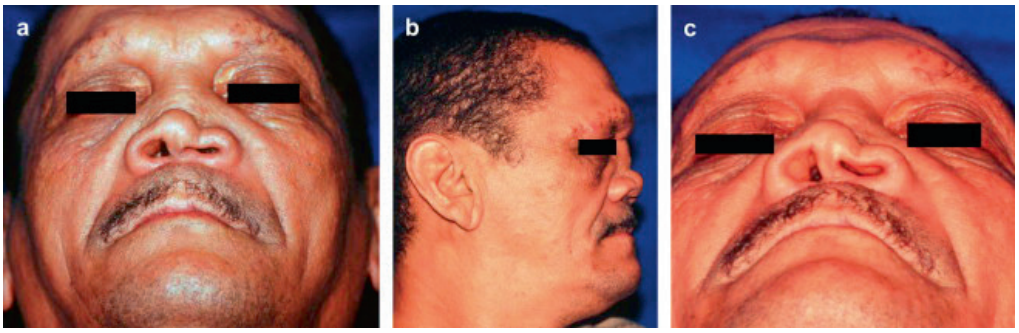

Figure 4. (a–c) Preoperative views of a patient with a grade III saddle-nose deformity. Total destruction of the cartilaginous framework has caused a severe saddle-nose deformity. The columella is retracted due to the absence of the entire anterior nasal spine.

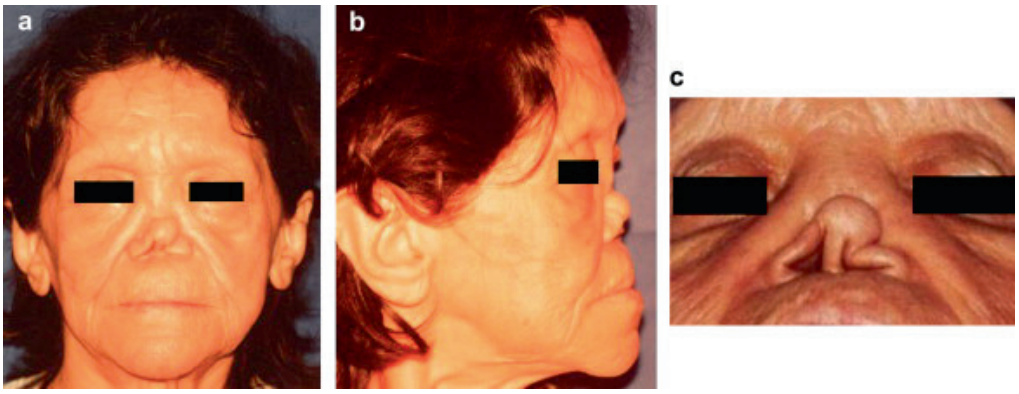

Figure 5. (a–c) Preoperative views of a patient with a grade IV saddle-nose deformity. Absence of both the anterior nasal spine and the total cartilaginous framework, typical vertical alar grooves and vestibular stenosis.

Surgical techniques and cartilage implants

All 24 patients were treated in general anaesthesia using an external approach. A broken columella incision was used in 20 patients; a V–Y procedure was used in four patients in order to lengthen the retracted columella. Typically, in rhinoplasty of the leprosy nose, scar tissue is present in nearly all parts of the nose, accompanied by resorption, and therefore elimination, of the cartilaginous framework. However, it was possible to free and use the soft tissue envelope in all patients after the dissection and removal of scar tissue. Even in grade IV deformities there was no need for additional skin tissue using cutaneous rotation or free transplant grafts in the reconstruction. On the contrary, the outer lining of the nose was well preserved in all patients. However, with the progression of disease, scar tissue retraction in the area of the lateral crus of the lower lateral cartilages could cause vertical alar grooves where the alar soft-tissue sub-units meet the cheek and upper lip units. In the case of a severe vertical alar groove, there was a shortage of vestibular skin. This was dealt with by using an auricular composite graft. By contrast with the upper lateral cartilages and the nasal septum, the lower lateral cartilages, like the soft tissue envelope, were relatively well preserved. The condition and the amount of mucosal lining of the remnants of the nasal septum and the lateral walls of the nasal cavity decreased with progression of disease. Especially in the more severe cases, there was complete destruction of the nasal septum and all turbinates with crust formation and severe secondary inflammation. Given this, none of the remaining mucosa could be used for reconstructive purposes as local flaps or as a recipient site, for example for the transplantation of oral mucosa. Since only skin tissue and the lower lateral cartilages were preserved, the reconstruction of the nasal skeleton was performed using cartilage grafts to replace the nasal septum, the upper laterals and the anterior nasal spine. Depending on the level of severity of the saddle deformity, conchal ear cartilage alone (grade I) or costal cartilage from the seventh or eighth rib combined with auricular composite grafts was required for the reconstruction. From these different cartilage grafts, implants were sculptured for reconstructive purposes for each patient. All patients needed a dorsal onlay and a columellar strut made from either conchal or rib cartilage. In order to reconstruct and camouflage the acute nasolabial angle due to the absorption of the anterior nasal spine we created a new type of columellar strut from rib cartilage. This strut had an extension at the proximal side to replace the absent anterior nasal spine (Fig. 6).

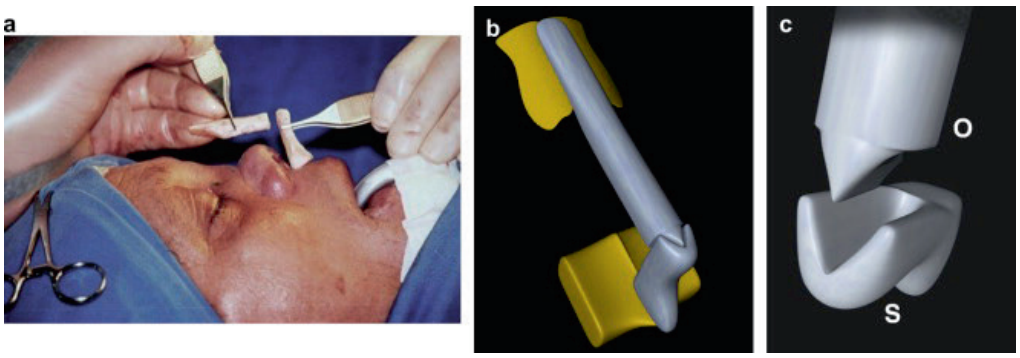

Figure 6. (a) Peroperative view of a patient with a grade III saddle-nose deformity. Autogenous costal cartilage was sculptured into a dorsal onlay and a columellar strut. This strut had an extension at the proximal side to replace the missing anterior nasal spine in order to reconstruct both the acute nasolabial angle and the retracted columella. (b) Illustration of a dorsal onlay graft and a columellar strut with an anterior nasal spine replacement extension on the proximal side. (c) Detailed illustration showing the connection between the strut (s) and the dorsal onlay (o). Using this connection, it was possible to adjust the height of the dorsal onlay before permanent fixation with a non-soluble suture.

The onlay graft was attached to the columellar strut with non-soluble sutures (Ethilon® 5/0). Alar battens were used in 7/24 patients (29%) to correct vestibular insufficiency or to camouflage and reconstruct vertical alar grooves in grade IV saddle deformities. In order to improve tip projection, to camouflage asymmetries of the lower nasal third or to lengthen the nose, shield grafts were used in 23/24 patients (96%). In 7/24 patients (29%), the inner lining of the vestibule had to be restored or retraction of the columella had to be prevented. Auricular composite grafts were used in these cases. To prevent infection in the postoperative period, amoxicillin 500 mg was administered to all patients three times daily for seven days.

Evaluation of the postoperative results

To evaluate the postoperative results, we assessed both functional and aesthetic parameters in relation to the preoperative situation and the rate of resorption, warping, infection and extrusion of the cartilage grafts and morbidity of the donor sites. Functional improvement was defined as a subjective improvement of nasal breathing compared to the preoperative condition. Aesthetic improvement was considered to have been achieved if the patient concluded that there was aesthetic improvement and if two out of three parameters had improved at least two years after surgery compared to the preoperative condition. These parameters were as follows: (1) the presence and severity of recurrence of a saddle-nose deformity due to resorption of the dorsal onlay graft, (2) loss of nasal tip projection due to resorption of the shield graft, (3) the presence and severity of columella retraction due to resorption of the columellar graft. The existence and severity of vertical alar grooves due to the resorption of composite and alar batten grafts was evaluated. In order to examine these parameters, each cartilage implant was compared visually with the postoperative photographs and by palpation to assess graft integrity and the degree of

resorption and warping (Fig. 7a–f). Graft resorption was classified as none (0–25%), partial (25–75%) or complete (>75%).

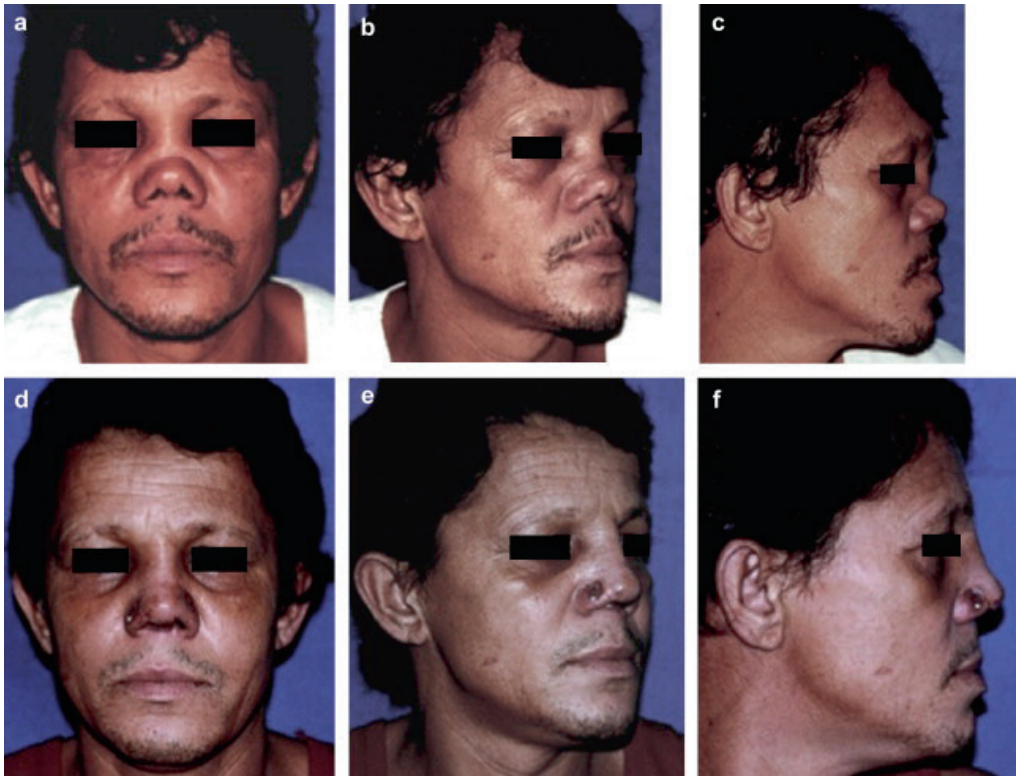

Figure 7. Pre- (a, b, c) and immediate postoperative (d, e, f) views of the same patient of Fig. 6a. Leprosy resulted in the destruction of the cartilaginous framework, causing a severe saddle-nose deformity with a retracted columella due to the absence of the entire anterior nasal spine. Reconstruction was performed using autogenous costal cartilage from the eighth rib via an external approach using a broken columella incision. A columellar strut with extension and a dorsal onlay were used from this graft to augment the nasal bridge and to restore the retracted columella. The projection of the nasal tip was increased with a shield graft. Silicone alar battens, visible on the skin of the nostrils, were used to support the distal part of the lateral crura of the lower laterals and were removed two weeks after surgery.

Results

Before surgery, 1/24 patients (4%) had a grade I deformity, 2/24 (8%) cases had a grade II deformity, 12/24 (50%) patients had a grade III deformity and 9/24 (38%) patients had a grade IV deformity. We examined the postoperative results at least two years after surgery. Patients treated in 2000 had not yet undergone long-term follow-up (5/24 patients and two revision cases, 29%). Some patients received follow-up several times during the five years after surgery (Figs. 8a–c and 9a–c). Seventeen of all 24 patients (71%) received follow-up lasting at least two years. Patients with a

grade I deformity (N = 1) and a grade II deformity (N = 2) showed no signs of the recurrence of a saddle-nose deformity, retraction of the columella or loss of nasal tip projection (Table 2). Of the 12 patients with a grade III deformity, eight were followed up for a period of between two and five years. Of these eight, one patient suffered a mild recurrence of a saddle-nose deformity due to the partial resorption of a costal cartilage dorsal onlay graft. Three out of eight patients with a grade III deformity had a mild recurrence of retraction of the columella due to the partial resorption of the columellar strut. Four out of eight patients had some loss of nasal tip projection compared to the immediate postoperative period as a result of the partial resorption of the shield graft. The follow-up of grade III saddle-nose deformities did not identify any cases of complete recurrence of a saddle-nose formation, columella retraction or a total loss of tip projection (Table 2). Six out of nine patients with a grade IV deformity were followed up for at least two years. No recurrence of a saddle deformity was detected in three out of six patients. Mild recurrence was found in two patients, one with an auricular onlay graft and one with a costal onlay graft. Complete resorption of costal dorsal onlay cartilage with major saddle-nose formation after a two-year follow-up period was seen in one patient. This patient also had a complete recurrence of columella retraction and lost all nasal tip support, as was the case prior to surgery. Another patient from this group also suffered complete resorption of a costal columellar strut and shield graft combined with partial resorption of the dorsal onlay graft. These last two patients did not achieve functional or aesthetic improvement as defined in Materials and methods (2/17 patients). Resorption of auricular cartilage alar battens (0/7, 0%) or composite grafts (0/4, 0%) was not observed. We found no warping of autogenous rib dorsal onlay implants (0/11). None of the patients (0/17, 0%) developed infection or extrusion of the implants or complications during or after surgery of the donor sites.

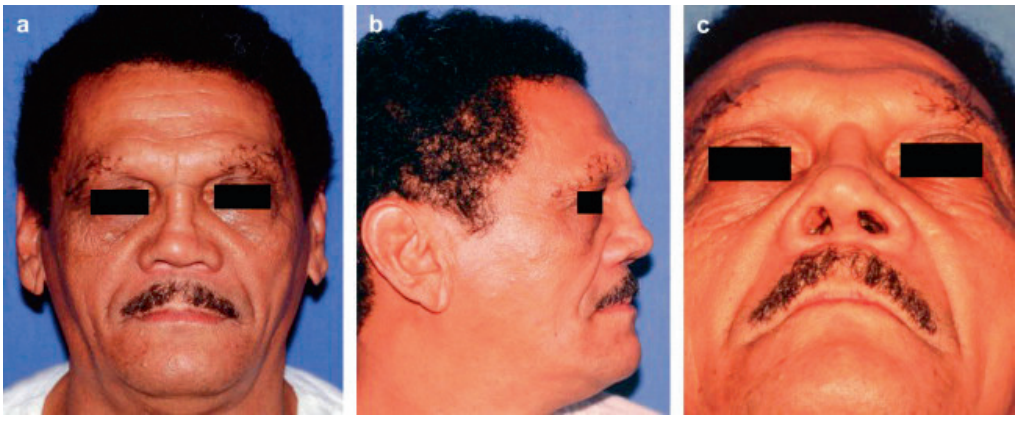

Figure 8. (a–c) Follow-up of the same patient as in Fig. 3a–c. Postoperative result, two years after surgery for a grade II saddle deformity. Reconstruction was performed with a dorsal onlay, a columellar strut with an extension to rebuild the anterior nasal spine and a shield graft from autogenous rib cartilage.

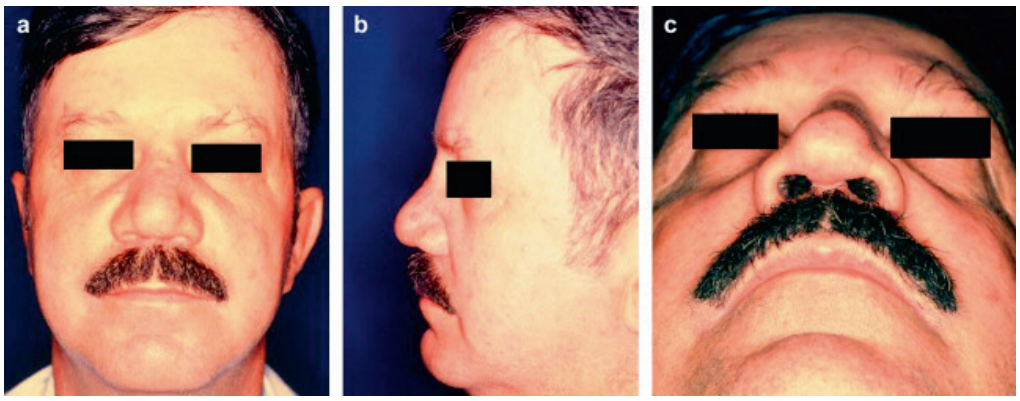

Figure 9. (a–c) Postoperative result, four years after surgery, for the patient in Fig. 4a–c. The grade III saddle-nose deformity was reconstructed with the use of a costal dorsal onlay that was attached to a columellar strut with an extension on the proximal side and a shield graft.

Table 2. Follow-up 2-5 years: Resorption of implants N=17 Patients (1995-2000)

	Grade of saddle nose deformity and resorption rate of implants														
	I (N=1)			**II (N=2)**			**III (N=8)**			**IV (N=6)**			**Total (N=17)**		
	*N**	*P***	*C****	*N**	*P***	*C****	*N**	*P***	*C****	*N**	*P***	*C****	*N**	*P***	*C****
Auricular cartilage															
Dorsal onlay (N=6)	1			2			2				1		5	1	
Columellar strut (N=6)	1			2			1	1			1		4	2	
Shield graft (N=7)	1			2			1	1		2			6	1	
Alar batton (N=7)							2			5			7		
Composite graft (N=4)							3			1			4		
Rib cartilage															
Dorsal onlay (N=11)							5	1		3	1	1	8	2	1
Columella strut (N=11)							4	2		2	1	2	6	3	2
Shield graft (N=9)							3	3			1	2	3	4	2

*None: 0-25 % resorption

**Partial: 25-75 % resorption

***Complete: >75 % resorption

Discussion

In addition to leprosy, a range of pathological factors can result in a saddle nose. The main aetiology of these deformities is the destruction of the nasal septum with loss of support of both the upper and lower laterals. This can be caused by a nasal septal abscess after trauma or prior nasal surgery, but cocaine abuse, relapsing polychondritis, Wegeners's granulomatosis, syphilis and cancer are other factors that must be ruled out in case of a saddle deformity of unknown cause. A variety of graft materials have been studied in recent decades for the reconstruction of saddle-nose deformities. The general materials of choice were autogenous cartilage and bone grafts or synthetic alloplasts such as silicones, Teflon and expanded polytetrafluoroethylene (PTFE). The most frequently used grafts for nasal reconstruction are, however, autogenous cartilage implants, either from donor sites of the nasal septum, auricular concha or costal cartilage.[8] Autogenous cartilage is successful in the long term, and infection or resorption in the nose is rare.[9-11] Autogenous bone grafts, on the other hand, have higher resorption rates, are more difficult to shape and sculpture to the recipient site and their biomechanical features are less tolerated in the natural flexibility of the nasal tip area.[12-16] Alloplasts are appealing because of their relative ease of use and availability in unlimited supplies but they have the disadvantage of a relatively high incidence of infection and extrusion.[17-22] Autogenous cartilage is therefore still the current material of choice for the reconstruction of saddle-nose deformities.[18, 23-26] In leprosy, saddle-nose deformities are often more severe than those in other aetiologies. This is due to the destruction of the nasal septum, which is a feature of saddle deformities with other aetiologies, and additional damage to the nasal spine, the rest of the cartilaginous framework and sometimes even the nasal bones and turbinates. The literature concerning saddle-nose deformities in leprosy describes a variety of reconstruction techniques and graft materials. Bone grafts, nasolabial skin flaps, forehead flaps, postnasal inlay of split-skin grafts, auricular and costal rib cartilage grafts and alloplasts are the most widely studied graft materials.[23, 27-32]

Bone grafts were associated with a 50% complication rate of infection or graft resorption in 24 leprosy patients in a study by Schwarz et al.[23] Despite these findings, they recommended bone grafts and skin flaps in more severe cases of saddle deformities. However, the same group concluded that the use of conchal cartilage in moderate cases was associated with minimal complications and the best aesthetic results. Tovey suggested another type of reconstruction of the leprosy nose in his description of the 'Crockett operation'.[27] In this procedure, bone grafts, a skin graft and diced cartilage cubes were used for reconstruction. The reported resorption rate of autogenous iliac bone dorsal onlay grafts was low. Total resorption was found in 2/31 patients (6%) and partial resorption in 1/31 patients (3%). Bone grafts from the second metatarsal of the foot were used by Malaviya and Husain in 23 leprosy patients[30]. They observed total resorption of the implants in 2/23 (9%) and partial resorption in 5/23 patients (22%). However, there was late postoperative morbidity – an overriding toe in the donor foot – in the donor site in 15/23 (65%) patients. Bone grafts from the olecranon were used by Antia and Pandya in 14 leprosy patients.[29] In this group, the bone graft was partially resorbed in 6/14 patients (43%) and infected in 2/14 patients (14%). Nasolabial skin flaps, forehead flaps and postnasal inlay of split-skin grafts were

also described by Antia and Pandya.[29] The technique of a postnasal inlay of split-skin graft was used in 72 leprosy patients.[31] In this procedure, a split-skin graft was wrapped onto a gutta percha mold with the raw side outwards to create a skin-lined nasal cavity. After 6–9 months, the gutta percha was replaced by a permanent acrylic prosthesis.[31] This technique produced fair results in 8/72 patients (11%) and poor results in 6/72 patients (8%). However, 9/72 patients (12%) developed erythaema of the overlying soft tissue envelope and 6/72 patients (8%) a cutaneous fistula. Nasolabial flaps were used in four patients, all with poor results. Forehead flaps were used in three patients, two with fair results and one with a poor result.[29] Reports about the use of alloplasts in leprosy are less frequent in the literature. One study was performed by Wyss, who found relatively good short-term results with a soft polyethylene L-shaped implant.[32] In theory, however, the risk of infection and extrusion of synthetic materials in the leprosy nose is higher than in saddle-nose deformities due to other causes. The first reason is that the condition of the remaining mucosal lining of the nasal cavity is poor even after mono- or multitherapy and asepsis. Secondly, the risk of a port of entry from the nasal cavity is higher per- and postoperative as a result of scar formation, the severe pathology and chronic crusting and rhinitis in these patients. We do not therefore consider alloplasts to be the materials of choice in leprosy. This is supported by the follow-up of 8 leprosy patients with silicone implants.[29] Fifty percent of them were infected and had to be removed. Based on our findings, we developed a surgical decision tree for the use of cartilage grafts (Table 3).

Table 3. Grade of Saddle-Nose Deformity and Preferred Reconstruction

	Grade of saddle nose deformity			
	I	**II**	**III**	**IV**
Conchal ear cartilage	**x**	**x**	**x**	**x**
Rib cartilage		**x**	**x**	**x**
Auricular composite graft				**x**
Columella strut	**c**	**r**	**r**	**r**
Dorsal onlay	**c**	**r**	**r**	**r**
Shield graft	**c***	**c**	**c**	**c**
Alar batton			**c****	**c**
Composite graft				**a**

* to lengthen the nose or to increase the projection of the nasal tip
** to correct vestibular insufficienty or mild vertical alar grooves
c: conchal cartilage, r: rib cartilage, a: auricular composite graft

In this model, the grade of severity of the saddle-nose deformity (Table 1) determines the donor site for harvesting cartilage and the implants that are sculptured and used for an optimal aesthetic and functional reconstruction (Table 3). For grade I saddle-nose deformities, we recommend conchal ear cartilage from either one or two ears. In general, this graft would be sufficient to sculpture a columellar strut, a shield graft and a small dorsal onlay for an excellent functional and

aesthetic result. The onlay graft does not need fixation to the columellar strut. In certain cases, two layers of cartilage need to be applied in order to camouflage the saddle deformity. In grade II and grade III deformities the saddle deformation is more severe and camouflage of the dorsum and tip area alone is not satisfactory. Because of the significant destruction of the cartilaginous framework, the dorsal onlay cannot just rest on the upper laterals as in grade I deformities. On the contrary, the dorsal onlay should be elevated and held in position by a firm and strong columellar strut with an extension to rebuild the anterior nasal spine (Fig. 6). We therefore recommend both autogenous rib cartilage and auricular conchal cartilage as donor material. The ear cartilage can be used to sculpture a shield graft to increase the projection of the nasal tip, to lengthen the nose or to camouflage asymmetries of the lower nasal third. There are two reasons for the use of conchal rather than rib cartilage for the shield graft. Firstly, with the technique using autogenous rib dorsal onlay implants attached to a columellar strut, there was more resorption of elements in the nasal tip area like the columellar strut and shield graft (11/20 patients, 55%) than of the dorsal implant (3/11 patients, 27%) and there was a rather high percentage of complete or partial resorption of rib cartilage in the nasal tip area. Our data suggest that there is a lower risk of partial or complete resorption of the shield graft and columellar strut when ear cartilage is used (3/13 patients, 23%) than when rib cartilage is used (11/20 patients, 55%) (Table 3). Ear cartilage is probably more resistant to long-term pressure and tension from the overlying soft tissue envelope on the implant than rib cartilage. Secondly, ear cartilage feels more flexible and natural when compared to the rigidity of rib cartilage, especially in the – normally mobile – nasal tip area. For the most severe level of saddle-nose deformities, grade IV, we recommend the use of conchal ear cartilage, rib cartilage and auricular composite grafts. The latter can be used to restore the inner lining in the caudal region of the nasal septum and to correct severe retraction of the columella. In these patients, alar batten implants from auricular cartilage should be used to reconstruct and camouflage the typical vertical alar grooves. In conclusion, we believe the use of this classification provides structured and practical guidelines on how to define the grade of severity of the saddle-nose deformity (Table 1) and about which type of cartilage and implant grafts to use in the reconstruction of the pathological features (Table 3). It should be noted that reconstruction of the nasal septum is not essential and in more severe cases even impossible. The difficulty is not the surgical technique but rather the very poor quality of the remnants of mucosal lining. Furthermore, impaired nasal breathing in these patients is mainly caused by a collapse of the inner nasal valve or stenosis of the vestibulum nasi. In our population, most patients (15/17, 88%) underwent a normalization of nasal breathing after surgery without reconstruction of the nasal septum. A sequel that we did not encounter, despite the fact that we did not stabilize the autogenous rib cartilage with Kirschner wires, was warping of the autogenous rib implants. This is probably because only the central portion of the rib grafts was used, after removal of the perichondrium and superficial parts. We do not therefore advocate internal stabilization as described in the literature.[33]

Acknowledgements

We would like to thank Marcos Virmond, director of the Lauro de Souza Lima Institute in Bauru, who made it possible for us to work in Brazil and helped us to recruit our patients. We would like to thank Nino van Baar, ENT surgeon and founder of the Lazarus Leprosy Society, and Ben Naafs, dermatologist, for their dedication, expertise and participation in this study and Paul Michel de Grood and Marijke Hoen, anaesthesiologists and members of the team, who made it possible to perform surgery in general anaesthesia.

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Chapter 2.3

Treatment of septal hematomas and abscesses in children

D.J. Menger, I.Tabink, G.J. Nolst Trenité

Facial Plastic Surgery. 2007 Nov;23(4):239-43.

Abstract

The cartilaginous part of the nasal septum of a child with a septal hematoma or abscess is at risk of destruction. Consequently, the noses of these children can collapse, causing a saddle nose deformity, and in time, the normal outgrowth of both the nose and maxilla will be disturbed. In adulthood, they will have an underdeveloped saddle nose deformity with too much upward rotation of the nasal tip and a retroposition of the midface. Sequelae like these should be prevented by prompt diagnosis and surgical intervention. In this article, the management of septal hematomas and abscesses is discussed with special focus on reconstruction of destructed septal cartilage with the use of autologous cartilage grafts fixed to a polydioxanon plate.

Keywords:

Child - nasal septum - hematoma - abscess - saddle nose - reconstruction - PDS plate

Introduction

Trauma of the nose in childhood, even relatively minor injuries without visible scarring or bruises of the external nose, can cause a nasal septal hematoma to develop. This process is thought to occur due to leakage or rupture of the mucoperichondrial blood vessels. For parents, it can be difficult to recognize that something is wrong with their child. Often, there is a short period of self-limiting epistaxis and partially or completely blocked nasal passage without accompanying symptoms or signs. After a couple of days without proper treatment, however, the hematoma can be contaminated by microorganisms, resulting in a nasal septal abscess. At this point, the child can become ill, developing fever with progression of pain. For most parents, this will be the moment to consult a general practitioner or an otolaryngology service. Unfortunately, the scenario described above, a delay of a couple of days after nasal trauma, is not uncommon. The goal of this article is to discuss diagnosis and management of nasal septal hematomas and abscesses in childhood in order to avoid functional and aesthetic problems of the nose and midface in the future. Without treatment, children with a septal hematoma or abscess can develop partial or complete loss of nasal septal cartilage by pressure-induced avascular necrosis and liquification. [1-4] Depending on the age of onset and the amount and location of septal cartilage destruction, the nose and maxilla can suffer from growth inhibition (Fig.1a-d). [5-8] In childhood, the nasal septum has two major growing centers, which are thicker (3 mm) than the surrounding cartilage (0.75 mm): the sphenodorsal zone, which stimulates the length and height of the nose, and the sphenospinal zone (basal), which is responsible for the development of the anterior nasal spine and the maxilla.[9] If the septal cartilage is completely destructed, including both the sphenodorsal and the sphenospinal zone, the outcome after the puberty growth spurt can be an underdeveloped nose with severe saddling and retraction of the columella and a retroposition of the maxilla. Smaller defects in the thinner anterior central part of the cartilaginous septum, located between the

major growing centers, do not appear to interfere with nasal growth.[9] Therefore, a nasal septal hematoma or abscess is a serious condition that requires adequate inspection and therapy of the cartilaginous nasal septum.

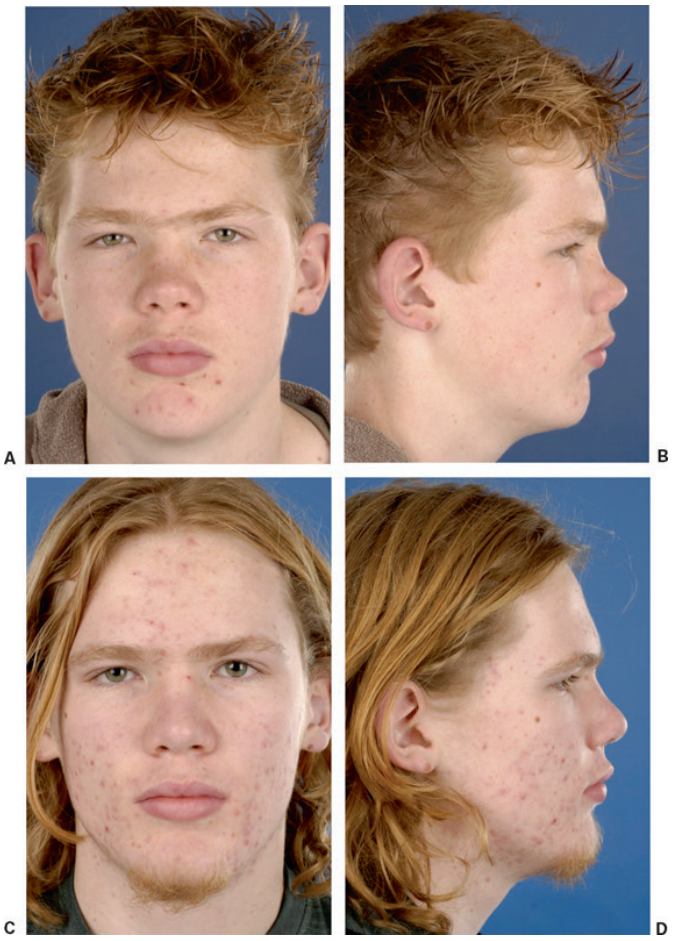

Figure 1 (a, b) Frontal and lateral view of a 15-year-old boy who developed a nasal septal abscess at the age of 7. Due to a subtotal destruction of septal cartilage, the nose is underdeveloped with upward rotation of the nasal tip and a low and broad dorsum. (c, d) Frontal and lateral views of the same boy at the age of 18 after reconstructive rhinoplasty with the use of autologous cartilage grafts.

Diagnosis and management

Clinically, with anterior rhinoscopy, recognition of a nasal septal hematoma or abscess is not difficult (Fig. 2). The nasal septum will be swollen on one or both sides, and there will be a bluish or reddish hue over the mucosa. Palpation of the septum with a cotton swab will show a mass underneath the mucosa instead of the normally rigid cartilaginous septum. Due to the swollen septum, the passage will be blocked partially or totally. At this phase, we promote to evaluate the condition of the nasal septum under general anesthesia.

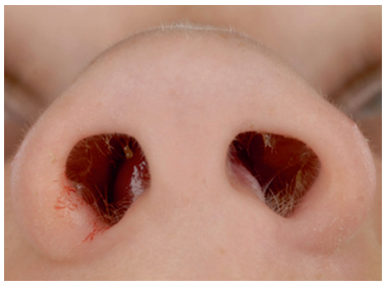

Figure 2 Clinical example of a child with a nasal septal hematoma. In the right vestibule, the mucosa of the nasal septum is visible due to the formation of a hematoma between the septal cartilage and the mucoperichondrium

Management of a Nasal Sepal Hematoma or Abscess without Loss of Cartilage

A nasal septal hematoma or abscess can be located unilateral or bilateral. Although unilateral vascularization from the mucoperichondrium is sufficient for the cartilaginous septum to survive, a unilateral hematoma formation between the cartilage and the mucoperichondrium should be evacuated in order to avoid liquification and destruction of the cartilage in case the hematoma turns into a septal abscess. Evacuation of a unilateral mass can be performed through needle aspiration. However, if needle aspiration shows a purulent collection instead of hematoma, we advise to open the nasal septum through a hemitransfixion and to evaluate whether the cartilage shows defects. In bilateral hematomas, the subperichondrial space should also be opened through a hemitransfixion. The hematoma or abscess should be drained carefully and cultures should be taken for microbiologic examination. The space between the mucoperichondrium layers should be rinsed with NaCl 0.9%. Then the septal cartilage must be inspected for defects. Both in unilateral and bilateral hematomas and abscesses without cartilaginous defects, the mucoperichondrial layers should be approximated to the septal cartilage in order to avoid dead space and the formation of a new hematoma and to promote vascularization of the cartilage. This can be performed with the use of absorbable mattress sutures, fixating the bilateral mucoperichondrium layers upon the septum. The hemitransfixion should be closed with soluble sutures. Adequate packing of the nose should be applied for 2 or 3 days in order to ensure good tissue approximation and to prevent the formation of a new septal hematoma. Systemic broad-spectrum antibiotics (for example, amoxicillin/clavulanic acid: 50/5 mg per kg, every 6 hours) should be administered for 7 days. Depending on culture results, the antibiotic regimen should be changed if necessary.

Management of a Nasal Sepal Hematoma or Abscess with Loss of Septal Cartilage

In case there is loss of cartilaginous septum due to destruction of cartilage, we promote to reconstruct the nasal septum with autologous cartilage grafts from the auricle or rib. In order to improve the exposition of the nasal septum, the hemitransfixion can be altered into an external approach rhinoplasty through a broken columellar incision. The diameter of absent septal cartilage should be estimated carefully in order to ensure a total reconstruction of the septum. If the amount of cartilage needed for reconstruction is large, we advocate the use of costal cartilage from the seventh or eighth rib from the right side. Auricular conchal cartilage can be used in the younger child where less cartilage is needed (Fig. 3a). The next step is the reconstruction of the nasal septum. We recommend to stabilize and fix the cartilage grafts (Vicryl 4/0) on polydioxanon (PDS) plate (Ethicon™, Norderstedt, Germany; 0.15 × 50 × 40 mm; Fig. 3b,c). PDS plate, or foil, degrades in 10 to 25 weeks and does not disturb the normal healing process. Multiple studies have shown that PDS plate has a positive effect on the regeneration of septal cartilage in a rabbit model[10-12] and in the regeneration of bone in the reconstruction of orbital defects.[13] This thin but strong material makes it possible to ensure good tissue-to-tissue approximation of the grafts in one implant. The next step is to position the implant very precisely between the vomer, the upper lateral cartilages, and the perpendicular plate and/or remnants of the cartilaginous septum. After implantation of the implant, it should be fixed between the mucoperichondium layers with the use of absorbable mattress sutures and an internal nose dressing, to prevent the formation of a septal hematoma. The internal nose dressing can be removed after 1 or 2 days. Systemic broad-spectrum antibiotics (for example, amoxicillin/clavulanic acid: 50/5 mg per kg, every 6 hours) should be administered for 7 days. Depending on culture results, the antibiotic regimen should be changed if necessary.

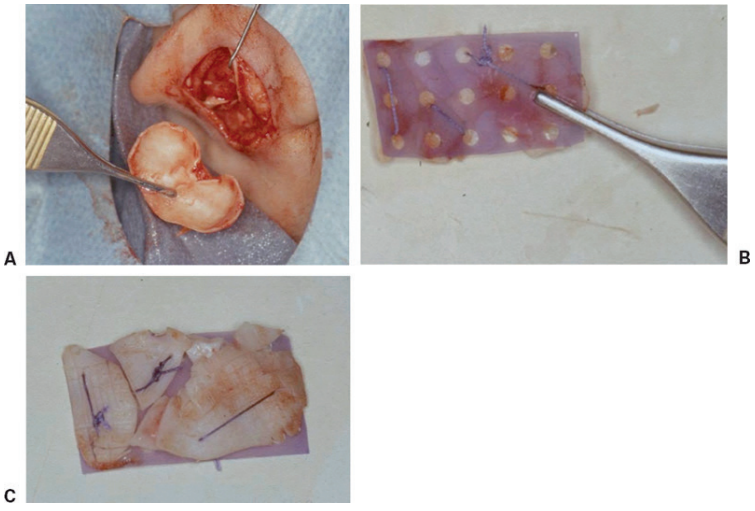

Figure 3 (a) Auricular cartilage from the concha of the left auricle, harvested through a posterior incision. This cartilage graft was used for the reconstruction of the completely resorbed septal cartilage of a 3-year-old boy (figure [4a-d]). (b, c) Auricular cartilage grafts fixed to PDS plate. PDS plate stabilized the cartilage grafts and dissolved in 10 to 25 weeks.

As mentioned before, small defects of the cartilaginous septum between the major growing centers do not interfere with the normal outgrowth of the nose and the maxilla. In order to avoid a septal perforation, however, we believe it is safer to reconstruct such defects with autologous cartilage grafts. In our clinic, we evaluated the long-term clinical outcome of a series of children with a history of a septal abscess and a (sub)total destruction of septal cartilage. In these children, reconstruction was performed with the use of autologous auricular or rib cartilage grafts attached to PDS plate; these results will be reported in the near future (Fig. 4a-d).

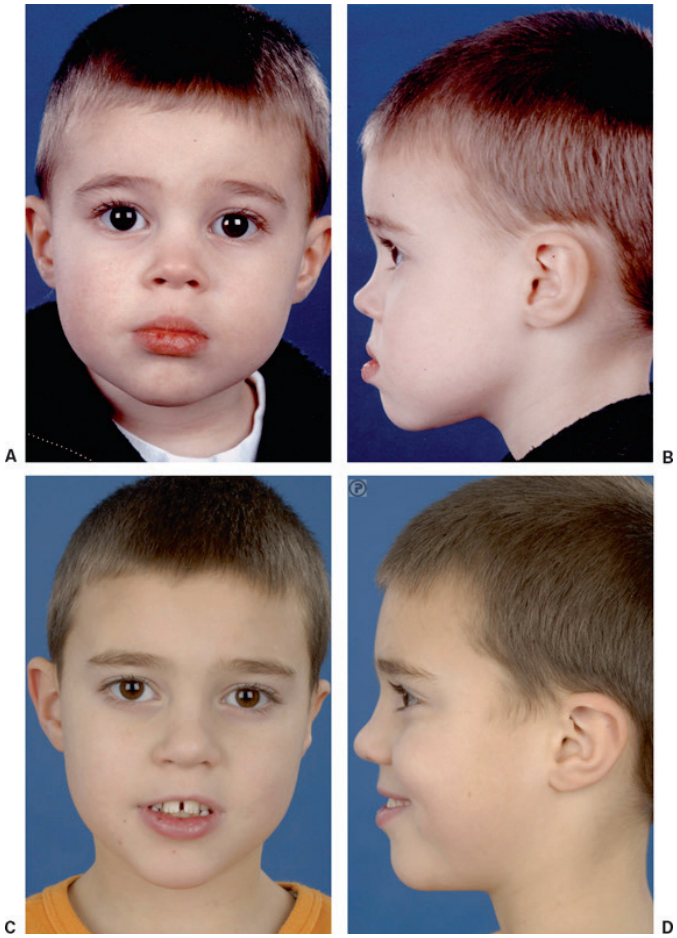

Figure 4 (a) Preoperative frontal view of a 3-year-old boy with complete loss of the cartilaginous part of the nasal septum. This picture was taken 3 weeks after nasal trauma and the development of a septal abscess. In the frontal view, the middle third of the nose was relatively broad due to the slight collapse of the upper lateral cartilages. (b) Despite the entire loss of septal cartilage, there was only slight overrotation of the nasal tip, so far without indications of an upcoming saddle nose deformation. (c, d) Postoperative frontal and lateral views of the same patient at the age of 8 years, 62 months after reconstruction of the nasal septum with autologous auricular cartilage on PDS plate. The nose and midface had grown in proportion to the rest of the face.

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Chapter 2.4

Nasal septal abscess in children: reconstruction with autologous cartilage grafts on polydioxanone plate

D.J. Menger, I.C.Tabink, G.J. Nolst Trenité.
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Abstract

Objective: To assess outgrowth and aesthetics of the nose in children after reconstruction of the cartilaginous nasal septum with autologous cartilage grafts on polydioxanone plate.

Design: Prospective nonrandomized case series.

Setting: University hospital.

Patients: Six patients (5 boys and 1 girl), aged 3 to 11 years, with nasal septal abscess.

Intervention: The nasal septa of 6 children with a history of nasal septal abscess and partial or complete destruction of nasal septal cartilage were reconstructed with autologous cartilage grafts of the auricle or rib fixed on polydioxanone plate.

Main Outcome Measures: Nasal outgrowth was measured by the length of the nose and by the amount of nasal tip projection and was compared with standardized growth curves. Aesthetic outcome variables included nasolabial angle, columellar retraction, and development of saddle nose deformity and were classified as normal, mild, or severe.

Results: The duration of follow-up ranged from 10 to 68 months (mean follow-up, 38 months). Four children had complete loss of the cartilaginous septum. Areas 1 and 2 (caudal parts) had been destroyed in 2 children. Auricular cartilage was used in 5 children; costal cartilage was needed in 1 child. Compared with standardized growth curves, the length of the nose and the amount of nasal tip projection were within 1 SD in all children. None of the children developed saddle nose deformity. One child had mild columellar retraction; 3 children had mild overrotation of the nasal tip.

Conclusion: Total reconstruction of abscess-induced destruction of nasal septal cartilage with autologous cartilage grafts fixed on polydioxanone plate has, so far, resulted in normal development of the nose during follow-up, without expected aesthetic problems.

Introduction

The nasal septum is an essential structure of the nose. Destruction of septal cartilage, partial or complete, can affect the function and shape of the nose. In the growing child, this can be accompanied by disturbance of the normal development of the nose and maxilla.[1-6] Total destruction of the cartilaginous septum will result in an underdeveloped and overrotated saddle nose deformity with columellar retraction and retroposition of the midface. Therefore, loss of

septal cartilage in childhood is a serious condition that requires adequate surgical therapy to prevent functional and aesthetic problems in the future.[5-6]

Most frequently, destruction and loss of septal cartilage in childhood are a complication of septal hematoma or abscess due to sinusitis, nasal trauma, dental infections, or septorhinoplasty.[2, 7-14] In normal circumstances, the metabolism of septal cartilage depends on the perichondrium. However, the formation of a hematoma between the cartilage surface and the perichondrium can result in insufficient oxygenation and sterile necrosis.[15] Frequently, the process of necrosis and liquification is intensified by collagenases that are produced by *Staphylococcus aureus*, *Haemophilus influenzae*, or *Steptococcus* species strains. These microorganisms can contaminate the hematoma, resulting in an abscess through microlesions in the mucoperichondrium or hematogenously.[1, 9-11,16-17] These children can become ill with fever and partial or complete blockage of the nasal passage (Figure 1).

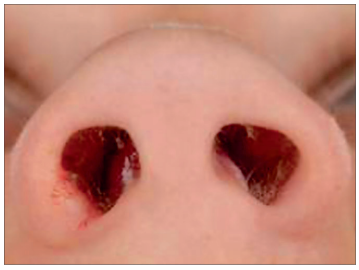

Figure 1. Nasal septal abscess in an 11-year-old boy. The photograph was taken 4 weeks after nasal trauma and septal abscess that was treated with oral antibiotics by a general practitioner.

Life-threatening complications such as thrombosis of the cavernous sinus or brain abscesses are rare and are often associated with delayed diagnosis and management.[13] There is no consensus in the literature regarding the management of nasal septal abscesses in children. Drainage, antibiotic use, needle aspiration, packing of the nose, and combinations of these have been described in the literature. The role of an intact cartilaginous septum in the normal development of the nose and midface has generally been underestimated.

To improve normal outgrowth of the nose and maxilla, the nasal septum has been reconstructed with homologous donor cartilage implants.[5-6,18] The long-term postoperative results of these studies are conflicting. Huizing[5] reported 2 cases of reconstruction with homologous cartilage resulting in normal outgrowth of the nose and midface. In contrast, Grymer and Bosch[6] studied identical twin boys, one of whom developed a septal abscess that was reconstructed with homologous cartilage. During follow-up, he developed the expected long-term adverse sequelae of the nose and maxilla. This finding is in line with clinical evidence and animal models that have demonstrated replacement of original homologous cartilage grafts with fibrous tissue during

follow-up.[19-20] Homologous cartilage grafts are less suitable for the replacement of structures in the nose with support function such as the nasal septum.

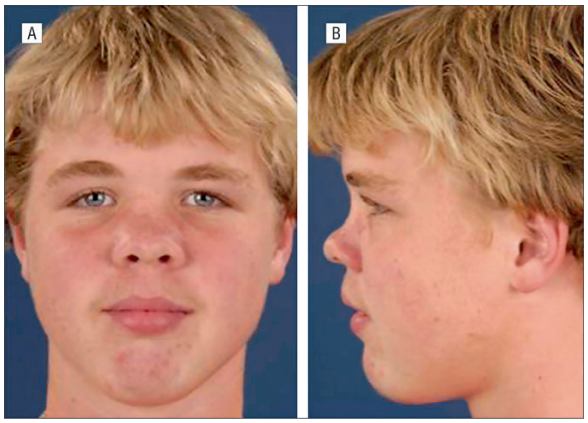

Figure 2. Adverse sequelae after reconstruction of the nasal septum with irradiated homologous cartilage. A, Frontal view of a 16-year-old boy with an underdeveloped nose and midface due to nasal septal abscess at the age of 2 years. Multiple nasal septal reconstructions were performed elsewhere with the use of homologous donor cartilage. Despite these reconstructions, the nose is short with a broad bony pyramid. B, Lateral view of the same patient. Because of the absence of the cartilaginous septum, the bony and cartilaginous dorsum was underdeveloped, and the columella was retracted with upward rotation of the nasal tip, causing an overlarge nasolabial angle (103°). The length of the nose was 4.1 cm (less than –2 SD), and the amount of nasal tip projection was 1.7 cm (–2 SD); both are too small for age and sex.

To ensure normal development of the nose in a growing child, the reconstructed nasal septum should be able to grow. It is likely that chondrocytes from the perichondrium fail to migrate toward the matrix of homologous cartilage implants. A clinical example of adverse sequelae that can develop after reconstruction of the nasal septum with irradiated homologous cartilage is shown in Figure 2. At present, autologous cartilage is the implant material of choice, which is consistent with the objectives of optimal long-term postoperative results with limited risk of resorption, infection, or extrusion.[21-23] Dispenza et al[24] used residual autologous septal cartilage in their technique of “mosaicplasty.” However, most children in our series with a septal abscess had complete or near-complete loss of the cartilaginous septum. In this case, large autologous cartilage grafts are needed, and we believe that auricular and costal cartilage are the donor sites of choice for septal reconstruction in these children.

Methods

Patients

Between June 5, 2001, and April 19, 2006, we performed rhinoplastic surgery on 6 children (5 boys and 1 girl) with partial or complete loss of the cartilaginous nasal septum. All children had a history of nasal trauma, septal hematoma, and septal abscess. Initially, 2 of these children were treated by a general practitioner for blockage of the nasal passage and fever that had developed a few days after the nasal trauma. Inferior turbinate hypertrophy or fever of unknown origin was assumed, so these children were treated with topical decongestants or systemic antibiotics. By the time of the initial visit at our department, these children still had a swollen nasal septum with complete or near-complete loss of the cartilaginous septum on palpation. Clinically, these children had a normal nasal profile with marginal flattening and broadening of the supratip area and slight columellar retraction. In 2 other children, nasal abscess had been diagnosed and drained elsewhere, including treatment with antibiotics, before being seen at our department. Temporary reconstruction with irradiated homologous rib cartilage (Tutoplast; Tutogen Medical GmbH, Neunkirchen am Brand, Germany) to prevent adhesions between the mucoperichondrium layers was performed elsewhere in the 2 other children. These children were seen at our department for reconstruction of the nasal septum with autologous cartilage grafts.

Surgical Technique

In all children, reconstruction of the nasal septum was performed using general anesthesia through an open rhinoplasty using a broken columellar incision. After opening the submucosal space, cultures were taken for microbiologic examination, and the abscess was drained. Only 2 children still had a purulent collection between the mucosal layers. At this phase, the diameter of absent septal cartilage was estimated to ensure total reconstruction of the septum (Figure 3). If the amount of cartilage needed for reconstruction was large, costal cartilage from the seventh rib was harvested on the right side (Figure 4A). Auricular conchal cartilage was used when the quantity needed was less than 1 auricular concha (Figure 5A). The next step was reconstruction of the nasal septum. The cartilage grafts were stabilized and fixed (using polyglactin 4-0 sutures) on polydioxanone plate (0.15 x 50 x 40 mm; Ethicon, Norderstedt, Germany). This thin but strong material ensures good tissue to tissue approximation of the cartilage grafts in a single large implant (Figures 4B and 5B). This implant was positioned precisely between the vomer, the upper lateral cartilages, and the perpendicular plate or remnants of the cartilaginous septum. Polydioxanone plate or foil degrades in 10 to 25 weeks and does not disturb the normal healing process. Studies[25-27] have shown that this material has a positive effect on the regeneration of septal cartilage in a rabbit model and in the regeneration of bone in the reconstruction of orbital defects.[28-29] The next step was to fixate the implant with the use of soluble mattress sutures (Figures 4C and 5C). An internal nose dressing was applied for 1 or 2 days. Systemic broad-spectrum antibiotics (a combination of amoxicillin [50 mg/kg] and clavulanic acid [5 mg/kg], every 6 hours) were administered during 7 days. Depending on culture results, the antibiotic regimen is changed if necessary.

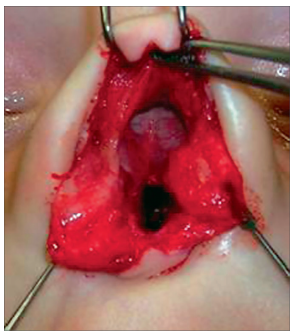

Figure 3. Perioperative view of a 5-year-old girl with complete loss of the cartilaginous septum. This photograph was taken 2 weeks after septal abscess that was treated with oral antibiotics by a general practitioner. The external approach provides maximal exposure of the nasal septum for optimal reconstruction and does not interfere with the normal outgrowth of the nose.

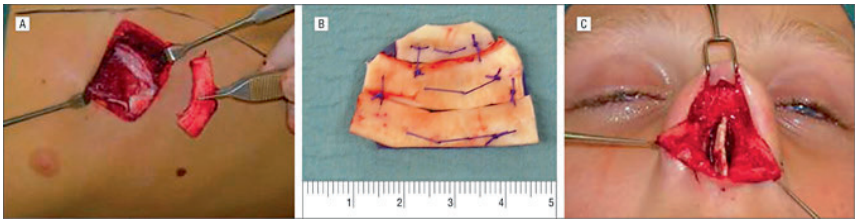

Figure 4. Same patient as in Figure 1. A, Perioperative view. Costal cartilage of the seventh rib was harvested to reconstruct the cartilaginous septum, which had completely disappeared. B, Two-millimeter sections of rib cartilage affixed to polydioxanone foil with polyglactin 4-0 soluble sutures. The polydioxanone plate was exactly the same shape as the absent septum. To avoid warping the graft, only the central part of the rib was used after removal of the outer layers, which have a greater tendency to warp. C, The rib implant on polydioxanone plate was positioned between the perpendicular plate, the vomer, and the upper lateral cartilages and was fixated between the mucoperichondrium layers with polyglactin 4-0 mattress sutures.

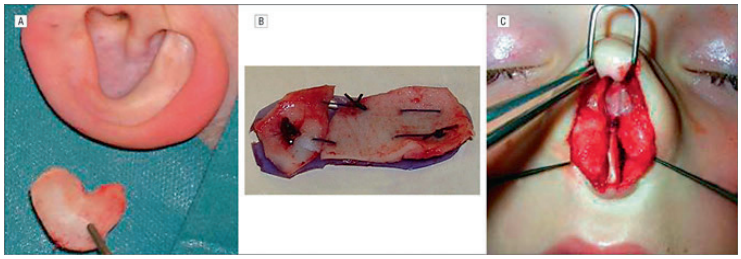

Figure 5. Same patient as in Figure 3. A, Perioperative view. Autologous auricular conchal cartilage was harvested through a posterior approach to avoid a visible scar of the left ear. Harvesting conchal ear cartilage does not interfere with the normal outgrowth or shape of the auricle. B, The cartilaginous nasal septum was reconstructed with 2 pieces of ear cartilage from the same auricular concha. The grafts were affixed to polydioxanone foil that matched the diameter of the lost septal cartilage with polyglactin 4-0 soluble sutures. C, Perioperative view of the reconstructed nasal septum after implantation of the auricular grafts on polydioxanone plate between the mucosal layers.

Evaluation of nasal growth

To evaluate the development of nasal growth, we compared the length of the nose and the amount of nasal tip projection in our children with standardized growth curves for central Europe. These growth curves were based on measurements of 2500 healthy individuals in Switzerland aged 0 to 97 years.[30] All measurements of the length of the nose and the amount of nasal tip projection (nasal protrusion) were performed in accord with the recommendations by Zankl et al.[30] In addition to measuring the length of the nose and the amount of nasal tip projection, we evaluated columellar retraction and the development of saddle nose deformity. These variables were analyzed and classified as normal, mild, or severe (Table 1). Finally, we measured the nasolabial angle and classified the angle as normal (<100° for boys and <115° for girls), mildly overrotated (>100° for boys and >115° for girls), or overrotated (>115° for boys and >130° for girls). Midfacial growth was not considered because cephalometrics were not performed during follow-up.

Table 1. Follow-up Nasal Growth

Patient No.	Follow-up, mo	Age, y	Length of Nose, cm[a]	Tip Projection, cm[a]	Saddle Deformity	Columellar Retraction	Nasolabial Angle
1	62	8	3.8 (–1 SD)	1.5 (Mean)	No	No	98° (Normal)
2	12	6	3.4 (–1 SD)	1.6 (1 SD)	No	No	116° (Mildly overrotated)
3	68	14	4.5 (–1 SD)	1.9 (Mean)	No	Mild	110° (Mildly overrotated)
4	10	12	4.7 (Mean)	2 (1 SD)	No	No	110° (Mildly overrotated)
5	54	15	4.8 (–1 SD)	2.1 (1 SD)	No	No	88° (Normal)
6	24	13	4.8 (Mean)	1.9 (Mean)	No	No	85° (Normal)

[a]Parentheses indicate comparison with standardized growth curves.

Results

The ages at which septal abscess developed ranged from 3 to 11 years (mean age, 8 years). Four children had complete loss of the cartilaginous septum; in 2 children, only areas 1 and 2 (caudal parts) of the nasal septum were resorbed (Table 2). In 5 children, auricular conchal cartilage was adequate for total reconstruction, whereas costal cartilage was required in 1 child. Follow-up ranged from 10 to 68 months (mean follow-up, 38 months). Two children still had a purulent collection between the mucoperichondrium layers during surgery. In these children, microbiologic cultures were positive for *H influenzae* and *Streptococcus milleri*. None of the children developed postoperative infections or other complications. Compared with standardized growth curves, the length of the nose and the amount of nasal tip projection were within 1 SD in all children (Table 1 and Figure 6). None of the children developed saddle nose deformity; mild columellar retraction was noted in 1 child (patient 3 in Tables 1 and 2). The nasolabial angle was normal in 3 children; mild overrotation was observed in 3 children. Outgrowth of the nose was normal in all the children, without signs of underdevelopment or development of saddle nose deformity.

Table 2. Reconstruction of the Cartilaginous Nasal Septum

Patient No./ Sex	Age at Onset, y	Previous Therapy	Length of Defect/ Height of Defect, mm	Area Defect	Cartilage Graft
1/M	3	Antibiotics and drainage	23/15	Total	Auricular
2/F	5	Antibiotics	30/20	Total	Auricular
3/M	8	Antibiotics, drainage, and septal reconstruction with irradiated homologous costal cartilage[a]	32/20	Total	Auricular
4/M	11	Antibiotics	36/25	Total	Costal
5/M	11	Antibiotics, drainage, and septal reconstruction with irradiated homologous costal cartilage[a]	20/25	1, 2	Auricular
6/M	11	Antibiotics and drainage	20/25	1, 2	Auricular

[a] Tutoplast (Tutogen Medical GmbH, Neunkirchen am Brand, Germany).

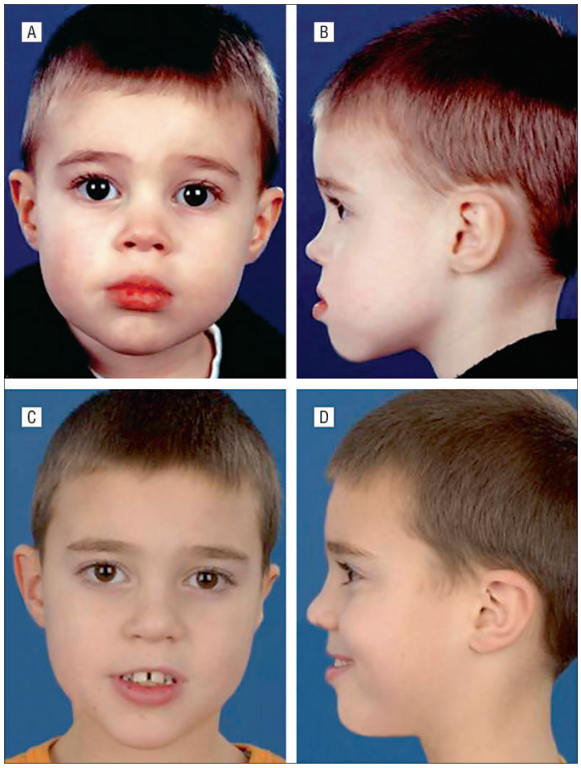

Figure 6. Patient 1 in Tables 1 and 2. A, Preoperative frontal view of a 3-year-old boy with complete loss of the cartilaginous part of the nasal septum. This photograph was taken 3 weeks after nasal trauma and the development of septal abscess. The abscess was treated elsewhere with oral antibiotics and drainage through a hemitransfixion incision. In the frontal view, the middle third of the nose was broad due to slight collapse of the upper lateral cartilages. B, Despite entire loss of septal cartilage, there was only slight overrotation of the nasal tip, so far without indications of saddle nose deformity. C and D, Postoperative frontal and lateral views of the same patient at the age of 8 years, 62 months after reconstruction of the nasal septum with autologous auricular cartilage on polydioxanone plate. The nose and midface had grown in proportion to the rest of the face. Examination and palpation of the nasal septum revealed intact cartilaginous septum with good support to the upper lateral cartilages and without development of saddle nose deformity. Follow-up will continue to the age of 18 years.

Comment

Septal hematomas and abscesses require prompt drainage and inspection and may necessitate reconstruction of the nasal septum. Frequently, there is no loss of septal cartilage. In such cases, adequate drainage and administration of antibiotics will be sufficient for a good long-term postoperative result without adverse sequelae such as underdevelopment or development of severe saddle nose deformity. The normal nasal septum has 2 major growing centers, which are thicker (3 mm) than the surrounding cartilage (0.75 mm). These include the sphenodorsal zone, which regulates the length and height of the nose, and the sphenospinal zone (basal), which stimulates the development of the anterior nasal spine and the maxilla. Smaller defects in the thinner anterior central part of the cartilaginous septum, located between the major growing centers, do not seem to interfere with nasal growth.[31] Nevertheless, reconstruction of such small defects should be considered to avoid the development of septal perforation.

In children with complete or near-complete destruction of septal cartilage, reconstruction of the nasal septum is required. The fact that the operative field is infected with microorganisms does not detract from this statement. After careful rinsing of the subperichondrial space with large quantities of an isotonic sodium chloride solution, the risk of infection in the cartilage implant is low, especially after intravenous or oral administration of broad-spectrum antibiotics. In our case series, autologous cartilage grafts attached to polydioxanone plate for reconstruction of the nasal septum after septal abscess showed normal development of the length of the nose and the amount of nasal tip projection, both in accord with standardized growth curves of the nose. Little is known about the type of growth in the cartilage grafts. We do not know whether new chondrocytes derive from the perichondrium (appositional growth) or from within the lacuna of the graft (interstitial growth). Furthermore, it is not fully understood whether the histologic properties of the original implants change in time toward a hyaline type of cartilage. It is anticipated that future animal studies will answer these kinds of questions.

We are aware that our series of 6 children is small. Nevertheless, to our knowledge, it is the largest documented group in the literature and is the only report in which nasal growth is reported objectively according to standardized growth curves. Our clinical data are preliminary, as the children have not reached the age of 18 years, but, so far, the results of the described technique are promising and, in our view, represent the best alternative for children with complete loss of nasal septal cartilage. Follow-up will be continued during the pubertal growth spurt until our patients are 18 years of age.

Conclusions

In the growing child, reconstruction of partially or completely destructed septal cartilage is essential for normal development of the nose and maxilla. To achieve a successful long-term functional and aesthetic postoperative result, the implant material should provide sufficient support function and should be able to grow between the mucoperichondrium layers. Autologous cartilage grafts of the auricle or rib are, so far, the implant materials of choice in line with current medical practice

to achieve these goals. The ideal solution would be to restore the septum with a single large cartilaginous implant instead of multiple smaller grafts. For this reason, the autologous cartilage grafts were affixed to polydioxanone plate, which ensured good tissue-to-tissue approximation of the individual grafts. The nasal septa of 6 children were reconstructed using this technique. This approach has, so far, resulted in normal development of the nose during follow-up in all children.

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Chapter 3

Suspension suture techniques and objective measurements in nasal valve surgery

Chapter 3.1

Lateral crus pull-up:

a method for collapse of the external nasal valve

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Abstract

Collapse of the nasal vestibule during inspiration is a frequently encountered symptom, often caused by weak or medially displaced lateral crura in the lower lateral cartilages. Numerous techniques are available for lateralizing and strengthening the lateral crura using cartilage grafts or suture techniques. In most cases, they involve an external rhinoplasty approach or additional incisions. An elegant endonasal method for widening and strengthening the lateral component of the nasal valve area is described herein. The basis of the procedure is a permanent submucosal spanning suture between the piriform aperture and the distal part of the lower lateral cartilage. The effect of this technique is 2-fold. First, it provides superolateral rotation of the lateral crura, increasing the cross-sectional area, and second, the spanning suture provides additional support for the lateral wall of the nasal vestibule.

Introduction

Collapse of the lateral wall of the nasal vestibule, the external nasal valve, is caused by negative pressure during inspiration under the influence of Bernoulli forces.[1] In general, either this area is too narrow or the lateral component is too floppy as a result of previous rhinoplasty, trauma, or anatomical features. In most cases, the lateral crura of the lower lateral cartilages are too weak or the distal part is medially displaced and protruding into the vestibule. To prevent collapse, the cross-sectional area of this segment needs to increase and the lateral component of the external nasal valve area needs to gain rigidity and strength. Various techniques to restore the external valve area have been reported, including the use of cartilage grafts such as the butterfly graft[2] and the alar batten graft.[3] During the past decade, however, multiple permanent suspension suture techniques have been described, such as a bilateral flaring suture passing through the caudal part of the upper lateral cartilage and tied over the nasal dorsum using an open rhinoplasty approach.[4] Paniello[5] described a method using a transconjunctival incision to lateralize and suspend the nasal wall with the use of a suture from the orbital rim to the point of maximum nasal collapse. Modifications of this technique have been proposed without the use of a transconjunctival incision but through an incision in the skin along the orbital rim. The suture at the point of the orbital rim is held in place by either a bone anchor system[6] or the periosteum and soft tissue.[7] Intranasally, the sutures pass through the point of maximum collapse and are initially exposed to the outside world in all 3 techniques. Eventually, after granulation, the permanent suture is buried submucosally. Alongside cartilage grafts and suture techniques, other methods have been presented to prevent the collapse of the lateral wall of the vestibule. Rettinger and Masing[8] described an endonasal technique in which the lateral crus is rotated into an upward position. In this technique, the lateral crus, including the dome area and part of the medial crus, is freed completely, thereby providing broadening and upward rotation of the nasal tip as a result of rotation of the lateral crus. Fixation of the lateral crus is achieved using nonpermanent sutures over a fluorocarbon resin foil intranasally. Hommerich[9] describes a modification of this method in which the lateral crura are fixed at the piriform aperture through a transoral approach in a retrograde manner. A silicone foil

is also positioned intranasally to secure the nonpermanent suture, which can be removed after 6 weeks. The technique described in this article was developed to restore external nasal valve collapse or narrowing of this segment due to weak or medially displaced lateral crura. It involves an endonasal approach without additional incisions in the face and with minimal distortion of the nasal tip. The lateral crus of the lower lateral cartilage is rotated in a superolateral direction and is held in place with a permanent spanning suture through the piriform aperture (Figure 1). Another goal was to position the entire permanent suture submucosally to reduce the risk of infection and granulation. Postoperative management is simple, without the need for additional devices or stenting procedures.[10]

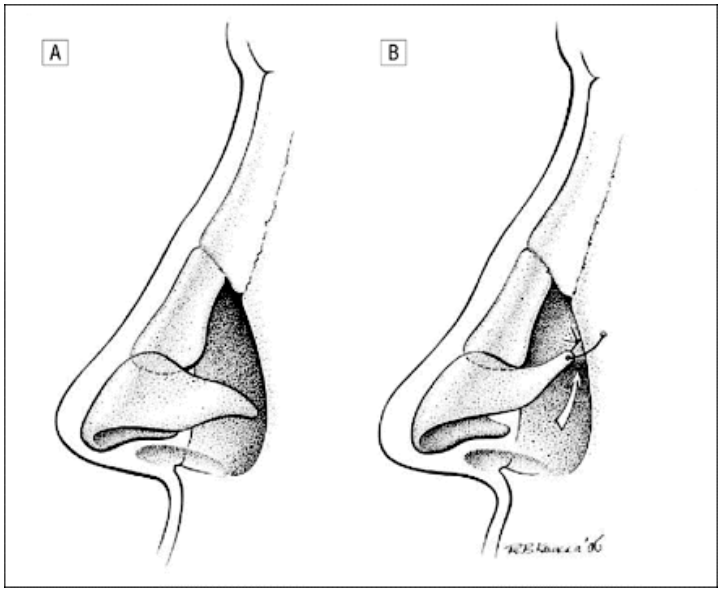

Figure 1. Schematic diagram showing the normal anatomy of the nose (A) and the anatomy after the endonasal lateral crus pull-up technique (B). The lateral crus of the lower lateral cartilage is rotated in a superolateral direction (arrow) and is fixated through the piriform aperture using a permanent suture that is positioned entirely submucosally.

Surgical Technique

The procedure may be performed under general or local anesthesia. After careful injection of infiltration anesthesia (2% lidocaine hydrochloride with 1:100 000 epinephrine to prevent bleeding), a delivery approach is performed. This first step starts with a marginal incision and an intercartilaginous incision, followed by dissection of the nonvestibular side of the lower lateral crura as close as possible to the cartilage surface. To reduce the risk of broadening the nasal tip, the dome area should not be freed (Figure 2A).

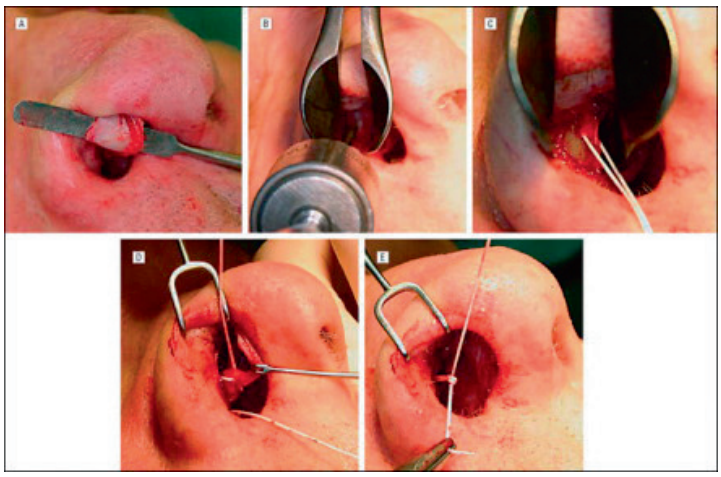

Figure 2. Endonasal lateral crus pull-up technique. A, The lateral crus of the lower lateral cartilage is mobilized using a delivery approach. The intercartilaginous incision can be limited without going around the anterior septal angle. To reduce the risk of broadening the nasal tip after the lateral crura are pulled up toward the piriform aperture, the dome area is not freed with the delivery approach. B, The piriform aperture can be exposed through the intercartilaginous incision after the periosteum on both sides is elevated. A nonmechanical drill is used to make an approximately 1-mm hole approximately 5 mm from the caudal border. C, A permanent suture is positioned through the drill hole. D, The same suture is placed through the distal part of the lateral crus. E, The suture through the piriform aperture and the lateral crus can be tied completely submucosally. Consequently, the lateral crus can rotate in a superolateral direction and supplies strength and firmness to the lateral wall as a result of the continuous traction of the permanent spanning suture.

The intercartilaginous incision is limited and does not need to go around the anterior septal angle. In fact, it should be extended in the opposite direction for 5 mm toward the head of the inferior turbinate to allow access to the piriform aperture. This next step, dissection through the intercartilaginous incision toward the caudal border of the bony pyramid, is performed using a sharp curved scissors. Once the piriform aperture is reached, the soft tissue envelope, including the periosteum, can be incised and elevated, exposing an area of approximately 10 mm. The same procedure is performed on the other side of the bony pyramid by tunneling the nasal mucosa in the subperiosteal plane. A small hole of approximately 1 mm is made in the bone using a simple mechanical or nonmechanical drill, leaving the nasal mucosa medial to the pyramid intact. This step can be performed with excellent exposure using a speculum through the intercartilaginous incision (Figure 2B). To ensure symmetry, the exact drilling location can be marked by passing a needle with ink through the skin. At this point, a permanent 3-0 suture (Gore-Tex [W. L. Gore & Associates Inc, Newark, Del] or Ethilon [Ethicon Inc, Somerville, NJ]) is placed through the drill breach from the medial to the lateral position so that the knot is eventually positioned medially (Figure 2C). The preferred suture material is Gore-Tex because it seems to have more strength against breakage and less chance to incise or cut through the cartilage over time compared with Ethilon. The next step is to suture the most distal part of the lateral crus, starting at the caudal

side (Figure 2D). With controlled force, this suture is tied, “pulling up” the lateral crus toward the frontal process of the maxillary bone into an upward and lateral position (Figure 2E). The spanning suture straightens the lateral crus and provides support for the lateral wall, preventing collapse. Finally, the marginal and intercartilaginous incisions are closed carefully using soluble sutures. An internal nose dressing, which can be removed after 24 hours, is applied to ensure good tissue approximation. Systemic broad-spectrum antibiotics are administered for 1 week to prevent infection. Before surgery, adequate evaluation of the nasal valve area is performed to ensure a positive surgical outcome. Surgical correction is indicated for collapse of the nasal vestibule during inspiration or medial displacement of the lateral crura, both diagnosed by means of a positive Cottle maneuver (improved airway on superolateral traction applied to the nasal groove). Patients with a narrow internal nasal valve, inferior turbinate hypertrophy in idiopathic or allergic rhinitis, caudal septal deviations, and other causes of impaired nasal breathing were excluded. Before and 3, 6, and 9 months after surgery, the nasal airway was evaluated subjectively by the patients.

Results

This preliminary article describes nasal surgery using the lateral pull-up technique on 7 patients. Five of these patients, none of whom had any history of nasal surgery, underwent bilateral surgery. Two patients were treated on only 1 side for the collapse of the ala during inspiration, and they were not concerned about possible asymmetries in the lower nasal third. One of these 2 patients had been given alar batten implants through an external approach in the past without success. In this patient, the auricular alar batten graft was too short and was removed during the lateral crus pull-up. Follow-up ranged from 3 to 13 months. Three, 6, and 9 months after surgery, all the patients experienced improved normal nasal breathing and forced inspiration compared with the condition before surgery. Patients with insufficiency of the ala before surgery did not experience collapse of the ala during normal breathing, forced inspiration, or physical exercise (Figure 3).

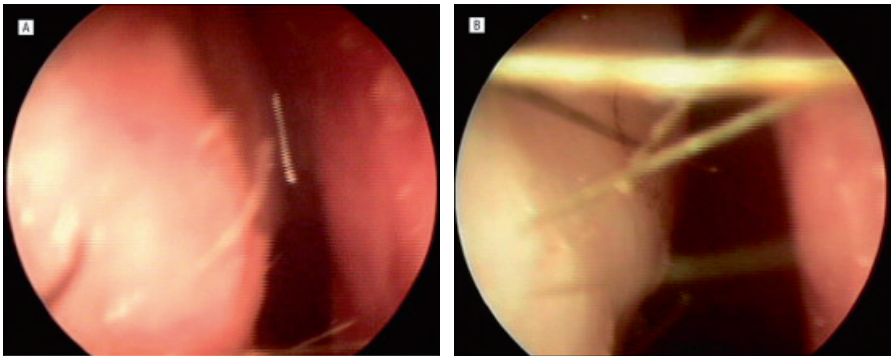

Figure 3. Endoscopic view of the right vestibule before (A) and 3 months after (B) surgery. The cross-sectional diameter is increased by the superolateral rotation of the lateral crus of the lower lateral cartilage.

The results remained stable after 3, 6, and 9 months; none of the patients experienced a decline in nasal breathing across time. After surgery, mild edema and ecchymosis could occur at the site of the piriform aperture where the periosteum had been elevated. Postoperative infections or other complications did not occur in this population. Minimal postoperative aesthetic changes in the nasal tip were possible, with slight upward rotation and a higher position of the caudal border of the nostril (Figure 4). Little broadening was seen between the lobule and the piriform aperture owing to the upward and lateral position of the lateral crus of the lower lateral cartilage. None of the patients had aesthetic objections to these features.

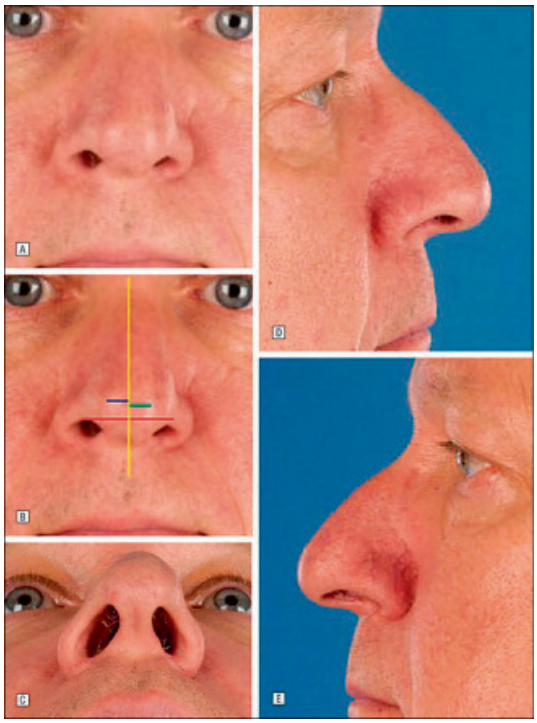

Figure 4. Postoperative views, 3 months after surgery, of a patient who underwent a unilateral lateral crus pull-up of the right side because of alar insufficiency. The technique was performed unilaterally because the patient was not concerned about asymmetries of the nasal tip. A, Anterior view. B, In the anterior view, 2 aesthetic features of the nasal tip are changed compared with the untreated left side: (1) the light reflex, the defining point of the right dome (blue line), showed slight upward rotation compared with the left dome (green line), and (2) the caudal border of the right nostril (red line) was positioned higher compared with the left side. C, The basal view shows a wider vestibule on the right side without distortion or broadening of the nasal tip. The lateral view of the right side (D) did not show signs of alar retraction or increased columellar show compared with the left side (E).

Comment

The technique described in this article was performed endonasally without additional incisions. The permanent spanning suture from the distal part of the lateral crus to the frontal process of the maxillary bone was positioned submucosally to prevent infection. Because only the lateral crura of the lower lateral cartilages were mobilized through a delivery approach, they could easily be rotated into a superolateral position with negligible upward rotation and negligible distortion of the nasal tip (Figure 4). The new position of the lateral crura did not cause problems with respect to closure of the endonasal incisions. Where the bony pyramid, the upper nasal third, was very narrow, it was not possible to lateralize the lateral crura using the technique described. Nevertheless, it was possible to rotate the crura upward and to straighten them, therefore supporting the lateral segment of the valve area. In the case of a narrow upper nasal third, the technique described is appropriate for patients with weak lateral crura rather than those with stenosis of the vestibule due to medial displacement of the lateral crura. A solution to this problem could be lateral osteotomies with outfraction of the pyramid to make lateralization of the lateral crus possible. This article focused on the lateral crus pull-up technique, and the results are preliminary. Surgical outcome is being evaluated in a larger population, and there will be a comparison with other surgical methods for restoring external nasal valve function. This planned study will examine a variety of variables and will include a validated questionnaire dealing with the nasal airway, acoustic manometry and rhinomanometry, and peak nasal inspiratory flow and an objective measurement of the minimum cross-sectional area of the nasal valve area using computed tomography.[11]

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Chapter 3.2

Suspension suture techniques in nasal valve surgery

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Abstract

Impaired nasal breathing or collapse of the lateral side wall of the nasal valve region during inspiration is a frequently encountered symptom. In general, this is caused by a cross-sectional area that is too small, a weak lateral side wall, or a combination of both. Over the years, many techniques have been described to improve the nasal patency in these patients with the use of nasal grafts, repositioning techniques, devices, or suspension suture techniques. This article presents a systematic overview of different suspension suture techniques in nasal valve surgery.

Introduction

The nasal valve region is the narrowest area of the upper airway and was first described by Mink[1] almost a century ago. Today, there is consensus that the nasal valve region is divided into two distinct components, which are defined as the internal and the external nasal valve. The internal nasal valve is located at the caudal border of the upper lateral cartilages with the nasal septum, where they form a T-bar structure, the roof and the medial wall of this valve, respectively. The angle between the nasal septum and the upper lateral cartilages is 10 to 15 degrees at the caudal junction and becomes wider cephalically. The cross-sectional area of this valve also contains the nasal floor inferiorly and the head of the inferior turbinate and alar muscles in the lateral component. In general, the internal nasal valve is the site of maximum resistance.[2,3] The external nasal valve, or nasal vestibule, is localized caudally to the internal nasal valve. The medial wall of this region is formed by the medial crura of the lower lateral cartilages and the cartilaginous and membranous nasal septum. The inferior part is formed by the floor of the nasal vestibule. Pathophysiologically, the most important component is the lateral side wall, which is formed by the lateral crus of the lower lateral cartilage, fatty tissue, and alar muscles. For both nasal valves, impaired nasal breathing can be the result of a cross-sectional area that is too small, insufficient support of the lateral side wall, or a combination of both. This can be the result of previous rhinoplasty, trauma, anatomic or congenital features, weakness of the cartilages and other components as seen in elderly, or facial palsy. If the cross-sectional area of the valve region becomes smaller, the intranasal pressure during inspiration drops due to Bernoulli forces.[4] This negative pressure can cause the collapse of the only mobile component of the valve area, which is the lateral side wall. The goal of most procedures in nasal valve surgery is therefore to widen the cross-sectional area and/or strengthen the lateral side wall. Until now, different surgical methods to deal with nasal valve collapse or stenosis have been described; they can be divided into four groups. The first group consists of autologous cartilage grafts such as the spreader graft,[5] the upper lateral splay graft,[6] the butterfly graft,[7] and the alar batten graft.[8] The second group includes repositioning and reallocation techniques like the upward rotation of the lateral crura of the lower lateral cartilages[9] or an alar base Z-plasty to widen the external nasal valve. The third group comprises alloplast implants such as titanium implants to widen and strengthen the nasal valves (a Wengen, [Breathe-implant, Heinz Korz GmbH, Dusslingen, Germany]) or polyethylene implants

to reverse the collapse of the midnasal third.[10] The fourth group consists of suspension suture techniques, methods in which sutures are used to lateralize or strengthen the lateral component of the nasal valve region. This article presents a systematic overview of different spanning suture techniques in nasal valve surgery.

Suspension Suture Techniques

In nasal valve surgery, suspension sutures can be used to widen the internal or external nasal valve, or both. In some cases, they can also support the lateral side wall, which is prone to collapse in many patients who suffer from breathing problems in this area. In most techniques, the suture is placed at the site of maximum collapse through the upper or lower lateral cartilage and fixed to a rigid anchor point located laterally to the nasal valve. Often, this rigid point is through a hole in the bone at the site of the orbital rim or nasal bone. In some methods, however, periosteum or a bone-anchored screw is used to fix the suture. The surgical approach and the site of incisions are different in many techniques. Endonasal, external, and transoral approaches with or without additional incisions in the conjunctiva or elsewhere in the skin of the face have been described. Taken altogether, there are three major techniques described in the literature: nasal valve suspension in the direction of the orbital rim; spanning sutures across the nasal dorsum; and the suspension and rotation of the lower laterals toward the piriform aperture (Table 1).

Table 1. Overview of Different Suture Techniques to Widen or Stenghten the Nasal Valve Area

			valve		**suture**		
Technique	**Fixation**	**Approach**	**external**	**internal**	**soluble**	**permanent**	**submucosal**
Paniello	orbital rim	transconjunctival	X	X		X	
Park	across dorsum	open rhinoplasty		X		X	X
Mendelsohn	across dorsum	open rhinoplasty	X			X	
Hommerich	piriform apert.	transoral	X		X		
Menger	piriform apert.	endonasal	X			X	X

Nasal Valve Suspension toward the Orbital Rim

Paniello[11] described a technique in which a double-armed 3-0 polypropylene suture was introduced endonasally at the site of maximum collapse and in the direction of a transconjunctival incision. Once both needles appeared through the conjunctival incision, they were affixed to the orbital rim (Fig. 1). Paniello described three options for this fixation: through the periosteum, using a screw, or through a hole drilled in the bone. When the suture was tightened, the cross-sectional area increased at the site of maximum collapse. Lee and Glasgold[12] modified this method by using 4-0 polypropylene sutures and an infraorbital incision through the skin to expose the orbital rim. The next step was the placement of an anchor point with the use of a suture passing the periosteum

and soft tissue. Two double-armed sutures were then placed in the way described by Paniello: one suture in the upper part and one suture in the lower part of the upper lateral cartilage. The sutures were tied to the retaining suture placed previously at the site of the orbital rim. Friedman and colleagues[13,14] and Nuara and Mobley[15] used a soft tissue anchor system to affix the suture to the orbital rim. Friedman used a small infraorbital skin incision to pass the suture to the nasal valve, where it entered the nasal airway cephalically to the point of maximum collapse. The suture retreated from the caudal area of this point toward the anchor system, where it was tied. Rizvi and Gauthier[16] described a similar method with another fixation point. In this technique, the internal nasal valve was widened using a suspension suture that was fixed to the periosteum and superficial musculoaponeurotic layer of the lateral side of the nasal bone. Endonasally, in all the methods described except the last, a short length of the suture was exposed to the outside world inside the nasal valve area. After a period of granulation, the permanent suture was buried underneath the mucosa or vestibular skin.

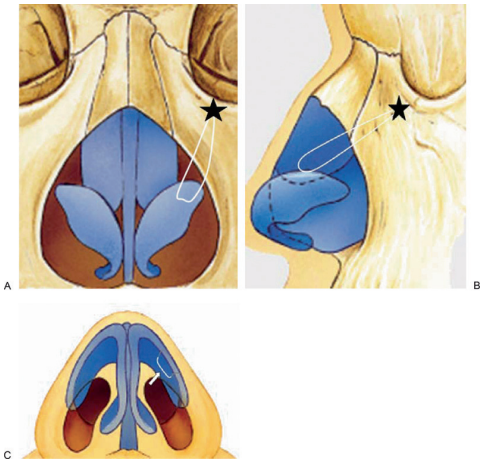

Figure 1 Nasal valve suspension toward the orbital rim. A suture is placed between the orbital rim and the point of maximum collapse in the nasal valve area. (A) The suture is affixed through the periosteum, a hole in the bone or a bone-anchored system (black star). The lateral crus of the lower lateral cartilage is suspended, resulting in widening of the external nasal valve. The approach is transconjunctival or trough a skin incision at the site of the orbital rim. (B) The same technique can be used to suspend the internal nasal valve by lateralizing the upper lateral cartilage. (C) In all techniques, the suture is visible in the nasal vestibule (white arrow). After a period of granulation, the suture should be buried underneath the vestibular skin or nasal mucosa.

Spanning Sutures across the Nasal Dorsum

Park and Schlosser[17,18] introduced a suspension suture technique to widen the internal nasal valve angle in combination with spreader grafts in open-approach rhinoplasty. The technique was developed for patients with vertically oriented upper laterals. The response of these individuals to the placement of spreader grafts alone was often minimal because the body of the upper laterals was not repositioned, resulting in minimal widening of the internal valve angle. The goal

of Park's "flaring" suture was to lateralize these upper lateral cartilages with a 4-0 nylon suture. The suture was placed through the caudal and lateral portions of the upper lateral cartilage and then passed across the nasal dorsum to the contralateral side in a similar fashion. When the suture was tightened, the upper lateral cartilages began to "flare" laterally, increasing the minimum cross-sectional area of the internal nasal valve (Fig. 2).

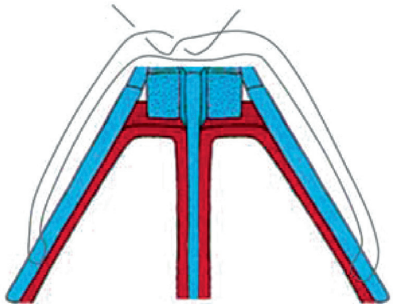

Figure 2 Spanning sutures across the nasal dorsum. Park's "flaring suture" in combination with spreader grafts. The goal of this suture is to lateralize the upper lateral cartilages to increase the internal nasal valve angle. Approach: open rhinoplasty.

Sciuto and Bernardeschi[19] proposed a similar surgical method to widen and strengthen the internal nasal valve. They used sutures to pull the dorsal margins of the upper laterals dorsally over the nasal septum and spreader grafts. Mendelsohn and Golchin[20] described a comparable method for widening and reinforcing the external nasal valve in patients in whom this area was too narrow and/or the side wall of this segment was too floppy. The technique was performed through an external approach. Prior to the placement of the "lateral expansion sutures," the nasal tip was stabilized using trans- and interdomal 5-0 polypropylene sutures to prevent distortion and flaring of the dome region. Between three and five lateral expansion sutures (5-0 polypropylene) were then placed. Near the caudal border of the lateral crus, the suture passed through the cartilage and vestibular skin into the nasal vestibule and looped back through the vestibular skin and lateral crus. The suture passed across the nasal septum to the contralateral side, where the same procedure was performed. The suture was then carefully tied, thereby opening the external nasal valve (Fig. 3). If the cartilage was weak, the lateral crus was reinforced with high-density porous polyethylene to prevent the sutures from pulling through the cartilage.

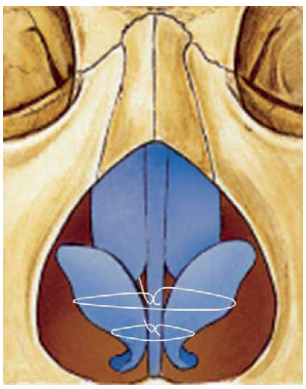

Figure 3 Spanning sutures across the nasal dorsum Mendelsohn's technique to widen the external nasal valve. The caudal borders of the lateral crura of the lower lateral cartilages are approximated with sutures and tied over the nasal dorsum, resulting in a wider nasal vestibule. Approach: open rhinoplasty.

Suspension and Rotation of the Lower Laterals toward the Piriform Aperture

Rettinger and Masing[9] described a technique for widening the external nasal valve by rotating the lateral crura of the lower lateral cartilages in an upward position in the direction of the upper laterals. The lateral crura were freed completely and fixed with a soluble mattress suture tied over polytetrafluoroethylene foil. Hommerich[21] modified this procedure by fixating the lateral crus through a hole in the piriform aperture, the lateral rhinopexy. Exposition of the piriform aperture was achieved with a transoral approach. The lateral crura and upper laterals were dissected retrogradely; the suture was a nonpermanent Vicryl 2-0 and it was exposed intranasally, where it was secured with silicone foil. The foil had to be removed after 6 weeks. A modification to this technique was the "lateral crus pull-up,"[22] which was designed to widen the external nasal valve and to strengthen the lateral side wall. The basis of this procedure was a completely submucosal, permanent, suspension suture (Gore-tex 3-0 [W. L. Gore, Flagstaff, AZ]) between a drill breach in the piriform aperture and the distal part of the lateral crus (Fig. 4). The procedure was performed endonasally using a delivery approach without additional incisions. When the suture was tied, the lateral crus was pulled up toward the frontal process of the maxillary bone into an upward and lateral position. This maneuver increased the cross-sectional area of the valve complex and provided additional support for the lateral wall of the nasal vestibule.

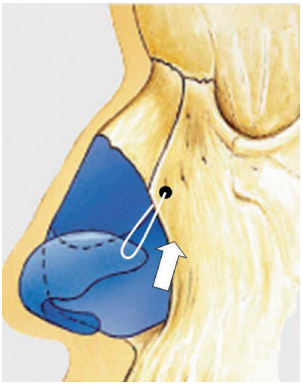

Figure 4 Suspension and rotation of the lower laterals toward the piriform aperture. The nonvestibular side of the lateral crus of the lower lateral cartilage is dissected free and rotated upward and laterally (white arrow) and then fixated with a permanent and completely submucosal spanning suture through a hole in the bone of the piriform aperture. Approach: endonasal.

Discussion

In recent decades, suture techniques have gained in popularity in rhinoplastic procedures. Today, the use of permanent and semipermanent sutures is an accepted approach for altering the shape of individual cartilaginous structures, fixating grafts or stabilizing or strengthening regions of the cartilaginous nasal skeleton. Until now, little to no evidence has been found that these sutures, if not exposed to the outside world, cause complications in the short or long term with respect to infection, extrusion, or function loss. Sutures can also be used to suspend components of the lateral side wall of the valve area to increase the cross-sectional diameter of the valve region or to improve the support function of this side wall. These techniques suspend the upper lateral or the lateral crura of the lower lateral cartilages in a lateral direction and hold them in place with permanent sutures at the site of the orbital rim or the nasal bone, or connect them to each other across the nasal dorsum.

The main drawbacks of the valve suspension techniques reported in the literature so far are the risk of infection and loss of suspension. In the procedures with suspension sutures leading toward the orbital rim, reported infection rates were up to 24%.[15] Interestingly, the site of infection was not in the valve region where the sutures were exposed to the outside world but at the site of the anchor system at the orbital rim. Despite antibiotic treatment, the sutures had to be removed in all cases. Loss of suspension (in the techniques with suspension toward the orbital rim) was reported at levels of up to 35% and this increased with the duration of follow-up.[15] This loss could be immediate due to blunt force (33%) or it could occur gradually over a period of up to 22 months after surgery (66%). No major complications were noted with the flaring suture technique described by Park in which the upper laterals were suspended to each other across the nasal dorsum.

A survey of the effectiveness of this suspension suture was performed in cadavers (acoustic rhinometry) and in clinical setting (subjective patency scale). The flaring suture had the greatest impact in combination with the placement of spreader grafts.[18] No complications or unfavorable functional results were reported with the method described by Mendelsohn and Golchin in which the lateral crura were suspended and connected to each other across the nasal dorsum.[20] The upward rotation of the lateral crus and suspension to the piriform aperture resulted in the doubling of nasal flow, as verified by rhinomanometry, 1 year after surgery.[21] Subjectively, all patients reported improvements in subjective patency, and this was also found during forced inspiration.[22] No complications were seen with these techniques. By comparison with other methods, suspension sutures are relatively safe to use, effective, and, in most cases, reversible. In general, there is less morbidity compared with techniques in which cartilage grafts are needed, due to the fact that there is no donor site. However, the long-term results, and particularly the possibility of suspension loss, should be evaluated in more detail in future studies.

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Chapter 3.3

Objective computerized determination of the minimum cross-sectional area of the nasal passage on computed tomography

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Abstract

Objectives/Hypothesis: Current methods that measure cross-sectional areas of the nasal passage on computed tomography (CT) do not determine the minimum cross-sectional area that may be an important factor in nasal airway resistance. Objective measurement of the dimensions of the nasal passage may help in the diagnosis, as well as the choice and evaluation of surgical treatment for upper airway insufficiencies.

Study Design: Retrospective and clinical study.

Methods: Software was developed that automatically calculates the minimum cross-sectional area of the nasal passage on CT.

Results: Evaluation shows that the minimization algorithm in the software reliably calculates the position and orientation of the oblique plane on which the minimum cross-section lies.

Conclusion: The developed method may be used for objective and observer-independent evaluation of surgical treatment options.

Introduction

Measurement of the cross-sectional area of the nasal passage on CT may be valuable for assessing the effect of different treatment options in nasal valve surgery and for validating other nasal valve measurement methods like acoustic rhinometry.

Current methods to determine the cross-sectional area of the nasal passage on CT do not determine the section with the minimum area.[1-7] In many cases, measurements are made on coronal slices[1,2,4] resulting in cross-sectional areas that may be up to 50% higher than areas determined on a tilted plane[5]. Considerable improvement can be obtained when a center line of the nasal passage is either drawn or calculated, and areas are determined in planes perpendicular to this line.[6-8] However, these methods still do not determine the location and orientation where the minimum cross-sectional area in the passage occurs, and furthermore, the presented methods involve steps that require laborious manual input.

Software was developed that allows determination of the cross-sectional area on any oblique plane intersecting with the nasal passage on CT. Furthermore, a minimization procedure was developed that automatically determines the location of the minimum cross-sectional area of the nasal passage. The method was evaluated retrospectively using CT scans from patients who were elected for sinus surgery.

Method

Minimization of the cross-sectional area

The minimum cross-sectional area of the nasal passage on CT lies on some oblique plane that slices through the recorded dataset. The position of the reslice-plane can be parameterized by a depth coordinate, y, running from anterior to posterior through the nasal passage, and the orientation of the plane can be defined by two angles, Alpha and Beta, respectively the rotation of the plane around the vertical axis and around a horizontal axis. If Alpha and Beta are zero, the plane corresponds to the coronal plane, if Alpha is 90 degrees and Beta zero the plane corresponds to the sagittal plane, and if Alpha is zero and Beta is 90 degrees the plane corresponds to the axial plane. A software program has been made showing four separate views on the CT data, namely three orthogonal views (coronal, sagittal, and axial), and the oblique reslice-plane itself (Figure 1).

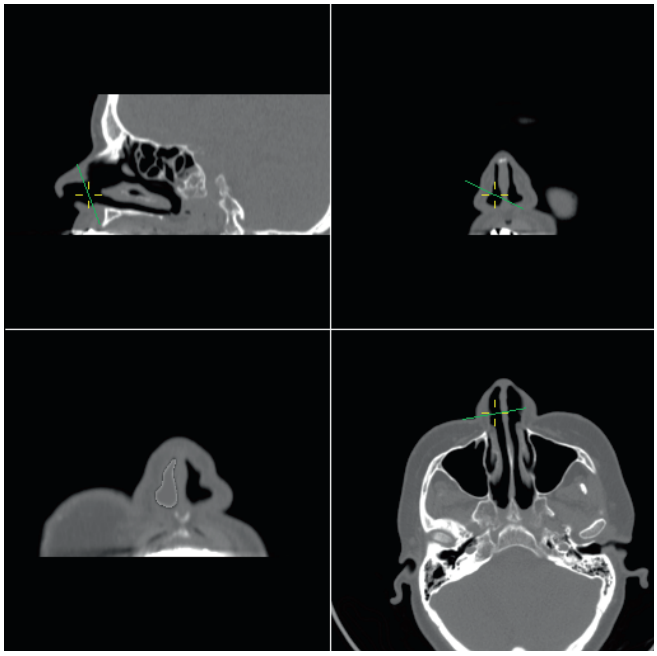

Figure 1: Views of the CT presented by the software. The yellow cross-hair indicates the selected location corresponding in all three views. The green line indicates the intersection of the oblique slice plane with the orthogonal views. Top-left shows the sagittal slice plane, top-right the coronal plane and bottom-right the axial plane. Bottom-left shows the oblique slice plane with the determined area of the nasal passage in white.

Furthermore for evaluation of the results a fifth view is presented that shows a 3D virtual endoscopic rendering of the CT data (Figure 2). The three orthogonal views are interlinked so that selecting a point in one view will automatically make the other two orthogonal views run through the same selected point. A green line indicates the intersection line between the reslice-plane and the view.

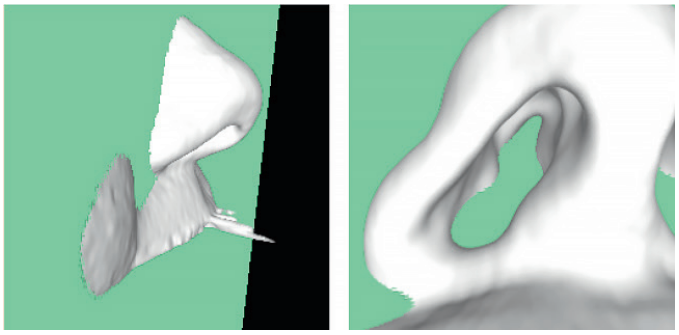

Figure 2: Two 3D virtual endoscopic views of the CT as presented by the software. The green plane is the calculated oblique slice plane containing the minimum cross-sectional area. Users can fly freely through the 3D visualization using their mouse, for instance to go into the nose to inspect the intersection of the plane with the nasal anatomy to asses if the minimum cross-section is located at the nasal valve.

The cross-sectional area of the nasal passage in a given reslice-plane is determined by automatic segmentation with a fixed threshold. To determine the location and orientation of the reslice-plane that results in the minimum cross-sectional area, an iterative minimization algorithm was implemented that uses the Downhill Simplex Method.[9] Depending on the initialization values chosen for the plane parameters, the downhill simplex might, however, converge on a local minimum rather than the global minimum.

To ensure that a global minimum is found, a three step approach is adopted. In the first step the user provides an initial estimate of the location of the reslice-plane by selecting a location on the three orthogonal views with a few mouse clicks. In the second step, the downhill simplex is executed thirty-six times at initialization values distributed regularly around the initial estimate. In the third step, the initialization value that resulted in the minimum result in the second step is used to perform a final downhill simplex with a slower but more accurate tolerance setting.

For the initialization values in the second step, nine different values for the depth coordinate are used, 2.0 mm apart and ranging from -8.0 mm to +8.0 mm distance to the initial user estimate. At each of the nine depths, four different combinations of the two reslice angles are used, each angle either plus or minus 20 degrees from the user estimate.

After completion of minimization, the results are saved for further analysis and the user may verify the results by visual inspection of the intersection line of the plane in the views. Furthermore, a 3D virtual endoscopic visualization is presented of the CT which the user may fly through to inspect the plane (Figure 2).

Equipment

The CT images for this evaluation study were acquired with a Philips Mx8000 spiral CT scanner, with the standard sinus protocol with a pitch of 0.875, at 120 kV and 50 mAs. Reconstructions were made with voxels of 0.7 x 0.324 x 0.324 mm. CT data was Gausian filtered with standard deviation of 1.0 mm.

The pixel values for a tilted reslice-plane are determined from the neighboring CT voxel values using trilinear interpolation, with a pixel size of the reslice-plane of 0.25 x 0.25 mm. The algorithms and interfaces are programmed in MS Visual C++ using the VTK and QT toolboxes, and the C++ numerical recipes, and the software runs on a normal PC.

Evaluation

An evaluation of the software and minimization algorithm was performed retrospectively using four randomly selected CT sets from patients undergoing sinus surgery. These patients were not decongested prior to CT scanning. For each CT, the algorithm was tested four times on both nasal passages using random initialization for the location of the reslice-plane, whereas the initialization for the angles was kept at zero degrees. After the reslice-plane was determined the angles were set to zero to compute the cross-sectional area on the same location but in the coronal plane. The calculated area and the orientation of the reslice-plane were recorded as well as the area determined on the orthogonal coronal slice at the same location.

Results

Repeated execution of the algorithm on the same nasal passage with random initializations showed that the algorithm reliable converges on the minimum cross-section with little variation (Table 1). The orientation of the plane containing the minimum cross-section is in some cases far from the orthogonal coronal slice plane (Alpha=0, Beta=0).

Table 1: Results of the Evaluation of the Algorithm

CT set	Alpha (degrees)	Beta (degrees)	Minimum Area (cm2)	% of Coronal area
1 left	24.4 ± 0.5	33.9 ± 1.6	0.56 ± 0.003	56
1 right	-30.8 ± 0.9	41.1 ± 0.6	0.76 ± 0.001	54
2 left	-26.1 ± 0.5	25.6 ± 0.2	0.52 ± 0.002	65
2 right	13.0 ± 0.7	19.0 ± 0.2	0.48 ± 0.001	66
3 left	-18.5 ± 1.2	37.3 ± 0.2	0.55 ± 0.002	*
3 right	-3.8 ± 0.9	-1.3 ± 0.5	0.79 ± 0.004	99
4 left	13.5 ± 0.1	3.3 ± 0.3	0.83 ± 0.002	*
4 right	-8.0 ± 0.4	7.5 ± 0.1	0.80 ± 0.002	*

Values are means plus or minus one standard deviation

* The coronal section runs through the opening in the nostril no closed contour in the cross-section was present at the location

Discussion

The presented method provides an objective and observer independent measurement of the minimal cross-sectional area of the lumen of the nasal cavity. Results showed that the plane of this minimal cross-sectional area often was tilted with respect to the coronal plane. This finding demonstrates that methods that determine the cross-sectional area only on coronal slices[1,2,4], are not able to calculate the true minimum cross-sectional area of the nasal cavity.

In the present technique, the intersection of the plane of the minimal cross-sectional area is directly shown on orthogonal slices, thereby demonstrating the relation between the anatomy and the narrowest plane of the nasal airway. In general, the narrowest plane of the nasal airway is defined as the internal nasal valve region that by definition includes the caudal end of the upper lateral, the nasal septum, the head of the inferior turbinate, the piriform aperture, and the floor of the nose. Narrowing of parts of this segment can result in impaired nasal breathing. Physical examination of the nose is not always unambiguous in determining the exact anatomical site that causes this functional impairment, making the choice of the surgical procedure (e.g. spreader graft or alar batten implantation, inferior turbinoplasty) sometimes troublesome. Our present method to measure cross-sectional area of the nasal passage on CT can objectively assess and visualize in 3D which anatomical structures are involved in the plane of the minimal cross-sectional area, in order to determine the most adequate surgical plan to reach maximum functional improvement as well as to validate it in the postoperative situation. In the present study we determined the minimum cross-sectional area in a metrical sense were the highest air flow velocities can be expected. In future studies we would like to examine flow patterns through this plane to examine the question whether this plane is also the narrowest plane in a physiologic sense.

In the presented retrospective evaluation of the algorithm, no decongestion with Xylomatazoline was applied prior to CT scanning. In principal, decongestion only reduces the thickness of the mucosa and does not alter the anatomy of the internal nasal valve. However, decongestion prior to CT scanning in the assessment of a patient with impaired nasal breathing due to inferior turbinate hypertrophy could result in a false minimal cross-sectional area, possibly leading to improper diagnosis and treatment regime. On the other hand, applying no decongestion prior to CT scanning, biases could occur due to temporary factors that influence the thickness of the mucosal lining like the nasal cycle, allergy, inhalation of dust and smoke, alcohol, or a decrease of nasal resistance due to exercise. Nevertheless, decongestion with Xylometazoline is more powerful than other factors influencing mucosal thickness and therefore the evaluation of the minimum cross-sectional area to be performed in the most physiological condition. However, it will be interesting to evaluate the effects of topical decongestion on the minimum cross-sectional area on CT and compare this to subjective symptoms of the patients and other tools like rhinomanometry.

Conclusion

Software was developed that automatically calculates the minimum cross-sectional area of the nasal passage on CT that may be an important factor in nasal airway resistance. Objective and observer independent measurement of the dimensions of the nasal passage may help in the diagnosis, as well as the choice and evaluation of surgical treatment for upper airway insufficiencies. Research will be continued and the method will be validated against other diagnostic tools like acoustic rhinometry, rhinomanometry, and nasal peak flow. Moreover, the method will be used to compare cross-sectional areas at the internal nasal valve level before and after surgical procedures as spreader graft and alar batten implantations.

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Chapter 3.4

Surgery of the External Nasal Valve: The Correlation between Subjective and Objective Measurements

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Submitted

Abstract

Objectives/hypothesis: CT-MCA is an objective computerized determination of the minimum cross-sectional area of the nasal passage on CT. CT-MCA was evaluated before and after surgery of the external nasal valve using the "Lateral Crus pull-up" procedure (LCPU). The outcomes of CT-MCA were compared with other currently available objective tests for nasal valve patency.

Study design: Prospective cohort study.

Methods: This study included 34 patients undergoing surgery of the external nasal valve with the use of the LCPU technique. CT-MCA was performed before and after surgery and compared with the subjective perception of nasal passage using the Nasal Obstruction Symptom Evaluation (NOSE) scale, and with objective tests; acoustic rhinometry (A-MCA), rhinomanometry (NAR) and Peak Nasal Inspiratory Flow (PNIF).

Results: This study showed a significant correlation between CT-MCA and the NOSE-scale, PNIF and NAR. Paired samples *t*-tests showed significantly improvement after surgery of CT-MCA, PNIF and the NOSE-scale. Multiple linear regression analysis showed that PNIF, CT-MCA and NAR were significantly associated with the NOSE scale

Conclusion: CT-MCA and PNIF were both significantly correlated and associated with the patient's subjective perception of nasal passage. The surgical procedure, the "Lateral Crus pull-up" showed a significant improvement of the postoperative result both subjectively and objectively.

Introduction

Nasal passage, or the ability to breathe through the nose, is a subjective feeling in which multiple factors contribute. These factors include the anatomical architecture of the nose, mucosal features, the requirements of the respiratory system or the force of inspiration, the quality and temperature of the inhaled air, and psychological factors. Today, there is still no consensus regarding the value of objective measurements in the evaluation of nasal patency. Both rhinomanometry (a dynamic test that calculates nasal airway resistance: NAR) and acoustic rhinometry (a static test that calculates a minimal cross sectional area: A-MCA) correlate poorly with the individual subjective sensation of breathing.[1] This correlation seems to be stronger when each nostril is evaluated individually and in the presence of breathing complaints. However, results are conflicting and knowledge about the role of these techniques in current medical practice is limited.[1]

In the quest for an objective, quantifiable test that correlates with the subjective complaints of the patient we developed and described an objective computerized determination of the minimum cross-sectional area of the nasal passage on CT (CT-MCA).[2] This software allowed determination

of the cross-sectional area on any oblique plane intersecting with the nasal passage on CT. Results of CT-MCA showed that the plane of the minimal cross-sectional area often was tilted with respect to the coronal plane.[2] This finding demonstrated that methods that determine the cross-sectional area only on coronal slices, are not able to calculate the true minimum cross-sectional area of the nasal cavity.[2-5] The effect of nasal valve surgery on CT-MCA was prospectively evaluated by comparing pre- and postoperative outcomes in patients who presented with external nasal valve insufficiency and who underwent a specific surgical procedure, the "lateral crus pull-up" (LCPU).[6] CT-MCA was compared with the Nasal Obstruction Symptom Evaluation (NOSE) scale. The validated NOSE scale measures the subjective complaints of nasal breathing in order to allow us to capture the true patient experience.[7] The results of CT-MCA were compared with other objective tests A-MCA, NAR and Peak Nasal Inspiratory Flow (PNIF).

Materials and methods

This study included 34 patients undergoing surgery of the external nasal valve with the use of the LCPU technique between November 2006 and February 2011 in the Academic Medical Center, University of Amsterdam, Netherlands. No patients were excluded

Patient selection and surgical technique:

All patients had a history of impaired nasal breathing and progression of symptoms during forced inspiration due to collapse of the vestibular side wall. This alar insufficiency was the result of a narrow external valve area due to medially displaced- or weak lateral crura of the lower lateral cartilages. There was an indication for external nasal valve surgery in all patients. The surgical method used was the "lateral crus pull-up technique, a method for collapse of the external nasal valve".[6] This is an endonasal technique, performed in general anesthesia, in which the lateral crus was rotated upward and affixed to the piriform aperture with the use of a sub-mucosal permanent Gore-tex 3/0 spanning suture.

Subjective score and objective measurements:

Before and three months after surgery all patients were evaluated for subjective symptoms and objective measurements, unilateral for each nostril. Each nostril was scored for subjective symptoms in nasal obstruction with the validated NOSE scale (Appendix 1).[7] In line with the recommendations, the NOSE score was scaled from 0 to 100 by multiplying the raw score by 5. Higher scores indicate more severe nasal obstruction. Within 30 minutes and without decongestion of the nasal mucosa, all patients underwent the following objective tests; CT-MCA, A-MCA, NAR and PNIF.

The CT images for this study were acquired with Philips CT scanners, a standard sinus protocol with a pitch of 0.875, at 120 kV and 50 mAs. The software that automatically calculates CT-MCA was performed for each nasal passage as described in the original paper.[2] In summary, this process

was performed by an initial estimate of the location of the CT-MCA by selecting a location in one of three orthogonal CT-views. The three orthogonal views were interlinked so that selecting a point in one view automatically made the other two orthogonal views run through the same selected point. The second step, the downhill simplex was executed thirty-six times at initialization values distributed regularly around the initial estimate. In the third step, the initialization value that resulted in the minimum result in the second step was used to perform a final downhill simplex with a slower but more accurate tolerance setting. The calculated CT-MCA and the orientation of the planes were recorded. The orientation was defined by two angles, Alpha and Beta, respectively the rotation of the plane around the vertical axis and around a horizontal axis. If Alpha and Beta were zero, the plane corresponded to the coronal plane. If Alpha was 90 degrees and Beta zero the plane corresponded to the sagittal plane, and if Alpha was zero and Beta was 90 degrees the plane corresponded to the axial plane.

The A-MCA was measured in the standard procedure for each individual nostril using an A1 acoustic rhinometer (GM instruments Ltd, Kilwinning, Scotland, UK). NAR was measured using the active anterior method, for each nostril separately, with the NR6-2 rhinomanometer from GM instruments (GM instruments Ltd, Kilwinning, Scotland, UK). PNIF was measured for each nostril individually by securely and water-tide-closing the contra-lateral side with foam tape, without changing the anatomy of the tested nostril. Each nostril was tested three times; the highest peak flow was recorded. All measurements were performed with the same PNIF-instrument using the in-check nasal, a portable hand-held inspiratory flow meter (Clement Clarke Int Ltd, Harlow, UK).

Statistical analysis:

All analyses were conducted using IBM SPSS Statistics (version 20) for Windows. For all tests, *p*-values <0.05 were accepted as significant. In case the data distribution was skewed, the data were log-transformed. Pre- and postoperative differences between scores were analyzed with paired sample t -tests. Pearson's *r* correlations were calculated to document correlations between NOSE score, CT-MCA, A-MCA, NAR and PNIF. To examine the possible relationships between the measurements further, multiple linear regression analysis was performed with NOSE scale as the dependent and the other tests as the independent variables. The assumption of linearity was tested and not violated. Corrections were made for the confounders age and gender.

Results

In total 34 patients were analyzed. The sample was 76% male (*N* = 26) and averaged 51.4 years of age (*SD* = 12.2, range: 23-78). In all cases, the orientation of the plane of the CT-MCA was tilted with respect to the coronal plane. In the computed CT-MCA's Alfa ranged from -32 to 42 degrees (mean: 1.4, S.D.: 18.5) and Beta ranged from -8 to 61 degrees (mean: 26.9, S.D.: 19.4). None of the calculated CT-MCA's was found in the coronal CT-scan plane.

No significant correlations were found between the outcomes of the right and the left nostril for both the NOSE-score and the objective measurements (Table 1). Therefore, we decided to use the unilateral data (N=68).

Table 1. Correlations between Right and Left Nostril

	P-value	R
CT-MCA	0.054	-0.34
NOSE-scale	0.121	-0.27
PNIF	0.128	0.26
A-MCA	0.570	0.10
NAR	0.957	-0.01

Differences between the pre- and postoperative scores were analyzed with paired samples *t*-tests. Table 2 shows the pre- and postoperative data of the NOSE-scale, CT-MCA, PNIF, NAR and A-MCA. After surgery, the NOSE-scale, CT-MCA and PNIF were significantly improved. No significant differences between pre- and postoperative scores were found for NAR and A-MCA.

Table 2. NOSE scale and Objective Measurements before and after Surgery.

N=68	**NOSE score•**	**CT-MCA**	**PNIF**
Before surgery	57.1 (27.4)	0.33 (0.19)	41.7 (33.8)
After surgery	23.1 (23.6)*	0.38 (0.17)**	59.6 (32.5)*

*P<0.0001, **P <0,02 compared with pre-operative score, values are mean (SD)

• Higher scores indicate worse nasal obstruction

Table 3 shows the correlation coefficients of the preoperative data between CT-MCA, the NOSE-scale, PNIF, NAR and A-MCA (Table 3). The NOSE-scale showed a significant correlation with PNIF and CT-MCA. The CT-MCA was significantly correlated to the NOSE-score, PNIF and NAR. No significant associations were found between A-MCA and any of the other parameters. For the postoperative data, the same pattern of correlations was found (data not shown).

Table 3. Correlation Coefficients of the Preoperative Data

		NOSE	CT-MCA	PNIF	A-MCA	NAR_ln
NOSE	Pearson Correlation	1				
	P-value					
CT-MCA	Pearson Correlation	-,31*	1			
	P-value	0,01				
PNIF	Pearson Correlation	-,33**	,44**	1		
	P-value	0,01	0			
A-MCA	Pearson Correlation	0,18	0,13	0,12	1	
	P-value	0,15	0,3	0,33		
NAR_ln	Pearson Correlation	0,26	-,46**	-,44**	-0,09	1
	P-value	0,06	0	0	0,55	

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

The relationships between the objective and subjective measurements were further analyzed using multiple linear regression analysis, corrected for age and gender. A higher PNIF was significantly associated with a lower score on the NOSE scale (Regression coefficient B= -0.32, 95% confidence interval (CI)= 95% (-0.51 to -0.13), $p<0.001$). CT-MCA also demonstrated to be significantly inversely associated with the NOSE scale (B= -47.11, 95% CI= 95% (-81.42 to -12.81), $p<0.01$), as well as NAR (B=8.30, 95% CI= 95% (1.28 to 15.50, $p<0.02$). A-MCA showed no statistical significant relationship with the NOSE scale.

Discussion

This study showed a significant correlation between CT-MCA and the NOSE-scale, PNIF and NAR. Since PNIF was significantly correlated and associated with the NOSE-scale we recommend this objective test for the evaluation of nasal patency in patients that experience alar collapse during forced inspiration. The surgical procedure, the LCPU technique showed a significant improvement of the postoperative outcomes for the NOSE-score, CT-MCA and PNIF.

Symptoms and their impact on the quality of life are the main factor for a patient to seek medical attention. In clinical practice there is a tendency to objectify these subjective complaints with tests in order to assess and quantify the medical problem. In the ideal situation this objective quantification is supportive in medical practice or research. Previous studies have shown that the patient's subjective perception of nasal obstruction is not strongly associated with objective assessments of disease severity.[1,9,10] There are multiple explanations for this finding. For example, subjective patient-based instruments quantify an aspect of the disease that is not detected by objective testing or the same objective disease severity can have different patient-subjective assessments of the impact of that disease. Another reason might be that in most studies performed in the past both the patient population and the tests were too heterogeneous. The patients in our study however, had a specific problem of the external nasal valve; this region was too narrow and the lateral component that was too floppy. This could be the result of medially displaced- or weak lateral crura of the lower lateral cartilages. A pathognomonic sign in these patients was due to Bernoulli forces; collapse of the nasal vestibule during forced nasal inspiration. During physiologic breathing on the other hand, this symptom did not occur or more restricted. When the requirements of the respiratory system increased, the nasal airflow in these patients decreased. Therefore, the force of inspiration played an important role in the symptoms and signs of these patients. Consequently, external nasal valve insufficiency is a specific feature with unique characteristics compared to other causes of impaired nasal breathing like internal nasal valve problems, septal deviations or mucosal diseases like rhinitis, CRS or nasal polyps. Objective tests are heterogeneous; they have particular methods of measuring nasal passage. A-MCA and CT-MCA for example are static tests; NAR is a low flow dynamic tests and PNIF a high flow dynamic test. In fact, each objective test has specific characteristics and therefore each test might be more or less appropriate for measuring a specific type of breathing problem. Beside the fact that in most studies both the patient population and the objective tests were heterogeneous, the subjective complaints of patients were often not defined or were measured with non-validated instruments. Possibly for this reason, most studies showed no correlation between the subjective perception of the patient and objective tests like NAR, A-MCA and PNIF.[1,6,10-14] In relatively recent publications validated questionnaires such as the SinoNasal Outcome Test (SNOT-16, 20, 22) and the Nasal Obstruction Symptom Evaluation test (NOSE) have been developed to be good and validated assessment tools in both clinical and research setting.[7-9,15-17] The SNOT-16 and 20 variants however were not designed to evaluate nasal patency. Visual analogue scales (VAS) have also been used to evaluate the effect of endoscopic sinus surgery and rhinitis, however for nasal patency there is no validation and the outcome not always correlated with symptom scores.[18-21]

In our study all measurements were performed unilateral, on both sides. In total 68 nasal airways in 34 patients were tested. Correlations between CT-MCA and the NOSE scale and between PNIF and the NOSE scale were observed, both before and after surgery. We did not find correlations between A-MCA or NAR and the NOSE-scale. Some other studies only found correlations in patients with high levels of subjective complaints and A-MCA and NAR.[1, 22-25] In our study we could not observe this phenomenon. The correlation in our study between the NOSE scale and PNIF was in line with several other reports.[26-28] Some papers mentioned possible false low values of PNIF as a disadvantage of the test due to collapse of the nasal valve during forced inspiration.[10] In order to overcome this problem the use of special devices has been suggested.[29] In our patient population however, low PNIF results due to nasal valve collapse was a pathognomonic sign of external valve collapse and not a false negative outcome. Another potential disadvantage mentioned in literature concerning PNIF was the fact that both nostril sides were tested together instead of unilateral.[30-31] In order to overcome this potential disadvantage in our study PNIF was measured unilateral by securely and water tide closing the contra-lateral side with foam tape. CT-MCA not only correlated significant with the NOSE-scale but also with PNIF and NAR. Multiple linear regression analysis showed that PNIF, CT-MCA and NAR were significantly associated with the NOSE-scale. Concerning the results of our study, we advocate PNIF in patients with collapse of the external nasal valve in order to evaluate the severity of nasal patency both before and after surgery as a first choice in contrast to the more expensive and time consuming tests like CT-MCA or NAR.

LCPU showed a significant improvement of the postoperative subjective perception of disease severity using the validated NOSE scale and significantly improved values of PNIF and CT-MCA (Table 2). Thus, LCPU is an effective surgical technique in patients with a weak or narrow external nasal valve area that experience collapse of the valve during forced inspiration. Concerning the improved postoperative outcome of PNIF and CT-MCA; the lateral component of the external nasal valve must have gained strength and rigidity due to the superolateral rotation and permanent fixation of the lateral crus to the piriform aperture in addition to the measured increase of the MCA on CT.

A weakness of the study is the lack of a control group. An alternative surgical treatment for external nasal valve collapse could be the placement of alar batten- or a butterfly graft. However, the study was designed to evaluate the relation between CT-MCA and other objective tests and the patient's subjective perception of disease severity, not to evaluate the surgical technique. A strong feature of this study, in contrary to many other studies, was the fact that each nasal passage was tested separately both for subjective and objective tests. Furthermore, the homogenous patient population with a specific breathing problem, a single surgical procedure, assessment of the subjective perception of the patient with a validated questionnaire, the NOSE scale and different objective tests including CT-MCA, NAR, A-MCA and PNIF. Future studies will have to be performed in order to evaluate the relations between the different objective test and other specific breathing problems like the internal nasal valve, the nasal cavity and features of the nasal mucosa.

Conclusion

CT-MCA is an objective computerized determination of the minimum cross-sectional area of the nasal passage on CT. In our present study we found a significant correlation between CT-MCA and the NOSE-scale, PNIF and NAR. PNIF was significantly correlated and associated with for the NOSE-scale. Compared to CT-MCA we advocate PNIF for the evaluation of nasal patency in patients with external nasal valve insufficiency. PNIF has lower morbidity, is more costs effective and easy to use in daily practice. NAR and A-MCA showed no correlation with the NOSE-score in our population and therefore we do not recommend the use of these tests in patients with external valve insufficiency. The surgical procedure, the "lateral crus pull-up technique" showed a significant improvement of the postoperative outcomes for the NOSE-score, CT-MCA and PNIF.

Appendix 1. Nasal Obstruction Symptom Evaluation (NOSE) scale

Over the past ONE month, how much of a problem were the following conditions for you?
please circle the most correct response

	not a problem	very mild problem	moderate problem	fairly bad problem	severe problem
1. Nasal Stuffiness	0	1	2	3	4
2. Nasal blockage or obstruction	0	1	2	3	4
3. Trouble breathing though my nose	0	1	2	3	4
4. Trouble sleeping	0	1	2	3	4
5. Unable to get enough air through my nose during exercise or exertion	0	1	2	3	4

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Chapter 3.5

Evidence based case report

Does functional septorhinoplasty provide improvement of the nasal passage in validated patient reported outcome measures for adults with an anatomical obstruction of the nasal valve?

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Submitted

Abstract

Objective: The aim of this study was to determine whether functional septorhinoplasty provides improvement of the nasal passage in validated patient reported outcome measures (PROMs) for adults with an anatomical obstruction of the nasal valve.

Methods: A systematic Pubmed, Embase and Cochrane library search was performed to identify relevant articles. Articles were critically appraised and ranked according to validity and relevance.

Results: Fifteen articles met our inclusion criteria and after critical appraisal 10 were eligible for further analysis. In 9 studies de NOSE score increased from 35 to 60. In 1 studie de SNOT-22 increased with 3,5 points.

Conclusion: The results suggest that there is a significant improvement of validated PROMs after functional septorhinoplasty in the first postoperative year.

Recommendation: Adults with nasal breathing problems due to an anatomical problem of the nasal valves should be considered undergoing functional septorhinoplasty.

Introduction

Clinical scenario

A 33-year-old woman was referred to an otorhinolaryngologist because of bilateral nasal breathing problems. The complaints of the nasal passage were constantly present without signs of (non-) allergic rhinitis or rhinosinusitis. She had no medical history except for the breathing problems. Examination of the nose showed concave lateral crura of the lower lateral cartilages and the nasal septum was deviated to the left in area I and to the right side in area II and III. Endoscopic evaluation of the nose showed a normal condition of the nasal mucosa. Peak nasal inspiratory flow showed a value of 55 L/min. The subjective perception of nasal patency was measured using the NOSE scale. The patient scored a value of 75 out of 100, higher scores meaning more severe nasal obstruction. A skin prick test for allergies was negative. Three months of topical nasal steroid spray did not improve her breathing problems. The patient wanted to know whether or not she might be a candidate for functional rhinoplasty and how other patients experienced functional septorhinoplasty; did they notice improvement of their nasal passage?

Background

Nasal passage, or the ability to breathe through the nose, is a subjective feeling. Symptoms and their impact on the quality of life are the main reason for a patient to seek medical attention. In clinical practice however, there is a tendency to objectify these subjective complaints.

The most frequently used objective tests are acoustic rhinometry (a static test that calculates a minimal cross sectional area: A-MCA), rhinomanometry (a low flow dynamic test that calculates nasal airway resistance: NAR), and Peak Nasal Inspiratory Flow (PNIF: a high flow dynamic test). Literature showed evidence that nasal septal surgery improves nasal patency assessed by objective methods.[1] Nevertheless, multiple studies have shown that the patient's subjective perception of nasal obstruction is not strongly associated with objective assessments of disease severity.[2-8] There are multiple explanations for this finding. For example, subjective patient-based instruments quantify an aspect of the disease that is not detected by objective testing, or the same objective disease severity can have different patient-subjective assessments of the impact of that disease. Another explanation might be that in many studies the subjective complaints of patients often was not well defined or measured with non-validated instruments.

Validated patient reported outcome measures (PROMs), such as the SinoNasal Outcome Test (SNOT-16, 20, 22) and the Nasal Obstruction Symptom Evaluation score (NOSE) have been developed to be good and validated assessment tools in both clinical and research setting.[9-13] The SNOT-16 and 20 variants however were not designed to evaluate nasal patency.

Validated PROMs measure the subjective complaints of nasal breathing in order to allow us to capture the true patient experience. From a patient perspective, the symptoms are the reason to seek medical attention and these symptoms and signs should improve after functional septorhinoplasty.

Clinical question

Does functional septorhinoplasty provide improvement of the nasal passage in validated PROMS for adults with an anatomical obstruction of the nasal valve?

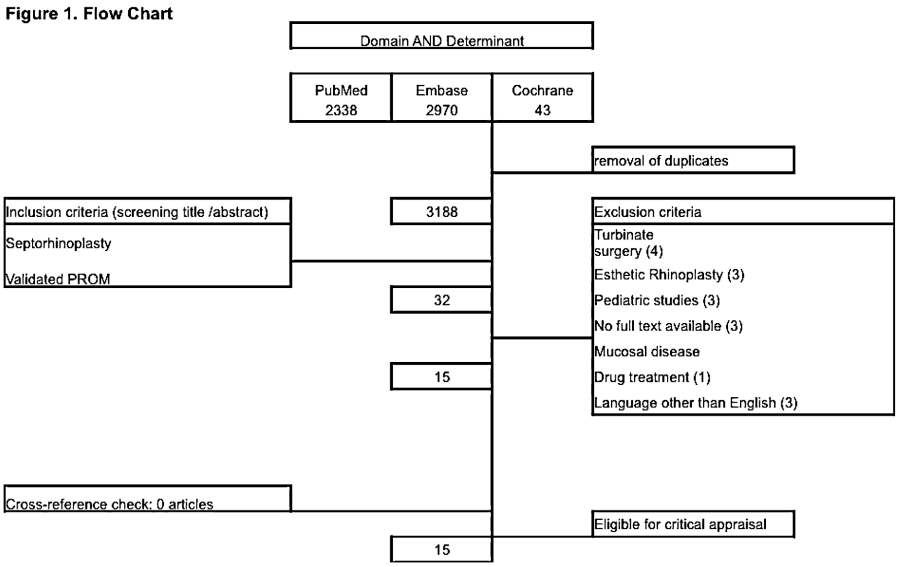
Methods

Search strategy and critical appriasal

A search was conducted using Pubmed, Embase and the Cochrane library on the 29st of July 2013 using the combination of keywords "nasal valve" and "rhinoplasty" and synonyms. See appendix 1 for syntax. Articles were selected based on in- and exclusion criteria, as shown in Figure 1. A cross reference check was performed using Web of Science to verify if any relevant articles were missed. All articles were screened by the first two authors independently. A criteria list to assess

the relevance and validity of the articles was developed and all selected articles were appraised by both authors independently (Table 1). Discordance in judgment was solved by consensus.

Figure 1. Flow Chart



3.5

Data extraction

We extracted the following data from each study; design, number of participants, type of PROMs performed, type of surgery performed, outcome and duration of follow-up. When the study reported other outcomes as well, only the relevant outcome was extracted. Outcomes of interest included validated PROMs for nasal patency, for different types of functional septorhinoplasty procedures.

Table 1. Critical Appraisal

	Validity								Relevance		
									Domain	Determinant	
Author, year	N = sample size	study design	Randomnization of treatment	Standardization of outcome measures	Standardization of surgical treatment	Standardization of non-surgical treatment	missing data	Blinding	Type of nasal obstruction	Surgical technique relevance	Outcome
Hytonen 2012	92	+	-	+	-	-	+	NA	+	+	+/-
Kahveci 2012	27	+	-	+	+	-	-	NA	+	+	+/-
Kim 2012	20	-	-	+/-	+	-	-	NA	+	+	-
Lindsay 2012	60	+	-	+	+	-	-	NA	+	+	+/-
Manestar 2012	60	+	-	+	-	-	+	NA	+	+	+
Mondina 2012	100	+	-	+	+	-	+	NA	+	+	+
Persichetti 2012	153	+	-	+	-	-	+	NA	+	+/-	-
Tan 2012	15	+	-	+	+	-	+	NA	+	+	+
Wee 2012	30	-	-	+	+	-	-	NA	+	+	-
Paradis 2011	63	+	+	+	+	-	+	NA	+	+	+
Tastan 2011	19	+	-	+	+	-	+	NA	+	+	+
Leclere 2010	12	+	-	-	+	-	+	NA	+	+	-
Most 2006	14	+	-	+	+	-	+	NA	+	+	+
Rhee 2005	20	+	-	+	-	-	-	NA	+	+/-	-
Stewart 2004	16	+	-	+	+	-	+	NA	+	+	+

Study design: + prospective, - retrospective
Standardization of outcome measures: PROM
Missing data: + no, - yes.
NA: not applicable

Results

Search strategy and critical appraisal

Our search strategy yielded 5351 results. After removing duplicates, applying the in- and exclusion criteria and screening on full-text, 15 articles remained for critical appraisal (Figure 1). Five studies were excluded for further analysis: in two studies the study design was retrospective and in two studies the standardization of the surgical treatment and the surgical relevance was undefined, multiple procedures including reduction of the turbinates had been performed but unclear in

whom. In one study the PROM was completed by the surgeon. Ten studies were selected for further analysis; these included 9 prospective cohort studies, level of evidence 2b and one randomized controlled trail (RCT), level of evidence 1b.

An overview of the final selection of articles with the type of PROMs, surgical intervention, and outcome measurements are presented in Table 2.

Internal nasal valve surgery

Three studies, 40 patients, reported a significant improvement regarding their nasal breathing after internal nasal valve surgery.[17, 24, 26] The applied surgical techniques were all designed to widen the internal nasal valve angle; spreader grafts with and without an upper lateral flaring suture or a modified spreader graft (H-graft). All studies used the NOSE score. The NOSE score improved between 38 and 60 points, the follow-up ranged from 1-3 to 12 months. No significant difference was reported between the first (1-3 months) and second (6-12 months) postoperative PROMs with the technique of spreader grafts in combination with an upper lateral flaring suture.[17]

External nasal valve surgery

Three studies, 38 patients, reported a significant improvement of the postoperative PROMs after surgery of the external nasal valve.[17, 21, 26] The surgical techniques used were J-flap, lateral crural strut graft and external valve suspension suture technique. In all studies the NOSE sore was used. Patients reported a significant improvement of the postoperative result in the NOSE score (range 40.8 – 46) with a follow-up between 1 to 13 months. No significant difference between the first (1-3 months) and second (6-12 months) postoperative PROMs was reported in patients where a lateral strut graft was applied.[17]

Combination of internal- and external nasal valve surgery

In 1 study, in total 30 patients underwent a combination of internal- and external nasal valve surgery.[17] Lindsay et al. used a spreader graft including an upper lateral flaring suture and a lateral crural strut graft. The reported outcome by the patients was a significant improvement compared with preoperative measures. The NOSE score improved 38.1 points (follow-up 6-12 months). The study lost patients during follow-up. Lindsay et al. reported a dropout of 2/30 after 1-3 months and 9/30 after 6-12 months.

Septoplasty

One RCT and five prospective cohort studies, 358 patients, reported a significant improvement of nasal patency after septoplasty. In five studies the NOSE score was used[10, 15, 18, 19, 23] and in one study the SNOT-22 questionnaire.[14] For the NOSE score the difference between the pre- and postoperative outcome improved between 35.2 and 48.9 points. The follow-up in these studies ranged from 1-16 months. The only RCT was performed by Paradis et al.,[23] they reported no difference in patient satisfaction between endoscopic versus conventional septoplasty, both

techniques had a significant improvement of the NOSE score. In two studies[10, 18] the postoperative PROM was measured twice. Both studies reported no significant difference in NOSE score between the first and second postoperative measurement, respectively 1 to 3 months and 3 to 6 months. Before and after surgery the SNOT-22 improved significantly with 3.5 points after a follow-up of 6 months. Manestar et al.[18] showed that disclosing information to patients about their postoperative rhinomanometry results could improve their NOSE score compared to patients that were unaware of this result.

Table 2. Study characteristics

Author / year	n	Study design	Tests	Type of obstruction	Surgical procedure	Follow up	Comparison pre- post
Hytonen 2012	92	P	SNOT 22	S	SSC	6 months	SNOT 3.5**
Kahveci 2012	27	P	NOSE	S	SSC	3-16 months	NOSE 48.9*
Lindsay 2012	14	P	NOSE	IV	SG + UL flaring sutrue	1-3 and **6-12** months	NOSE 57.7**
	16	P	NOSE	EV	LCS	1-3 and **6-12** months	NOSE 40.8**
	30	P	NOSE	IV + EV	SG + UL flaring suture + LCS	1-3 and **6-12** months	NOSE 38.1**
Manestar 2012	60	P	NOSE	S	SSC	1 and **3** months	NOSE 35.7**
Mondina 2012	100	P	NOSE	S	SSC	6 months	NOSE 35.2**
Tan 2012	15	P	NOSE	EV	J flap	9-13 months	NOSE 60**
Paradis 2011	32	P	NOSE	S	endoscopic septoplasty	3-4 months	NOSE 36**
	31	P	NOSE	S	conventional septoplasty	3-4 months	NOSE 44.5**
Tastan 2011	19	P	NOSE	IV	H-(spreader)graft	12 months	NOSE 60**
Most 2006	7	P	NOSE	IV	spreader graft	5-12 months	NOSE 38*
	7	P	NOSE	EV	external valve suspension	5-12 months	NOSE 46*
Stewart 2004	16	P	NOSE	S	SSC	3 and **6** months	NOSE 38.5**

P: prospective

Type of obstruction: septal (S), internal nasal valve (IV), external nasal valve (EV)

Surgical procedure: septal correction (SSC), spreader graft (SG), upper lateral (UL), lateral crural strut (LCS)

Comparison pre- post: difference between pre- and postoperative score

*<0,01

**<0,001

Discussion

All studies that were identified after systematic literature search and critical appraisal, reported an improvement of the PROMs after functional septorhinoplasty compared with preoperatieve values. The results were reported for different types of functional septorhinoplasty, including internal- and external nasal valve surgery and septoplasty.

The quality of the selected studies was limited. We studied 1 RCT, level of evidence 1b and 9 prospective cohort studies, level of evidence 2b. The moderate quality as well as the heterogeneity complicated firm conclusions.

Across the studies, the disease-specific quality of life as measured with the NOSE score improved with 35-60 points. A previous study reported that the smallest detectable clinical change was 19.4 points, based on a total score of 100.[10] The currently observed changes were approximately 2 to 3 times higher. This confirms that the impact of functional septorhinoplasty has a large clinical significance in addition to its statistical significance.

The selected studies represent different types of anatomical features of the nasal valves and different surgical techniques to improve nasal patency. The validated PROMs however, showed consistency regarding the significant improvement with just small variances for all reported techniques. Surgery of the internal nasal valve improved the NOSE score with 38 - 60 points. The NOSE score improved with 40.8 - 60 points for surgery of the external valve and with 38.1 points when both internal- and external valve surgery was addressed. Septoplasty improved the NOSE score with 35 to 48.9 points.

A comparison between conventional versus endoscopic septoplasty was made in the RCT by Paradis.[24] Both techniques significantly improved the NOSE score after surgery, but this improvement was not significantly different between the two techniques.

Patients subjective complaints can be influenced by the knowledge of the results of objective outcomes, as suggested by Manestar et al.[18] In this study half of the patients were informed about the significant improvement in postoperative rhinomanometry (NAR) results just before completing the NOSE score. There was no statistically significant difference in the postoperative NAR between both groups, but the informed patients reported a significant improvement of the postoperative NOSE score compared to patients that were unaware of their NAR result. This finding shows that the NOSE score can be influenced when providing information regarding the outcome of objective measurements. Bias like this should be prevented. According to the developers (Stewart et al) the questions of the NOSE score should be completed based on the subjective feelings over the past one month. This should be emphasized to the patient before completing the questionnaire.

The postoperative PROMs improved significantly compared with the measurements before surgery and showed no additional improvement during follow-up. No significant changes were reported between 1-3 and 6-12 months follow-up for internal-, external and combined surgery of the nasal valves.[17] For septoplasty, no significant changes were reported between 3 and 6 months follow-up.[10]

The strength of the current study is the systematic literature search. Moreover, the use of validated PROMs as outcome allowed us to examine the true patient experience. Previous studies showed evidence that nasal septal surgery improves nasal patency assessed by objective methods however patient's subjective perception of nasal obstruction is not strongly associated with objective assessments of disease severity.[1-8] From a patient perspective, symptoms and signs are the reason to seek medical attention and these symptoms should improve after functional septorhinoplasty. Therefore validated PROMs might be more important compared with objective measurements.

A weakness of these studies was the lack of a control group and randomization. There is however, no permanent alternative treatment for an insufficiency of the nasal valves other than surgical correction, so clinical equipoise does not allow for randomization away from septorhinoplasty to sham or placebo surgery or nonsurgical treatment.[10]

Conclusion

Based on the studies with moderate quality and surgical heterogeneity it is difficult to come to a firm conclusion about the validity of the results. However, the results were consistent across studies, suggesting that there is a significant improvement of validated PROMs after functional septorhinoplasty in patients with nasal valve problems in the first postoperative year.

Recommendation

We would recommend our patient functional septorhinoplasty because it may help her in to improve her nasal passage. However operation risk and complications should be considered.

Appendix 1. Search syntax

	Domain	Determinant	Combined (hits)
Pubmed	(Nasal valve[tiab] OR Internal nasal valve[tiab] OR External nasal valve[tiab] OR Nasal vestibule[tiab] OR Nasal cavity[tiab] OR Nose[tiab] OR Nasal airway[tiab] OR Nasal passage[tiab] OR Nasal breating[tiab] OR Impaired nasal breathing[tiab] OR Breathing disorder[tiab] OR Stenosis[tiab] OR Insufficiency[tiab] OR Inhalation[tiab] OR Respiration[tiab])	(Rhinoplasty[tiab] OR Septorhinoplasty[tiab] OR Septoplasty[tiab] OR Septal correction[tiab] OR Septal surgery[tiab] OR Nose surgery[tiab] OR Nasal surgery[tiab] OR Valve surgery[tiab] OR Nasal valve surgery[tiab] OR Alar batten[tiab] OR Spreader graft[tiab] OR Butterfly graft[tiab] OR Nasal graft[tiab])	2338
Embase	('Nasal valve':ab,ti OR 'Internal nasal valve':ab,ti OR 'External nasal valve':ab,ti OR 'Nasal vestibule ':ab,ti OR 'Nasal cavity':ab,ti OR 'Nose':ab,ti OR 'Nasal airway':ab,ti OR 'Nasal passage':ab,ti OR 'Nasal breathing':ab,ti OR 'Impaired nasal breathing':ab,ti OR 'Breathing disorder':ab,ti OR 'Stenosis':ab,ti OR 'Insufficiency':ab,ti OR 'Inhalation':ab,ti OR 'Respiration':ab,ti)	('Rhinoplasty':ab,ti OR 'Septorhinoplasty':ab,ti OR 'Septoplasty':ab,ti OR 'Septal correction':ab,ti OR 'Septal surgery':ab,ti OR 'Nose surgery':ab,ti OR 'Nasal surgery':ab,ti OR 'Valve surgery':ab,ti OR 'Nasal valve surgery':ab,ti OR 'Alar batten':ab,ti OR 'Spreader graft':ab,ti OR 'Butterfly graft':ab,ti OR 'Nasal graft':ab,ti)	2970
Cochrane Library	(Nasal valve):ti,ab,kw OR (Internal nasal valve):ti,ab,kw OR (External nasal valve):ti,ab,kw OR (Nasal vestibule):ti,ab,kw OR (Nasal cavity):ti,ab,kw OR (Nose):ti,ab,kw OR (Nasal airway):ti,ab,kw OR (Nasal passage):ti,ab,kw OR (Nasal breating):ti,ab,kw OR (Impaired nasal breathing):ti,ab,kw OR (Breathing disorder):ti,ab,kw OR (Stenosis):ti,ab,kw OR (Insufficiency):ti,ab,kw OR (Inhalation):ti,ab,kw OR (Respiration):ti,ab,kw OR	(Rhinoplasty):ti,ab,kw OR (Septorhinoplasty):ti,ab,kw OR (Septoplasty):ti,ab,kw OR (Septal correction):ti,ab,kw OR (Septal surgery):ti,ab,kw OR (Nose surgery):ti,ab,kw OR (Nasal surgery):ti,ab,kw OR (Valve surgery):ti,ab,kw OR (Nasal valve surgery):ti,ab,kw OR (Alar batten):ti,ab,kw OR (Spreader graft):ti,ab,kw OR (Butterfly graft):ti,ab,kw OR (Nasal graft):ti,ab,kw OR	43

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Chapter 4

Postoperative care of the nasal valve

Chapter 4.1

Postoperative management of nasal vestibular stenosis: the custom-made vestibular device

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Abstract

Objective: To evaluate the effect of a custom-made postoperative vestibular device on the occurrence and severity of restenosis.

Design: This was a retrospective study conducted at the Department of Otorhinolaryngology/ Head and Neck Surgery, Center for Facial Plastic and Reconstructive Surgery of the Academic Medical Center. In this tertiary care center between January 1994 and December 2000, 52 patients treated for nasal vestibular stenosis received a vestibular device directly postoperatively, with the intention to decrease the risk of restenosis. The vestibular device was composed of thermoplastic acrylic material and had a lumen to facilitate breathing. The shape of the device was custom-made within 1 week after surgery and was subsequently worn by the patient for 12 weeks (6 weeks continuously and 6 weeks only during the night). After this period, the occurrence and severity of restenosis of the nasal vestibule were evaluated and the necessity for a potential adjuvant operation was assessed.

Results: Preoperatively, of the 52 patients, 38 (73%) had severe stenosis, 13 (25%) had moderate stenosis, and 1 (2%) had mild stenosis. Postoperatively, 15 (29%) of the patients had mild restenosis, 1 had a case of moderate stenosis, and 1 had a case of severe stenosis. Only the latter patient required a subsequent revision. Functional improvement was noticed in 51 (98%) of the patients, whereas 49 (94%) of the patients showed aesthetic improvement after the initial procedure.

Conclusions: In case of surgical treatment of vestibular stenosis, the use of a custom-made vestibular device may help prevent restenosis. In addition to functional improvement, the device may also improve the aesthetic result. The device does not seem to have any negative adverse effects, was easy to make, and was comfortable for the patient to wear.

Introduction

In our clinic, we frequently encounter patients with impaired nasal breathing and aesthetic discomfort due to stenosis of the nasal vestibule. Most often, the stenosis is related to a congenital deformation, such as in patients with a cleft lip, or is acquired, as in the case of circumferential scar retraction of the vestibular lining after trauma, infection, or previous surgical procedures.

The treatment of vestibular stenosis is difficult and challenging. In managing this problem, thorough preoperative analysis and meticulous surgical planning are essential for making the procedure successful. When analyzing congenital or acquired vestibular stenosis, it is important to determine the anatomical pathological features. The pathological features can be caused by an aberrant anatomical structure, if not a malformation or a shortage of tissue (soft tissue and/or

cartilage).[1] In case of an aberrant anatomical structure, the stenosis can be caused by a deviated caudal septum, a protruding lateral crus, or a too broad columella. In such cases, reallocation and resection of redundant tissue are sufficient to correct the stenosis, and the chance of developing restenosis is small. For that reason, stenoses caused by aberrant anatomical structures were outside the scope of this study. More complicated surgical techniques are required in case of malformations or shortage of cartilaginous structures and/or the soft tissue envelope. In particular, scar tissue in the soft tissue envelope generally requires resection and replacement by free transplants of skin or auricular composite grafts.[2] In these cases, the operative techniques are more challenging and postoperative care should be more intensive to reduce the chance of restenosis.

Several studies[1-5] have shown that adequate postoperative care greatly influences final results. Recurrence of narrowing of the vestibule is a well-known problem after rhinoplastic surgery and is predominantly caused by scar tissue retraction. This is the problem, in particular, in patients in whom the internal nasal valve was involved in the pathology because this specific district requires a laminar flow pattern for sufficient flow and in case of stenosis this region is susceptible to impaired nasal breathing.[6] The cause of wound contraction is the inward movement of the intact edges of the injured tissue, which occurs during wound healing. The effect of this physiological phenomenon is to decrease the dimension of the area of trauma to its smallest possible extent and is due to the action of fibroblastic differentiation into myofibroblasts.[7] These myofibroblasts have ultrastructural characteristics of smooth muscle cells and are maximally present in the wound from the 10th until the 21st day. To avoid restenosis, it is necessary to maintain the contour of the nostril during wound contraction.[1, 8] To reach this goal and to prevent restenosis of the vestibule, many researchers[4, 9-13] proposed the use of some kind of nasal stenting in the postoperative period. Most of these splints are commercially available and made of elastic silicone or acrylic resin. The vestibular device we used in this study was inspired by the nostril splint, as described by Nakajima et al.[14] This group used a commercially available nostril splint, on which they placed silicone rubber material on the outside to provide additional support of the vestibule. However, custom-made splints also have been described, such as an expansible splint, used by Costa et al[13]; this splint was only tested on 1 patient. In our view, a vestibulum device should have a perfect fit (ie, a custom-made shape to reach optimal control during the postoperative period), preventing recurrence of stenosis. Therefore, we developed a custom-made vestibular device and tested it on patients with stenosis of the vestibule who underwent rhinoplasty.

Methods

All patients who received a custom-made vestibular device after surgical treatment for their nasal vestibular stenosis between January 1994 and December 2000 were included in this study. Fifty-two patients (24 males and 28 females) were studied.

Pathological anatomical features and operative techniques

The indication for surgery in the 52 patients (mean age, 29.1 years; median age, 25.3 years; age range, 3.4-79.1 years) was a unilateral cleft lip in 35 (67%), a bilateral cleft lip in 8 (15%), and narrowing of the vestibule due to previous surgery in 9 (17%) (percentages do not total 100 because of rounding). In all patients, stenosis of the vestibule due to previous surgery was caused by malformations or shortage of cartilaginous structures and/or of the soft tissue envelope. Most often, this was due to overresection of the lateral crus and scar tissue retraction of the vestibule lining. One patient had a shortage of tissue because of surgery of the lateral wall of the vestibule; the surgery was performed because of a melanoma. Surgical correction of vestibular stenosis caused by previous surgery was performed using cartilage and/or composite grafts to reconstruct the nasal skeleton and the soft tissue envelope. An auricular composite graft was especially useful in those patients in whom there was scar tissue in the dome area and overzealous resection of the lateral crus. In 4 patients, irradiated rib cartilage (Tutoplast; Tutogen Medical GmbH, Neunkirchen am Brand, Germany) was used. For the surgical correction of vestibular stenosis in the patients with unilateral and bilateral clefts, an external approach was appropriate, usually with the use of septum (n = 22) or ear cartilage (n = 16) grafts or an auricular composite graft (n = 11). (One patient received both septal cartilage and a composite graft.) Reconstruction of the lower nasal third was performed by reshaping malformed lateral crura with suture techniques and cartilage grafts and medialization of the caudal septum. The alar base was reallocated to a more medial position using a modified Z-plasty. An external approach was performed in 50 (96%) of the patients and an endonasal technique was used in 2 (4%) of the patients, both because of acquired stenosis of the vestibule.

Making the custom-made vestibular device

One week postoperatively, immediately after removal of the nasal packing and dressing, a cast of the nose and nasal vestibule was made. For this purpose, hydrophilic vinyl polysiloxane impression material, type regular (EXAMIX), was injected into the vestibule and on the external nose after blocking the nasal cavity posterior to the internal valve area with a 2-cm gauze. Underneath a plastic cap, the material had hardened after 5 minutes and could be removed (Figure 1A-C). Of this mold, a plaster of Paris cast model of the nose and nasal vestibules was made by the dental laboratory (Figure 1D). Based on this cast, a vestibular device was molded, which was made of thermoplastic acrylic. The design had a lumen so that normal nasal breathing was ensured (Figure 2). Patients were asked to wear this device the first 6 weeks continuously; after that, they were asked to wear the device for 6 weeks only at night (Figure 3).

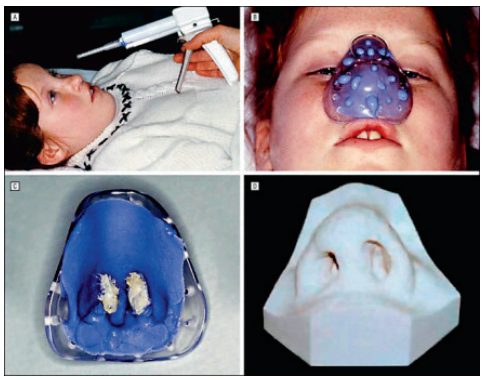

Figure 1. Injection of hydrophilic vinyl polysiloxane impression material (EXAMIX) into the vestibule and on the external nose after blocking the nasal cavity posterior to the internal nasal valve with a 2-cm gauze (A), hardening of the impression material for 5 minutes underneath a plastic cap (B), impression of the nasal vestibules and external nose in the impression material (the 2-cm gauze is visible at the impression of the most posterior part of the vestibule) (C), and plaster of Paris cast of the nose and nasal vestibules (D).

Figure 2. Custom-made vestibular device made of thermoplastic acrylic material with a lumen to facilitate breathing.

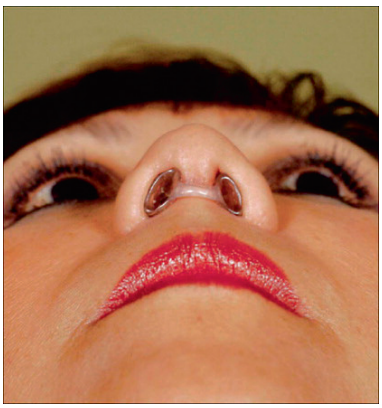

Figure 3. The custom-made vestibular device in situ; a 3-mm-thick transparent band over the columella is visible.

Definitions of the severity of the vestibular stenosis

The following items were studied retrospectively and collected in a database: age, sex, cause of stenosis, surgical approach, use of grafts, complications, total follow-up time, aesthetic improvement, functional improvement, and the necessity of revision surgery. Our objective was to study the functional improvement by determining the occurrence and severity of restenosis. For this purpose, we defined 3 levels of severity of the vestibular stenosis and a fourth level of no stenosis in case of a successful postoperative result. Each patient was scored on 3 variables preoperatively and postoperatively. The first level, severe stenosis, was defined as severe stenosis on clinical examination and photography, with continuous obstructive complaints, even at rest. The second level, moderate stenosis, was defined as moderate stenosis on clinical examination and photography, with complaints during mild exercise, like normal walking. The third level, mild stenosis, was defined as mild stenosis on clinical examination and photography, with complaints only during exercise, like running. The fourth level, no stenosis, was defined as no obvious stenosis on clinical examination or photography and no complaints during exercise. The patients were classified in a certain level of severity when at least 2 of 3 variables of that level were scored. In case 3 different levels of severity were scored for each variable, the mean of these levels of severity was chosen for that patient. Postoperative scoring was performed 4 weeks after the 12-week period of wearing the vestibular device. Functional improvement, after the surgical treatment and wearing the vestibular device, was established in case a patient could be classified in at least 1 higher level, as previously defined. Aesthetic improvement was achieved only as the surgeon and the patient concluded an aesthetic improvement had occurred compared with the preoperative condition

Results

Fifty-two patients (24 males and 28 females) were included in this study. The median time of wearing the device was 12 weeks (range, 6-49 weeks). In one case, in a patient with a unilateral cleft lip, the device was not worn for the full 12 weeks, due to a severe redeviation of the septum. Three patients wore the device for a prolonged period. The reasons for the prolonged application included a severe internal nasal valve insufficiency in 1 patient. Two patients necessitated a prolonged period because of the tendency of restenosis after 12 weeks. The median follow-up was 50.5 weeks, varying from 12 to 310 weeks. Before surgery, 38 (73%) of the 52 patients had severe stenosis; moderate stenosis was seen in 13 (25%) of the patients and only 1 (2%) of the patients had mild stenosis. After surgery, 1 (2%) of the patients had moderate restenosis and 1 (2%) had severe restenosis; 15 (29%) had mild restenosis. Of the 52 patients, 35 (67%) did not have stenosis postoperatively (Figure 4). Of all the patients, 51 (98%) showed functional improvement and 49 (94%) showed aesthetic improvement after the initial procedure, as defined in the “Definitions of the Severity of the Vestibular Stenosis” subsection of the “Methods” section (Figure 5, Figure 6, and Figure 7). Only 1 patient (2%) required revision surgery. This patient did not have functional improvement. Two patients (4%) improved by 1 level of severity, 28 (54%)

improved by 2 levels of severity, and 21 (40%) improved by 3 levels of severity. In 6 patients, the device had to be adjusted; and in 3 patients, a new device was made. Reasons for adjustment were a nonfitting device due to postoperative swelling or narrowing of the vestibule in the week between the making of the cast and the wearing of the device. Reasons for making a new device were either a device that was too large and could not be adjusted or a broken device. There was no noncompliance observed due to irritation of the vestibular skin or other problems. For the most part, patients felt comfortable wearing the device.

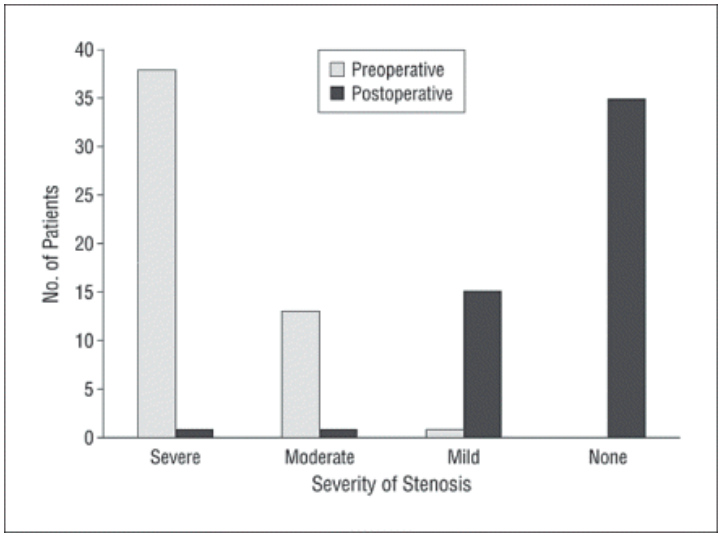

Figure 4. Severity of preoperative and postoperative stenosis. The preoperative bars indicate the number of patients with severe, moderate, and mild stenosis. After surgery, only 1 patient still had severe stenosis; most patients did not have signs or symptoms of vestibular stenosis after wearing the vestibular device.

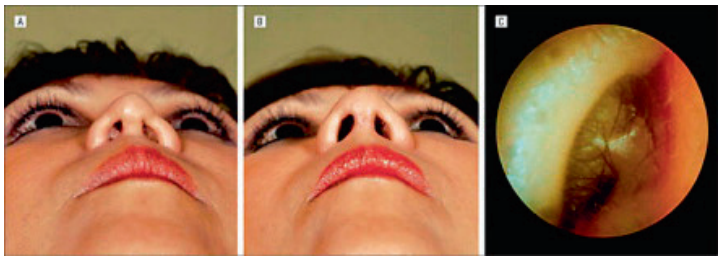

Figure 5. Preoperative (A) and postoperative (B) basal view of a patient with severe vestibular stenosis on both sides due to overresection of the nasal skeleton and soft tissue and preoperative endoscopic view of the vestibule of the same patient (C). The lateral wall of the vestibule is on the left and the nasal septum is on the right side; there were adhesions and synechia due to circular wounds after previous surgery. Reconstruction was performed through an open approach, with the use of auricular composite grafts.

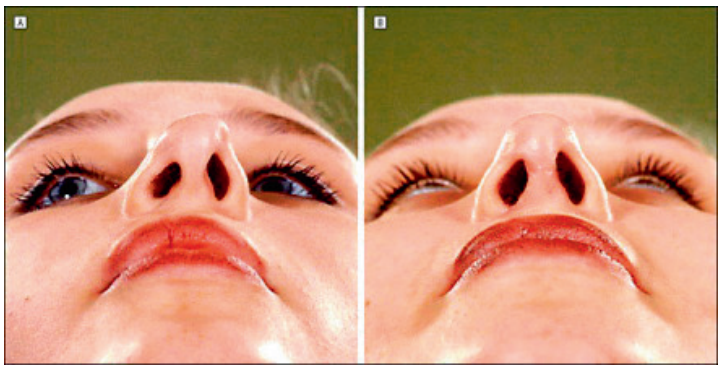

Figure 6. Preoperative (A) and postoperative (B) basal view of a patient with an asymmetric tip and vestibular stenosis due to a unilateral cleft lip on the right side. Surgical correction of the vestibule was performed through an external approach with the use of an autogenous ear cartilage.

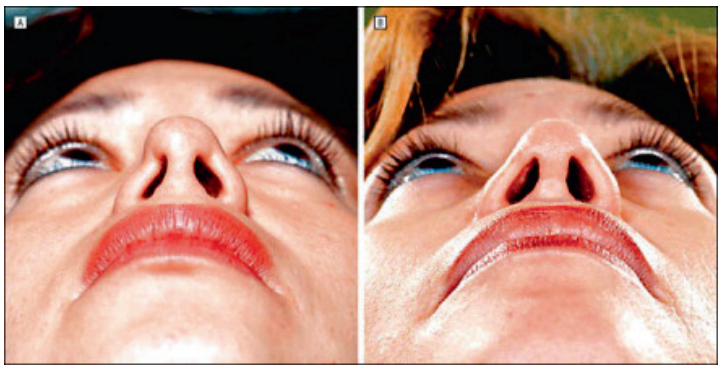

Figure 7. Preoperative (A) and postoperative (B) basal view of a patient with vestibular stenosis on the right side due to overresection of the lateral crus and vestibular skin. By using the external approach and an auricular composite graft, the shape of the vestibule was corrected.

Comment

The nasal vestibule, or the external nasal valve, is the first component of nasal resistance and is composed of the alar cartilage, the columella, the caudal end of the septum, and the soft tissue of the vestibular floor. Just behind this area, the internal nasal valve is situated; this is the narrowest segment of the airway. The internal valve area includes the caudal end of the upper lateral, the nasal septum, the head of the inferior turbinate, the piriform aperture, and the floor of the nose. Narrowing or stenosis in one of these valves results in impaired nasal breathing. In most of our patients in the present study, the stenosis was situated in external and internal valves. Internal valve problems, due to a caudal septum deviation, inferior turbinate hypertrophy, or a protruding lateral crus, and external valve problems, such as slitlike nostrils with weak alae, were outside the

scope of this study. This kind of pathological features were excluded because these patients do not need prolonged postoperative care because restenosis is uncommon.

Except for multiple case reports,[3, 12-13] to our knowledge, only one series[8] about postoperative management of vestibular stenosis has been published in the literature. In this previous series, between January 1988 and January 1994, a group of 52 patients with a cleft lip (5 with bilateral clefts and 47 with completely unilateral clefts) were studied. In this population, there was a postoperative recurrence of 10%, with more narrowing of the vestibule than in the preoperative situation. These patients required revision surgery. In the present study, there was no control group. However, even if a control group was included, we believe that it would be extremely difficult to randomize for the amount of vestibular pathological features, which by themselves may already influence outcome. Moreover, based on the good results we had with the vestibular device in the previous study, it seemed inappropriate to withhold from patients in a control group this adjuvant treatment possibility postoperatively.

We found that the custom-made vestibular device had a positive effect on maintaining the shape/contours of the nostril postoperatively, and we, thus, believe it has a positive effect on functional and aesthetic outcome. Other aspects of this device should be considered as well. The device could give local irritation, especially if not fitted adequately. This required an adjustment of the device; in 3 patients, a new and better-fitting device was to be made. In our study, no noncompliance was found because of irritation of the vestibular skin. Another factor was psychological. Although no patient in our group felt uncomfortable wearing the device, patients had to wear the device continuously during the first 6 weeks. Because there was the possibility that patients should feel uncomfortable wearing the device near other people, we designed the custom-made device in such a manner that as little as possible was visible externally. Only a 3-mm transparent band over the columella connected the 2 intranasal parts (Figure 3).

In conclusion, vestibular stenosis has a high risk of restenosis after surgical treatment due to wound contraction during wound healing. The use of a custom-made vestibular device may help reduce the chance of developing restenosis. In addition to functional improvement, the device also seems to improve the aesthetic result. The device does not seem to have any negative adverse effects, was easy to make, and was comfortable for the patient.

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Chapter 5

Discussion and conclusions

Discussion and conclusions

Functional- and aesthetic problems of the nasal valve area have diverse etiologies and surgical treatment options. The outcome of nasal surgery, is supposed to stay stable in the long term. However, there is lack of evidence on how different graft materials for nasal reconstruction behave in time regarding resorption and in contrast, even seem to grow in childhood. Although many surgical techniques exist, nasal valve pathology, especially collapse of the lateral sidewall during forced inspiration can be difficult to treat with the currents methods. With the use of objective measurements the outcome of surgery in terms of nasal patency, often correlates poorly with the subjective complaints of the patient and there is lack of evidence that patients benefit from functional septorhinoplasty. The diversity of etiologies, treatment options and lack of objective tests to evaluate the functional outcome, makes treatment of the individual patient in daily clinical practice challenging. This stimulated us to complete a number of research projects, containing 3 main themes that are present in this thesis:

1) Cartilage grafts and reconstruction of the nasal valve

- Irradiated homologous rib grafts (IHRGs) are widely used implant materials in nasal reconstruction but controversy persists about the resorption and complication rates. We performed a retrospective study, dating back 9 years, to assess the long-term efficacy for both augmentation and support function in rhinoplasty in general and for 9 specific recipient sites within the nose.

- Leprosy-related saddle-nose deformities are challenging to reconstruct due to the poor quality and quantity of the remaining nasal mucosa and retraction of the overlying soft tissue envelope. In this study we developed a grading system for leprosy-induced deformities of the nose and a new surgical technique with the use of autologous cartilage grafts. We evaluated the functional- and aesthetic outcome, resorption rate, warping, infection and extrusion. Based on these findings and the preoperative grading system we developed guidelines for nasal reconstruction in leprosy.

- Furthermore, we studied children with a history of nasal septal abscess and partial or complete destruction of nasal septal cartilage. Without surgical intervention the nose of these children would become underdeveloped with saddle nose deformities. In this study the nasal septa were reconstructed with autologous cartilage grafts of the auricle or rib fixed on polydioxanone (PDS) plate. Nasal outgrowth was measured by the length of the nose and by the amount of nasal tip projection and was compared with standardized growth curves. Aesthetic outcome variables included nasolabial angle, columellar retraction, and development of saddle nose deformity and were classified as normal, mild, or severe.

2) Suspension suture techniques and objective measurements in nasal valve surgery

- The first part of this chapter describes a new surgical technique the “lateral crus pull-up” an endonasal method for widening and strengthening the lateral component of the external nasal valve. The basis of the procedure is a permanent submucosal spanning suture between the piriform aperture and the distal part of the lower lateral cartilage. The surgical technique, post-operative care and preliminary results are presented.

- The second part of this chapter gives a review of suspension suture techniques in nasal valve surgery.

- In a quest for objective measurements in the evaluation of nasal patency we developed a computerized determination of the minimum cross-sectional area of the nasal passage on computed tomography (CT-MCA)

- In the fourth part of this chapter we evaluated CT-MCA. We compared pre- and postoperative outcomes in patients with external nasal valve insufficiency that underwent a “lateral crus pull-up” procedure. The nasal patency was assessed using a validated Nasal Obstruction Symptom Evaluation (NOSE) scale, the relations between objective tests CT-MCA, rhinomanometry, acoustic rhinometry and Peak Nasal Inspiratory Flow (PNIF) were evaluated.

- In the last part of this chapter we performed an evidence based case report. Validated patient reported outcome measures (PROMs), measure the subjective complaints of nasal breathing in order to allow us to capture the true patient experience. In this report we answer the question whether functional septorhinoplasty provide improvement of the nasal passage in validated PROMS for adults with an anatomical obstruction of the nasal valve.

3) Postoperative care after nasal valve surgery

- We studied postoperative management of nasal valve stenosis. We evaluated the effect of a custom-made postoperative vestibular device on the occurrence and severity of vestibular re-stenosis.

Cartilage grafts and reconstruction of the nasal valve

How is resorption of IHRGs characterized and what is the consequence for different recipient sites in the nose?

There are reports that IHRGs have low complication and resorption rates. [1-4] However, long-term follow-up series have shown that the incidence of resorption increases with the duration of follow-up and depends on the vascularity and microtrauma of the recipient site. [5-9] IHRGs that were used to reconstruct the auricle, for example, were more susceptible to graft failure than nasal grafts. [9] Moreover, some reports mentioned that resorption of IHRGs can be characterized by a loss of volume and/or a loss of support function due to the replacement of the original IHRGs by fibrous scar tissue.[1, 7, 8] In rhinoplasty, however, there are no reports about different resorption rates for specific nasal recipient sites. This triggered us to evaluate the augmentation and support function of IHRGs in rhinoplasty in general and for 9 specific recipient sites within the nose.[10] In this retrospective study we studied 66 patients, with a total of 177 IHRGs, dating back 9 years, with an average follow-up of 51 months. In this study we developed 3 levels of resorption and divided the patients into 3 groups depending on the duration of follow-up. In line with literature the rate of resorption increased with duration of follow-up. Complete resorption was found in 1 IHRG, and moderate resorption was observed in 55 IHRGs (31%). In contrast, in a recent study using 1025 IHRGs, much lower resorption rates have been reported, 0.48% post-infective and 0.53% non-infective resorption. [11] A possible explanation might be the fact that in our study chemically processed IHRGs from Tutoplast were used. In our study resorption was characterized by a loss of support function rather than a loss of volume. This was an important clinical finding. In line with literature this phenomenon was probably due to the replacement of the original IHRGs by fibrous scar tissue. For 8 recipient sites, this loss in tissue consistency did not negatively influence the functional or aesthetic result, only the use of IHRG shield grafts should be avoided, since nasal tip projection, definition and refinement were at risk in the long term. In facial plastic surgery there is lack of globally accepted definitions and guidelines regarding the evaluation of the rate of resorption of nasal grafts. This makes it difficult to compare data and to draw firm conclusions.

Does the preoperative grade of severity of leprosy-induced saddle-nose deformities influence surgical decision making?

There has still been no reduction in the detection rate worldwide for leprosy, despite supervised multi-drug therapy.[12] In time, leprosy can result in a severe saddle-nose deformity leading to functional problems, disfiguration and stigmatization. In severe cases, only the nasal skin and the lower lateral cartilages are preserved. In such cases, the ideal would be to restore the cartilaginous skeleton but this is complicated by the quantity and the poor quality of the remaining nasal mucosa. The literature describes a variety of reconstruction techniques and graft materials for leprosy-induced nasal deformities. For example, bone grafts, nasolabial skin- and forehead flaps, postnasal inlay of split-skin grafts, auricular and costal rib cartilage grafts and alloplasts are the

most widely used techniques and graft materials. [13-19] In a prospective study we performed nasal reconstruction in 24 Brazilian lepromatous leprosy patients involving the use of autogenous costal and/or auricular cartilage or -composite grafts. [20] We developed a grading system based on the preoperative severity of the nasal deformation and developed a new surgical technique using a costal cartilage dorsal onlay graft attached to a columellar strut with an extension on the proximal side to replace the destructed anterior nasal spine. We found that the resorption rate of cartilage rib grafts depended on the recipient site. Grafts in the nasal tip; like columellar strut grafts and shield grafts showed higher resorption rates (55%) compared to dorsal onlay grafts (27%). Furthermore, auricular cartilage grafts in the nasal tip showed lower resorption rates (23%) compared to costal cartilage grafts in the same region (55%). The clinical findings of this study in combination with the preoperative grade of severity were used to develop guidelines for optimal long-term functional and aesthetic outcome. In our study, functional and aesthetic improvement was clearly defined in materials and methods and was achieved in 15/17 patients. At the time our study was performed we defined functional improvement as a subjective improvement of nasal breathing compared to the preoperative condition. Today there are validated questionnaires to objectively evaluate nasal patency.[21-26] Nevertheless, in literature most studies do not have definitions or guidelines described in materials and methods regarding the evaluation of the outcome of rhinoplasty in leprosy patients. This makes it difficult to compare our data with these studies and to draw conclusions regarding the outcome of the used graft materials and surgical techniques. The same goes for the aesthetic result; in facial plastic surgery there is lack of globally accepted definitions and guidelines regarding the evaluation of the aesthetic result in rhinoplasty. This makes it difficult to compare data and to formulate conclusions.

Does complete reconstruction of the nasal septum with autologous cartilage grafts results in normal outgrowth of the nose in children?

There is still debate whether a nasal septal abscess in childhood requires reconstruction. Drainage, antibiotics, needle aspiration, packing of the nose, and combinations of these have been described as possible treatment options. There still remains lack of consensus in literature concerning the role of septal cartilage in childhood for the development of the nose. [27] Moreover, in children with destruction of septal cartilage both clinical observations and experimental studies have shown that these children will end up with an underdevelopment of both the nose and the maxilla. [28-39] In order to assess outgrowth and aesthetics of the nose in children after reconstruction of the cartilaginous nasal septum with autologous cartilage grafts on PDS plate we performed a prospective nonrandomized case series. Nasal outgrowth was measured by the length of the nose and by the amount of nasal tip projection and was compared with standardized growth curves. Aesthetic outcome variables included nasolabial angle, columellar retraction, and development of saddle nose deformity and were classified as normal, mild, or severe. Compared with standardized growth curves, the length of the nose and the amount of nasal tip projection were within 1 SD in all children. None of the children developed a saddle nose deformity, one

child had mild columellar retraction; 3 children had mild overrotation of the nasal tip. Our study, with limited amount of children, showed that the development of the nose was normal in all children. However, we have to follow-up the children until the age of 18. These results, together with new cases will be published in the future.

Suspension suture techniques and objective measurements in nasal valve surgery

Is the "lateral crus pull-up" technique an option to treat external nasal valve collapse?

Collapse of the nasal sidewall during inspiration is a frequently encountered symptom, often caused by weak or medially displaced lateral crura of the lower lateral cartilages. Different surgical methods to deal with nasal valve collapse have been described; cartilage grafts, repositioning and reallocation techniques, alloplast implants and more recently suspension suture techniques. [40-56] The latter triggered us to developed a new surgical method to deal with collapse of the external nasal valve, the "lateral crus pull-up" technique. [57] With the use of this procedure a permanent submucosal spanning suture pulls-up the distal part of the lower lateral cartilage towards the piriform aperture in order to increase the cross-sectional area and to provide additional support for the lateral wall of the external valve. The method is different from other suspension suture techniques because it is an endonasal technique in which the spanning suture is burried completely submucosal, there is no exposure to the outside world. Therefore, we expected lower postoperative infection rates compared to other techniques in which infection rates up to 24% have been reported. [50] In this preliminary report we studied 7 patients with a follow-up of 9 months. None of the patients had postoperative complications. The functional result was evaluated subjectively by the patients. Patients with insufficiency of the ala before surgery did not experienced collapse of the ala postoperative during normal breathing, forced inspiration, or physical exercise. The results remained stable after 3, 6, and 9 months; none of the patients experienced a decline in nasal breathing across time. However, there is lack of evidence in terms of objective measurements, that the lateral pull-up technique is effective. For this reason we performed a prospective study with the use of a validated questionnaire dealing with nasal patency and objective tests like acoustic manometry, rhinomanometry, PNIF and a new method to objective measure the minimum cross-sectional area using CT (CT-MCA). This study is presented in chapter 3.4.

Is CT-MCA reliable in calculating the position and orientation of the minimum cross-section area?

Current methods to determine the cross-sectional area of the nasal passage on CT do not determine the section with the minimum area. [58-64] This is due to the fact that most of these techniques perform measurements in the coronal plane while the true minimum cross-sectional area is often

on a tilted plane. [58, 59, 61, 62] This triggered us to develop software that allows determination of the cross-sectional area on any oblique plane intersecting with the nasal passage on CT. [65] Repeated execution of the algorithm on the same nasal passage with random initializations showed that the algorithm reliable converge on the minimum cross-section with little variation. The orientation of the plane containing the minimum cross-section was in all cases on a tilted plane with respect to the coronal plane. CT-MCA is reliable in calculating the position and orientation of the minimum cross-section area. Does CT-MCA correlate with validated questionnaires dealing with nasal patency? What is the relation with other objective tests that are currently available like; acoustic manometry, rhinomanometry and PNIF. These questions are studied and presented in chapter 3.4

What is the relation between CT-MCA and other objective measurements in patients that underwent a lateral crus pull-up procedure?

Current objective measurements to evaluate nasal patency like: rhinomanometry (NAR), acoustic rhinometry (A-MCA) and Peak Nasal Inspiratory Flow (PNIF) correlate poorly with the individual subjective sensation of breathing. [66, 67] This stimulated us to develop an objective computerized determination of the minimum cross-sectional area of the nasal passage on CT (CT-MCA). [65] To evaluate CT-MCA we compared pre- and postoperative outcomes in patients with external nasal valve insufficiency that underwent a "lateral crus pull-up" procedure. [57] Nasal patency was assessed using a validated Nasal Obstruction Symptom Evaluation (NOSE) scale [68-69] and evaluated in relation with objective tests A-MCA, NAR and PNIF. We found a significant correlation between CT-MCA and the NOSE-score, PNIF and NAR. PNIF also correlated significant with the NOSE-score and using multiple linear regression analysis also showed to have a significant positive predictive value for CT-MCA. In contrast to some other studies we did not only observe these correlations before surgery but also afterwards when the patients had significant minor complaints according their NOSE score. [70-73] In addition to the NOSE score the patients also had a significant improvement of CT-MCA and PNIF postoperatively. The lateral crus pull-up showed a significant improvement of both subjective- and objective results. Based on our results we advocate the use of PNIF in patients with external nasal valve insufficiency instead of CT-MCA. In contrary to CT-MCA, PNIF was more cost effective, had lower morbidity and was easy to use in daily practice. An advantage of CT-MCA however, is that it shows the MCA on a CT-scan, which might be helpful to determine the anatomical structures that are involved in the functional complaints of the patient. Future studies will have to be performed in order to evaluate the relations between CT-MCA and other objective tests for different surgical procedures.

Does functional septorhinoplasty provide improvement of the nasal passage in validated PROMS for adults with an anatomical obstruction of the nasal valve?

Validated PROMs concerning nasal patency, measure the subjective functional complaints of patients, they allow us to capture the true patient experience. From a patient perspective, the symptoms are the reason to seek medical attention and these symptoms and signs should improve after functional septorhinoplasty. We performed a systematic search using Pubmed, Embase and the Cochrane library. Our search strategy yielded 5351 results and after removing duplicates, applying the in- and exclusion criteria and screening on full-text 15 articles remained for critical appraisal. Ten studies were selected for further analysis; these included 9 prospective cohort studies, level of evidence 2b and one randomized controlled trail (RCT), level of evidence 1b. Based on the studies with moderate quality it is difficult to come to a firm conclusion about the validity of the results. It seems that there is a benefit in validated PROMs after functional septorhinoplasty in the first postoperative year.

Postoperative care after nasal valve surgery

Is the use of a custom-made vestibular device helpful in preventing restenosis?

Recurrence of narrowing of the vestibule is a well-known problem after rhinoplastic surgery and is predominantly caused by scar tissue retraction. In order to prevent restenosis adequate postoperative care greatly influences final results. [74-78] We performed a retrospective study, 52 patients treated for nasal vestibular stenosis received a vestibular device directly postoperatively, with the intention to decrease the risk of restenosis. The vestibular device was composed of thermoplastic acrylic material and had a lumen to facilitate breathing and was worn by the patient for 12 weeks (6 weeks continuously and 6 weeks only during the night). Preoperatively, of the 52 patients, 38 (73%) had severe stenosis, 13 (25%) had moderate stenosis, and 1 (2%) had mild stenosis. Postoperatively, 15 (29%) of the patients had mild restenosis, 1 had a case of moderate stenosis, and 1 had a case of severe stenosis. Only the latter patient required a subsequent revision. Functional improvement was noticed in 51 (98%) of the patients, whereas 49 (94%) of the patients showed aesthetic improvement after the initial procedure. A similar group of 52 patients without specific postoperative care, had a postoperative recurrence of 10%. [79] A weakness of the study, although the severity of stenosis was well defined in materials and methods, was the fact that we did not used a validated questionarre to evaluate nasal patency.

Conclusions

Based on results presented in this thesis, the long-term efficacy of IHRGs is safe for 8 different recipient sites in the nose. Only the use of IHRG shield grafts should be avoided since nasal tip projection, definition and refinement were at risk in the long term. In leprosy patients, autologous auricular cartilage grafts in the nasal tip were associated with lower resorption rates compared to autologous costal cartilage grafts. Based on the clinical findings of this study and the preoperative grading system we developed guidelines for nasal reconstruction in leprosy. The nose of children with partial- and complete destruction of septal cartilage showed a normal development when the septum was reconstructed with autologous cartilage grafts on PDS plate. Compared with standardized growth curves the length of the nose and the amount of nasal tip projection was within 1 SD in all children. Future studies are necessary to elucidate the development of the nose in these children after the age of 18. The lateral crus pull-up is an effective new technique for collapse of the external nasal valve. The method showed a significant improvement of both validated subjective- and objective measurements. We found a significant correlation between the new objective technique of CT-MCA with the NOSE-score, PNIF and NAR in patients with external nasal valve collapse that underwent a lateral crus pull-up procedure. Future studies are necessary to assess the relation between the different objective tests and other surgical procedures. We found a significant improvement of validated PROMs after functional septorhinoplasty in the first postoperative year. Adults with functional problems of the nasal valves due to anatomical pathology should consider functional septorhinoplasty. In patients with stenosis of the nasal vestibule, the use of a custom-made vestibular device may help reduce the chance of developing recurrence of stenosis.

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Chapter 6

Summary / Samenvatting

Summary

Chapter 1

In this chapter the relation between the cartilaginous nasal skeleton and the nasal valve region is discussed. The first two paragraphs focus on children, the normal development of the nasal skeleton and the indications for reconstruction of the cartilaginous nasal septum are outlined. In addition, the efficacy of different nasal grafts in reconstruction of the nasal skeleton in adults is discussed. The next paragraphs focus on the role of suspension suture techniques in nasal valve surgery and objective methods to evaluate nasal patency. The final paragraph focuses on the postoperative care of nasal valve stenosis.

Chapter 2.1

Controversy persists about the resorption and complication rates for irradiated homologous rib grafts (IHRGs) in the reconstruction of the nasal skeleton. In this chapter we studied the long-term efficacy of IHRGs for both augmentation and support function in rhinoplasty in general and for specific recipient sites within the nose. We evaluated 66 patients, with a total of 177 IHRGs, dating back 9 years, with an average follow-up of 51 months. The rate of resorption increased with duration of follow-up. Complete resorption was found in 1 IHRG, moderate resorption was observed in 55 IHRGs (31%). Resorption was characterized by a loss of support function rather than a loss of volume. Moderate resorption had a negative clinical outcome for shield grafts only.

Chapter 2.2

Despite supervised multi-drug therapy, there has still been no reduction in the detection rate worldwide for leprosy. In time, leprosy can result in a severe saddle-nose deformity leading to functional problems, disfiguration and stigmatization. These deformities are challenging to reconstruct because in severe cases only the soft tissue envelope and the lower lateral cartilages are preserved. The rest of the cartilaginous and bony skeleton is destructed completely with severe collapse of nasal valve region, the nasal mucosa is insufficient concerning the quantity and poor quality. In this chapter we studied 24 Brazilian lepromatous leprosy patients. Nasal reconstruction was performed using a new technique with autogenous costal and/or auricular cartilage and -composite grafts. Before surgery, the saddle-nose deformities were classified according to severity with a new developed grading system based on clinical signs and symptoms. Postoperative evaluation was performed at least two years after surgery (N = 17). Functional and aesthetic improvement, resorption rate, warping, infection and extrusion were analysed. Functional and aesthetic improvements were achieved in 15/17 patients. None of the patients developed an infection and extrusion or warping of the implants was not observed. The resorption rate depended on the localization and the type of cartilage implant. In general, auricular conchal cartilage implant grafts resulted in less resorption than costal cartilage. Least resorption (4/17 patients) was observed in the dorsal onlay grafts of both conchal (1/6) and costal cartilage grafts (3/11). Resorption of columellar strut grafts and shield grafts was observed in 7/17 patients. No

resorption was seen of composite grafts (0/4) and alar battens (0/7). Autogenous cartilage can be used to reconstruct saddle-nose deformities in leprosy with a minimum risk of complications. The preoperative grade of severity was used as a basis for the development of guidelines for optimal long-term functional and aesthetic outcome.

Chapter 2.3

The cartilaginous part of the nasal septum of a child with a septal hematoma or -abscess is at risk of destruction. Subsequently, the noses of these children can collapse causing a saddle nose deformity. In time the normal outgrowth of the nose and maxilla will be disturbed leading to an underdeveloped nose and maxilla. This chapter emphasizes the importance of adequate management of septal hematomas and abscesses in children. Diagnosis and surgical reconstruction of the nasal septum with the use of autologous cartilage is discussed.

Chapter 2.4

In this chapter we studied the outgrowth and aesthetics of the nose in children after reconstruction of the cartilaginous nasal septum with autologous cartilage grafts on polydioxanone (PDS) plate. The nasal septa of 6 children with a history of nasal septal abscess and partial or complete destruction of nasal septal cartilage were reconstructed with autologous cartilage grafts of the auricle or rib fixed on PDS plate. Nasal outgrowth was measured by the length of the nose and by the amount of nasal tip projection and was compared with standardized growth curves. Aesthetic outcome variables included nasolabial angle, columellar retraction, and development of saddle nose deformity and were classified as normal, mild, or severe. The duration of follow-up ranged from 10 to 68 months (mean follow-up, 38 months). Four children had complete loss of the cartilaginous septum. Areas 1 and 2 (caudal parts) had been destroyed in 2 children. Auricular cartilage was used in 5 children; costal cartilage was needed in 1 child. Compared with standardized growth curves, the length of the nose and the amount of nasal tip projection were within 1 SD in all children. None of the children developed saddle nose deformity. One child had mild columellar retraction; 3 children had mild overrotation of the nasal tip. Total reconstruction of abscess-induced destruction of nasal septal cartilage with autologous cartilage grafts fixed on PDS plate has, so far, resulted in normal development of the nose during follow-up, without expected aesthetic problems.

Chapter 3.1

This chapter describes the preliminary results of a new surgical technique for collapse of the external nasal valve, the “lateral crus pull-up”. Collapse of the nasal vestibule during inspiration is a frequently encountered symptom, often caused by weak or medially displaced lateral crura in the lower lateral cartilages. There are different surgical methods to deal with nasal valve collapse; cartilage grafts, repositioning and reallocation techniques, alloplast implants and more recently suspension suture techniques. The lateral crus pull-up is an endonasal technique using a permanent submucosal spanning suture that pulls-up the distal part of the lower lateral cartilage

towards the piriform aperture. The aim of this method is to increase the cross-sectional area and to provide additional support for the lateral wall of the external valve. In this preliminary report we studied 7 patients with a follow-up of 9 months. None of the patients had postoperative complications. The functional result was evaluated subjectively, patients with insufficiency of the ala before surgery did not experienced collapse of the ala after surgery during normal breathing, forced inspiration, or physical exercise. The results remained stable after 3, 6, and 9 months.

Chapter 3.2

This chapter presents a review of the literature of different suspension suture techniques in nasal valve surgery. Impaired nasal breathing or collapse of the lateral side wall of the nasal valve region during inspiration is a frequently encountered symptom. In general, this is caused by a cross-sectional area that is too small, a weak lateral side wall, or a combination of both. Until now, there are three major techniques described in the literature: nasal valve suspension in the direction of the orbital rim; spanning sutures across the nasal dorsum; and the suspension and rotation of the lower laterals toward the piriform aperture.

Chapter 3.3

The value of objective measurements in the evaluation of nasal patency is still not fully understood. Rhinomanometry (NAR), acoustic rhinometry (A-MCA) and peak nasal inspiratory flow (PNIF) correlate poorly with the individual subjective sensation of breathing. In this chapter we developed a new method to determine the minimum cross-sectional area of the nasal passage on CT (CT-MCA). Current methods to determine the cross-sectional area of the nasal passage on CT perform measurements in the coronal plane, while the true minimum cross-sectional area is often on a tilted plane. We developed software that allows determination of the cross-sectional area on any oblique plane intersecting with the nasal passage on CT. Repeated execution of the algorithm on the same nasal passage with random initializations showed that the algorithm reliable converge on the minimum cross-section with little variation. The orientation of the plane containing the minimum cross-section was in all cases on a tilted plane with respect to the coronal plane. The developed method can be used for objective and observer-independent evaluation of nasal valve surgery.

Chapter 3.4

CT-MCA is an objective computerized determination of the minimum cross-sectional area of the nasal passage on CT. In this chapter we studied CT-MCA by comparing pre- and postoperative outcomes in 34 patients with external nasal valve insufficiency that underwent a “lateral crus pull-up”. All patients had external nasal valve insufficiency due to medially displaced or weak lateral crura of the lower lateral cartilages. Before and after surgery all patients were evaluated, for each unilateral nasal passage, for both subjective and objective tests. The subjective perception of the patient was evaluated using a validated questionnaire, the NOSE score, the objective tests included NAR, A-MCA and PNIF. CT-MCA and PNIF were both significantly correlated and associated with

the patient's subjective perception of nasal passage, the NOSE scale. The surgical procedure, the "lateral crus pull-up technique" showed a significant improvement of the postoperative outcomes for the NOSE-score, CT-MCA and PNIF. Based on these results we recommend PNIF rather than CT-MCA, in the evaluation of external nasal valve insufficiency because it is more cost effective. CT-MCA however, can be helpful in the determination of the anatomical structures that are involved in the MCA.

Chapter 3.5

A systematic Pubmed, Embase and Cochrane library search was performed in order to answer the question whether functional septorhinoplasty provides improvement of the nasal passage in validated patient reported outcome measures (PROMs) for adults with an anatomical obstruction of the nasal valve. Articles were critically appraised and ranked according to validity and relevance. Fifteen articles met our inclusion criteria and 10 were eligible for further analysis. We studied 1 RCT, level of evidence 1b and 9 prospective cohort studies, level of evidence 2b. Based on the studies with moderate quality and surgical heterogeneity it was difficult to come to a firm conclusion about the validity of the results. The results suggest that there is a significant improvement of validated PROMs after functional septorhinoplasty in patients with nasal valve problems in the first postoperative year.

Chapter 4.1

Recurrence of vestibular stenosis is a common problem after surgery of the nasal valve. In many causes this is due to scar tissue retraction. In this chapter, we studied 52 patients treated for nasal vestibular stenosis that received a vestibular device directly postoperatively, with the intention to decrease the risk of re-stenosis. The vestibular device was composed of thermoplastic acrylic material and had a lumen to facilitate breathing and was worn by the patient for 12 weeks (6 weeks continuously and 6 weeks only during the night). Preoperatively, of the 52 patients, 38 (73%) had severe stenosis, 13 (25%) had moderate stenosis, and 1 (2%) had mild stenosis. Postoperatively, 15 (29%) of the patients had mild restenosis, 1 had a case of moderate stenosis, and 1 had a case of severe stenosis. Only the latter patient required a subsequent revision. Functional improvement was noticed in 51 (98%) of the patients, whereas 49 (94%) of the patients showed aesthetic improvement after the initial procedure. In case of surgical treatment of vestibular stenosis, the use of a custom-made vestibular device may help prevent re-stenosis. In addition to functional improvement, the device may also improve the aesthetic result. The device does not seem to have any negative adverse effects, was easy to make, and was comfortable for the patient to wear.

Samenvatting

Hoofdstuk 1

In dit hoofdstuk wordt de relatie tussen het kraakbenige neusskelet en de neusklep besproken. De eerste twee paragrafen concentreren zich op kinderen, hierin wordt de normale ontwikkeling van het neusskelet besproken evenals de indicaties voor reconstructie van het neusseptum, teneinde een normale groei van de neus te bevorderen. Vervolgens wordt ingegaan op de effectiviteit van verschillende typen implantaten voor de reconstructie van het neusskelet bij volwassenen. De daaropvolgende paragrafen richten zich op chirurgische technieken die met behulp van hechtdraden de neusklep verruimen en op methoden die de neus- doorgankelijkheid objectief kunnen beoordelen. De laatste paragraaf concentreert zich op de postoperatieve zorg van neusklepchirurgie, in het bijzonder om een recidief stenose te voorkomen.

Hoofdstuk 2.1

Het gebruik van bestraald humaan donor ribkraakbeen (IHRGs) voor de reconstructie van het neusskelet en de neusklep is controversieel op het gebied van resorptie en complicatierisico's. In dit hoofdstuk hebben we de lange termijn effectiviteit van IHRGs bestudeerd wat betreft het behoud van volume en steunfunctie voor 9 specifieke locaties in de neus. Hiervoor hebben we 66 patiënten onderzocht waarbij 177 IHRG implantaten zijn gebruikt met een follow-up tot 9 jaar en een gemiddelde follow-up van 51 maanden. De resorptie van IHRGs nam toe met de follow-up duur. Complete resorptie werd bij 1 IHRG waargenomen, matige resorptie werd bij 55 (31%) van de IHRGs geconstateerd. Resorptie werd gekarakteriseerd door een verlies van steunfunctie, het volume van het implantaat bleef behouden. Matige resorptie had alleen een negatieve invloed op het klinische resultaat bij het gebruik van IHRGs als shield graft.

Hoofdstuk 2.2

Ondanks gesuperviseerde behandeling is er wereldwijd geen reductie van de incidentie van Lepra. Gedurende het ziekteproces kan Lepra resulteren in een ernstige zadelneusdeformatie welke aanleiding kan geven tot functionele problemen, disfiguratie en stigmatisatie. Reconstructie van deze afwijkingen is uitdagend omdat in ernstige gevallen alleen de overliggende huid en het kraakbeen van de alaire kraakbeentjes zijn behouden. De rest van het kraakbenige- en benige neusskelet is vernietigd met als gevolg een collaps van de neusklep regio, de mucosa is insufficiënt ten aanzien van de kwantiteit en kwaliteit. In dit hoofdstuk hebben wij 24 Braziliaanse patiënten bestudeerd met lepromateuze Lepra. Reconstructie van het neusskelet werd uitgevoerd met behulp van een nieuwe techniek waarbij autogeen ribkraakbeen en/of oorschelpkraakbeen en auriculaire composite grafts werden gebruikt. Voordat reconstructie plaatsvond werden de zadelneus deformaties geclassificeerd aan de hand van een nieuw ontwikkeld graderingssysteem op basis van de ernst van de klachten en klinische verschijnselen. Postoperatieve evaluatie werd ten minste twee jaar na de ingreep uitgevoerd (N=17). Functioneel- en esthetische verbetering,

resorptie-, kromtrekken van de implantaten alsmede infectie en extrusie werden onderzocht. Functioneel- en esthetische verbetering werd bereikt bij 15/17 patiënten. Geen van de patiënten ontwikkelde een infectie, extrusie of kromtrekken van de implantaten werd niet waargenomen. De resorptie van de implantaten was afhankelijk van de lokalisatie en het type kraakbeen dat was toegepast. In het algemeen toonden implantaten van oorschelpkraakbeen minder resorptie dan ribkraakbeen. De minste resorptie (4/17 patiënten) werd waargenomen bij dorsal onlay grafts van zowel oorschelpkraakbeen (1/6) en ribkraakbeen (3/11). Resorptie van columellar strut grafts en shield grafts werd in 7/17 patiënten waargenomen. Geen resorptie werd gezien bij auriculaire composite (0/4) en alar batten grafts (0/7). Implantaten van autogeen kraakbeen kunnen worden toegepast bij de reconstructie van zadelneus deformaties bij Lepra met een minimaal risico op complicaties. Het preoperatieve graderingssysteem, waarmee de ernst van de nasale afwijkingen werd geclassificeerd, werd gebruikt voor de ontwikkeling van richtlijnen voor een optimaal functioneel- en esthetisch lange termijn resultaat.

Hoofdstuk 2.3

Het kraakbenige deel van het neusseptum van een kind met een septumhematoom of –abces, loopt het gevaar te worden gedestrueerd. Als gevolg hiervan kunnen de neuzen van deze kinderen inzakken wat zich klinisch presenteert als een zadelneus deformatie. Op latere leeftijd krijgen deze kinderen een gestoorde ontwikkeling van de neus en maxilla resulterend in een onderontwikkelde neus met zadeldeformatie en een retropositie van de maxilla. Dit hoofdstuk behandelt de relevantie van een adequaat beleid van neusseptumhematomen en –abcessen bij kinderen. In lijn met de huidige kennis worden diagnostiek en de chirurgische interventie besproken.

Hoofdstuk 2.4

In dit hoofdstuk hebben wij de uitgroei en esthetiek bestudeerd van de neus bij kinderen die een reconstructie hebben ondergaan van het kraakbenige septum met behulp van autogene kraakbeen implantaten op polydioxanone (PDS) folie. Het neusseptum van 6 kinderen met een geschiedenis van een neusseptumabces en gedeeltelijke of complete destructie van het septumkraakbeen zijn gereconstrueerd met autogene oorschelp- of ribkraakbeen implantaten op PDS folie. De uitgroei van de neus werd vergeleken met gestandaardiseerde groeicurven van de lengte van de neus en neustip projectie. De esthetische parameters waren de nasolabiale hoek, retractie van de columella en de ontwikkeling van een zadelneus deformatie en werden geclassificeerd als normaal, mild of ernstig. De follow-up duur bedroeg 10 tot 68 maanden (gemiddelde follow-up, 38 maanden). Vier kinderen hadden een compleet verlies van septumkraakbeen. Area I en II (caudale gedeelten) was gedestrueerd in twee kinderen. Oorschelpkraakbeen werd in 5 kinderen toegepast, bij 1 kind werd ribkraakbeen gebruikt. In vergelijking met de gestandaardiseerde groeicurven waren de lengte van de neus en de neustip projectie bij alle kinderen binnen 1 standaard deviatie. Geen van de kinderen ontwikkelde een zadelneus deformatie. Een kind had milde retractie van de columella en 3 kinderen een milde overrotatie van de neustip. Een complete reconstructie van een abces geïnduceerde destructie van het neusseptumkraakbeen met autogene kraakbeen implantaten

op PDS folie heeft, tot zover, geresulteerd in een normale ontwikkeling van de neus gedurende de follow-up, zonder de te verwachten esthetische problemen.

Hoofdstuk 3.1

Dit hoofdstuk beschrijft de voorlopige resultaten van een nieuwe operatieve techniek voor de behandeling van collaps van de externe neusklep, de "Lateral Crus Pull-Up" (LCPU). Collaps van het vestibulum nasi gedurende geforceerde inspiratie is een frequent voorkomend symptoom. Vaak is dit het gevolg van zwakke- of te veel naar mediaal georiënteerde laterale crura van de alaire kraakbeentjes. Er zijn verschillende chirurgische methoden voor collaps van de neusklep; kraakbeen implantaten, repositie en reallocatie technieken, alloplastische implantaten en meer recent "suspension suture techniques". LCPU is een endonasale techniek waarbij een permanente, submucosaal gelegen, hechtdraad het distale gedeelte van het laterale crus van het alaire kraakbeentje opwaarts- en lateraal fixeert aan de apertura piriformis. Het doel van de methode is het vergroten van de dwarsdoorsnede van de externe neusklep en het verstevigen van diens laterale wand. In dit voorlopige rapport hebben we 7 patiënten onderzocht met een follow-up van 9 maanden. Geen van de patiënten had postoperatieve complicaties. Het functionele resultaat is subjectief geëvalueerd, patiënten die voor de ingreep insufficiëntie van de externe neusklep vertoonden hadden dat niet meer na de ingreep bij normale nasale inspiratie, geforceerde inspiratie of gedurende lichamelijke inspanning. De resultaten waren stabiel na 3, 6 en 9 maanden.

Hoofdstuk 3.2

Dit hoofdstuk worden verschillende soorten "suspension suture" technieken voor neusklep chirurgie beschreven. Verminderde neuspassage of collaps van de laterale wand van het neusklepgebied bij inspiratie is een frequent voorkomend probleem. In het algemeen wordt dit veroorzaakt door een te kleine dwarsdoorsnede van het lumen, een te zwakke laterale wand of een combinatie van beiden. Tot nu toe zijn er drie typen suspension suture technieken beschreven in de literatuur; hechtdraden van de neusklep in de richting van de rand van de orbita, hechtdraden van de neusklep over de neusrug naar de contralaterale zijde en hechttechnieken van de externe neusklep richting de apertura piriformis.

Hoofdstuk 3.3

De waarde van objectieve metingen in de evaluatie van de neuspassage is nog niet opgehelderd. Rhinomanometrie (NAR), acoustische rhinometrie (A-MCA) en peak nasal inspiratory flow (PNIF) correleren vaak niet met de individuele subjectieve beleving van de neuspassage. In dit hoofdstuk beschrijven wij een nieuwe methode die de minimale dwarsdoorsnede van het lumen in het neusklep gebied kan berekenen met behulp van een CT scan (CT-MCA). Bestaande methoden die de minimale dwarsdoorsnede bepalen met behulp van een CT scan maken die berekening in het coronale vlak, terwijl het echte minimum zich vaak in een ander vlak bevindt. Wij ontwikkelden software waarmee het mogelijk gemaakt werd om de minimale dwarsdoorsnede te berekenen

in elk mogelijk oblique vlak door het lumen in het neusklep gebied. Herhaalde metingen van het algoritme in de luchtweg van dezelfde persoon met random gekozen beginpunten toonden aan dat de software met slechts weinig variatie steeds dezelfde minimale dwarsdoorsnede berekende. De oriëntatie van het vlak waarin het minimum lag was in alle geteste CT scans anders dan het coronale vlak. De ontwikkelde methode CT-MCA kan gebruikt worden voor een objectieve en onafhankelijke evaluatie van neusklep chirurgie.

Hoofdstuk 3.4

CT-MCA is een objectieve gecomputeriseerde berekening van de minimale dwarsdoorsnede van het lumen van de neusgang op een CT-scan. In dit hoofdstuk hebben wij CT-MCA bestudeerd door pre- en postoperatieve uitkomsten te vergelijken bij 34 patiënten met insufficiëntie van de externe neusklep die een “lateral crus pull-up” (LCPU) operatie hebben ondergaan. Alle patiënten hadden insufficiëntie van de externe neusklep door mediaal verplaatste of zwakke laterale crura van de alaire kraakbeentjes. Voor- en na de ingreep werden alle patiënten geëvalueerd, elk neusgat afzonderlijk, met objectieve- en subjectieve testen. De subjectieve beleving van de neuspassage werd geëvalueerd met behulp van een gevalideerde vragenlijst, de NOSE scale. De objectieve testen bestonden uit NAR, A-MCA en PNIF. CT-MCA en PNIF waren beide significant gecorreleerd en geassocieerd met de subjectieve beleving van de neuspassage, de NOSE scale. De methode LCPU liet een significante verbetering zien van het postoperatieve resultaat zowel subjectief als objectief. Op basis van deze resultaten adviseren wij PNIF boven CT-MCA voor de evaluatie van externe neusklep insufficiëntie omdat PNIF goedkoper is en makkelijker in het gebruik. CT-MCA echter, kan behulpzaam zijn bij het bepalen van de anatomische structuren die betrokken zijn bij de minimale dwarsdoorsnede van het lumen van de neusgang.

Hoofdstuk 3.5

Een systematisch onderzoek werd verricht in Pubmed, Embase en de Cochrane library teneinde de vraag te beantwoorden of functionele septorhinoplastiek een verbetering van de neuspassage geeft met behulp van gevalideerde “patient reported outcome measures” (PROMs) bij volwassenen met een anatomische obstructie van de neusklep. De artikelen werden kritisch beoordeeld en gerangschikt aan de hand van de validiteit en relevantie. Vijftien artikelen voldeden aan de inclusiecriteria en 10 artikelen kwamen in aanmerking voor verdere analyse. Wij bestudeerde 1 gerandomiseerd onderzoek, level of evidence 1b en 9 prospectieve cohort studies met een level of evidence 2b. Het was moeilijk om gedegen conclusies te trekken over de validiteit van de resultaten van deze studies met matige kwaliteit en chirurgische heterogeniteit. De resultaten suggereren een significante verbetering van de neuspassage na functionele septorhinoplastiek bij patiënten met functionele klachten door een anatomische obstructie van de neusklep in het eerste jaar na de operatie.

Hoofdstuk 4.1

Een recidief van een vernauwing van het vestibulum nasi is een vaak voorkomend probleem na chirurgie van de neusklep. In dit hoofdstuk hebben wij 52 patiënten bestudeerd die behandeld zijn voor een te nauwe neusklep en die direct postoperatief een “vestibular device” kregen aangemeten met de intentie de kans op her-stenose te verkleinen. Het vestibular device was gemaakt van acryl en had een lumen dat ademhaling mogelijk maakte en werd gedragen gedurende 12 weken (6 weken dag en nacht en 6 weken alleen ’s-nachts) Preoperatief hadden 38 van de 52 patiënten (73%) een ernstige stenose, 13 (25%) hadden een matige stenose en 1 (2%) had een milde stenose. Postoperatief, hadden 15 (29%) van de patiënten een milde stenose en 1 (2%) een matige stenose en 1 (2%) een ernstige stenose. Alleen deze patiënt had revisie chirurgie nodig. Functionele verbetering werd bij 51 (98%) en een esthetische verbetering bij 49 (94%) van de patiënten waargenomen. Bij de chirurgische behandeling van een stenose van het neusklep gebied kan een custom-made vestibular device de kans op een her-stenose verkleinen en het esthetische resultaat verbeteren. Het device lijkt geen nadelige bijwerkingen te hebben, was gemakkelijk te maken en comfortabel te dragen door de patiënt.

Appendix

A1: Abbreviations

A-MCA:	acoustic minimum cross-sectional area
BB:	borderline borderline
BT:	borderline tuberculoid
CT:	computed tomography
CT-MCA:	computed tomography minimum cross-sectional area
ENT:	ear nose throat
EXAMIX:	hydrophilic vinyl polysiloxane (impression material)
I:	indeterminate
IHRGs:	Irradiated homologous rib grafts
LCPU:	lateral crus pull-up
LL:	lepromatous leprosy
MCA:	minimum cross-sectional area
NAR:	nasal airway resistance
NOSE scale:	nasal obstruction symptom evaluation scale
PDS:	polydioxanone
PNIF:	peak nasal inspiratory flow
PROMs:	patient reported outcome measures
PTFE:	expanded polytetrafluoroethylene (Gore tex)
SD:	standard deviation
SNOT-22:	sinonasal outcome test
TT:	tuberculoid
WHO:	world health organisation

A2: List of publications

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A3: Dankwoord

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A4: Curriculum vitae

Dirk Jan Menger was born on March 11th, 1969 in Tiel, The Netherlands. After graduating from secondary school he started Medical Biology at the University of Amsterdam. He obtained his propedeuse and in 1991 started Medical School at the Academic Medical Center at the University of Amsterdam. After he obtained his medical degree in 1998 he started working as a resident at the department of Otorhinolaryngology / Head and Neck Surgery at the Academic Medical Center in Amsterdam. At this department he started his specialist training ENT in December 1999 under supervision of Prof. dr P.F. Schouwenburg and his successor Prof. dr. W.J. Fokkens. During his residency he had the opportunity to be trained by Prof. dr. Gilbert Nolst Trenité and he became interested in functional- and aesthetic rhinoplasty and facial plastic surgery. In 2004 he obtained a position as an ENT surgeon at the Academic Medical Center in Amsterdam and he started his PhD studies under supervision of Prof. dr. Gilbert Nolst Trenité. In these studies he investigated different aspects of the nasal valve. Since 2007 he also obtained a position at the Bergman Clinics in Amsterdam, Bilthoven and The Hague for aesthetic rhinoplasty, where he still works today. In 2009 he became national delegate for the European Academy of Facial Plastic Surgery (EAFPS) and course director of the International Course in Modern Rhinoplasty Techniques at the Academic Medical Center in Amsterdam. In June 2013 he left the Academic Medical Center and started with a position at the Onze Lieve Vrouwe Gasthuis (OLVG) in Amsterdam and at the University Medical Center in Utrecht where he completed this thesis. In 2014 he and Prof. Dr. Gilbert Nolst Trenité started the International Course in Advanced Rhinoplasty Techniques at the University Medical Center in Utrecht. He lives in Amsterdam and is married to Veronique Serpenti and is father of a daughter, named Eva Julie (2010).