THE CARTILAGINOUS NASAL DORSUM AND THE POSTNATAL GROWTH OF THE NOSE

THE CARTILAGINOUS NASAL DORSUM AND THE POSTNATAL GROWTH OF THE NOSE

(Het kraakbenige neusdak in de groeiende neus)

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Promotor:	Prof.Dr.C.D.A. Verwoerd
Overige leden :	Prof.Dr.P.C. de Jong
	Prof.Dr.J.C. Molenaar
	Prof.Dr.J. Voogd

This study is part of the project Airway Stenosis.
Supervisor: Dr.H.L. Verwoerd-Verhoef
Institute for Otorhinolaryngology
Erasmus University Rotterdam

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"The greatest achievements are not necessarily attained by the greatest efforts, but by someone exerting the greatest effort in a field where he has the greatest advantage."

"Nooit meer slapen", W.F.Hermans

to Cécile,
Germaine and Carline.

CONTENTS

CHAPTER 1

INTRODUCTION

Anomalies of the nose can be present at birth. They may be isolated or occur in association with other facial malformations such as cleft lip and palate or hypertelorism. Nasal deviations that arise at a later age are mostly the result of an earlier injury. The outwardly visible abnormalities are usually caused by the abnormal shape of the structure beneath the skin, i.e. in the nasal skeleton, which consists partly of cartilage and partly of bone. In the adult the cartilaginous section comprises the anterior part of the nasal septum that at the nasal dorsum merges into the upper lateral cartilages on both sides, forming the cartilaginous nasal dorsum. Separate from these structures are the alar cartilages in the tip of the nose. The bony part of the nasal skeleton consists of the left and right nasal bones, together with the frontal processes of the maxilla. The nasal bones are supported in the midline by the posterior bony part of the nasal septum.

Refinements in operating techniques now make it possible for deviations in the nose and nasal skeleton to be corrected surgically during childhood. Thus nasal surgery in children has become a focus of attention in the last two decades. At the same time there has been increasing interest in the immediate treatment of nasal injuries, which often occur in young children.

As the result of injury to the nose a haematoma can develop between the septal cartilage and the mucoperichondrium - on one side or both - and this can become infected. It has been known for a long time that the resulting septal abscess can partly or wholly destroy the septal cartilage. When this occurs at a young age it results in underdevelopment of the nose, which sometimes leads to a saddle-shaped sunken dorsum. Injuries can also cause fractures and deviations of the nasal septum and eventually lead to an outwardly visible deformation of the nose. The more serious septum deviations cause a blocked nose and recurrent or chronic inflammation of the nose, paranasal cavities and middle ear. The consequences can be so troublesome that the decision is made to correct the septal deviation by surgery. One ear, nose and throat specialist will take this decision sooner than another. It depends on the importance he attaches to the possible unfavourable effects of corrective surgery on the further development of the nose.

How serious the effects on the growth will actually be is, for various reasons, difficult to determine from clinical observations. In the first place the condition itself, inherent in the deformation that has to be corrected, may be responsible for further abnormal development. Secondly, the deviation caused by the injury and the necessary corrections are different in each patient. Thirdly, there are large differences in the shape of the nose due to inherited characteristics. Finally it is necessary to follow up patients until after the adolescent growth spurt before the ultimate shape (and function) of the nose can be evaluated (at the age of 16-18 years). The effects of injuries sometimes only become apparent as much as 10 years later.

Another way of helping to establish a rational basis for nasal surgery in children is by carrying out experimental research in young fast-growing animals. A carefully defined operation can be carried out in a series of young animals. The further development can then be studied and compared with that in a control group. In rabbits, for example, it has been studied how an interruption in the septal cartilage, disturbs later growth of the nose. The effects that various surgical techniques to correct the septal cartilage in children have on the development of the nose, have also been studied in experimental animals. Taken together the results of these studies indicate that injuries of the nasal septum at an early age have serious consequences for the final shape of the adult nose. Furthermore, not one of the methods to reconstruct an injured septum tested so far enables the growth to return to normal.

Until now the numerous articles about nasal surgery in children and the associated experiments have paid little or no attention to the cartilaginous nasal dorsum. Yet the importance of the upper lateral cartilages for the shape of the nose is well known to all who do nasal surgery in adult patients. Inadequate correction of asymmetries of these thin, cartilaginous, plate-like structures leads inevitably to external deviations of the nose.
Moreover, there is no detailed description of the upper lateral cartilages in children to be found in the literature. It has apparently been assumed that the anatomy of a child's nose is identical to that of an adult.

Consequently, with respect to nasal surgery in children the following questions have to be considered:

1. What is the anatomy of the cartilaginous nasal skeleton and, in particular, the cartilaginous nasal dorsum in children?

2. What is the role of the cartilaginous nasal dorsum (upper lateral cartilages) in the postnatal growth of the nose?

The first question is dealt with in the chapters 2 and 3, the second in the chapters 10, 11, 12 and 14. A general discussion will follow in chapter 15.

CHAPTER 2

LITERATURE ON THE CARTILAGINOUS NASAL DORSUM IN CHILDREN AND ADULTS

2.1 Introduction.

No description of the anatomy of the upper lateral cartilages in children could be found, either in the rhinological or in the anatomical literature. Therefore data on the cartilaginous nasal dorsum in the prenatal period and in the adult stage will be presented. The morphology in children may be expected to be a stage in the development between the former and the latter.

2.2 Prenatal anatomy.

In the third week of the embryonic period, the first anlage of the nose comprises a concentration of mesenchymal cells around the olfactory placodes. Later these condensations differentiate into cartilage and fuse to form the cartilaginous nasal capsule (Bosma '86). This fusion is complete by about the 10th week. The cartilaginous capsule then consists of two vaults open on their basal sides and with the medial sides fused to the primordium of the nasal septum. Between the vaults on both sides the supraseptal groove is found in the median line. The nasal capsule extends from the tip of the nose to the point where it merges into the cartilaginous base of the skull (fig. 1). The nasal bones and the frontal processes of the maxillary bone, which together form the bony nasal skeleton, develop by desmal ossification and lie superficial to the cartilaginous nasal capsule (Hamilton '66).

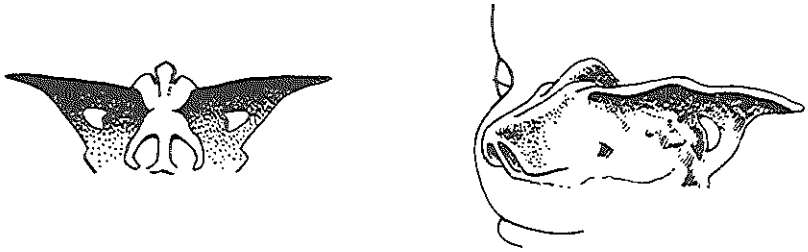


Fig. 1. The cartilaginous nasal capsule from a human foetus at 4 months after Kollmann. Frontal view on the left and oblique side view on the right (according to Straatsma '51, modified).

During the foetal period in which the nose attains its characteristic external form, the double-vaulted cartilaginous nasal capsule undergoes a series of changes. The nasal turbinates and the primitive paranasal sinuses are formed via a complicated process of folding, ossification and resorption of the dorsal and lateral parts of the nasal capsule (Schaeffer '10, '16 and '20). According to Wen ('40) the dorsal part of the nasal capsule changes about the 26th week from a double-vaulted structure into a triangular plate on both sides, as in the adult stage. He does not mention any extension of the upper lateral cartilage under the nasal bones. The ventral, foremost part of the nasal capsule is divided by the growth of connective tissue into the alar (lower lateral) cartilages and the upper lateral cartilages (Wen '40). This separation, beginning at each lateral side, should be completed by the 28th week (Wen '40).

2.3 Adult anatomy.

The cartilaginous structures in the nose of an adult are the anterior part of the nasal septum (the quadrangular cartilage) and on both sides the upper lateral cartilage (lateral or triangular cartilage), the accessory or sesamoid cartilages in the alae and the alar cartilage (fig. 2). Textbooks on anatomy and on rhinology (Spalteholz '61, Sobotta '67, Hollinshead '67, Hafferl '67, Dehneke '67, Hinderer '71 and Gray '80) differ considerably in the description of these cartilages. This could indicate a large degree of biological variation.

The upper lateral cartilage is usually depicted as a triangular-shaped piece of cartilage lying on both sides of the septum and fused to its dorsal rim. The extension, both laterally and towards the tip of the nose and the nasal bones, is described in various ways.

Straatsma et al ('51) have given the results of dissections of the nasal cartilage in 20 adults. They found that the upper lateral cartilage did not terminate at the edge of the nasal bone. The cartilage extends under both nasal bones for 7 - 14 mm. The extension is greatest near the midline and decreases laterally. A thin layer of connective tissue between bone and cartilage is considered as periosteum fused with perichondrium. The transition from the upper laterals to the septum is T-shaped at the tip of the nose, while in cranial direction it becomes Y-shaped, thus forming a supraseptal groove.

Converse ('55) confirms these findings and even records an extension of the upper lateral cartilage under the nasal bone for 20 mm. At the lateral side the lateral cartilage is joined to the edge of the piriform aperture (the alveolar and frontal processes of the maxilla) by fibrous tissue. The upper lateral cartilage is attached to the alar cartilages by dense connective tissue. The upper edge of the alar cartilage overlaps the lower edge of the lateral cartilage, like a roof tile. In the centre the two alar cartilages are joined together by an aponeurosis ("weak triangle").

Little has been added to our knowledge since Converse's study. Natvig et al ('71) observed that the cartilage under the nasal bone apparently becomes thinner from medial to lateral. According to Drumheller ('73) and Jost ('73) the lateral cartilage curls outwards at the overlapping "roof tile" transition, thus narrowing the angle with the septum. Le Pesteur ('77) prefers the term lateral or superior cartilage because according to him a real triangular shape is rarely found, except in the negroid race. Zelnik et al ('79) stress the variations in the size of the lateral crus of the alar cartilages, which must be taken into account when making incisions in rhinoplasty.

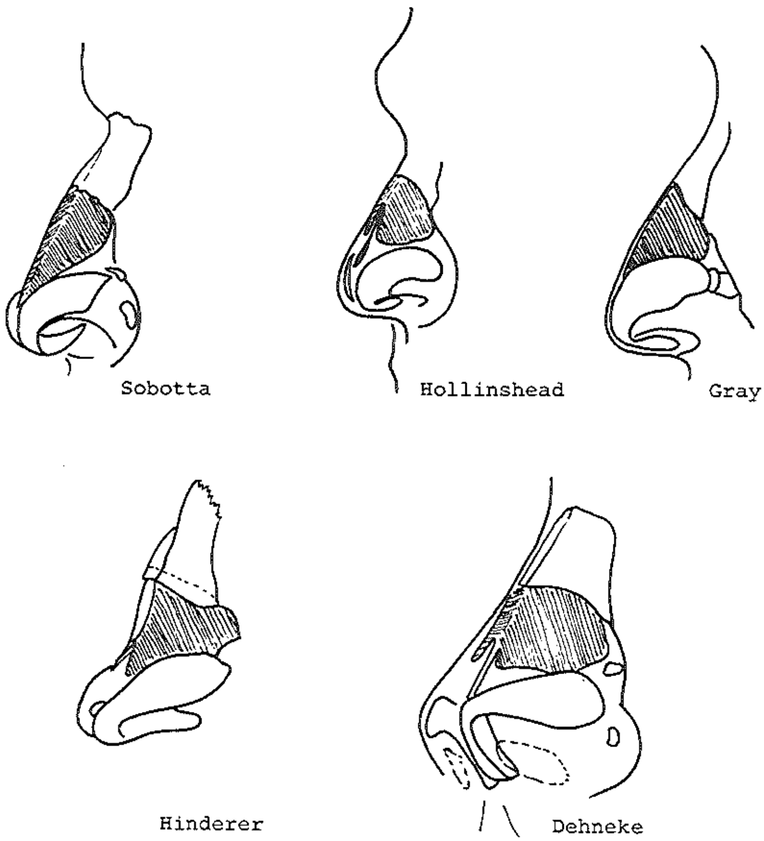


Fig. 2. *Impression of the structure and interrelationship of the lateral cartilages (shaded) in human adults, according to Sobotta '67, Hollinshead '67, Gray '80, Hinderer '70 and Dehneke '67. Only Hinderer indicates the overlap of the upper lateral cartilages from the lower laterals and the extension of the upper laterals under the nasal bones.*

Considering the information on the prenatal and adult anatomy some conclusions may be drawn:

1. The nasal cartilage shows a simultaneous regression of large parts and growth of the remaining parts.

2. The cartilaginous nasal dorsum initially merges into the cartilaginous anterior skull base. Together with the ossification of the skull base, large parts of the nasal cartilage "disappear" as a result of ossification and regression until only the anterior part of the septum, upper laterals and alar cartilages are left.

3. Septal cartilage and upper lateral cartilages are not separate anatomical entities but the medial and lateral parts of one double-vaulted structure already formed in the embryonic period.

4. The nasal bones are the product of desmal ossification close to the external surface of the cartilaginous nasal dorsum.

5. As far as the cartilaginous dorsum in children is concerned the stage of development between the foetal and adult situation is still not known and has to be studied by dissection.

CHAPTER 3

DISSECTION OF THE CARTILAGINOUS NASAL SKELETON IN NEONATES

The cartilaginous nasal skeleton was studied by dissecting the nose and surrounding structures from two stillborn human neonates (after a pregnancy of 36 and 38 weeks respectively). The specimens were fixed in a formaldehyde 10% solution within 24 hours of death. Both specimens were dissected following the same procedure. The observations in both cases were very similar. Therefore only drawings and descriptions of one specimen will be presented, being representative for both.

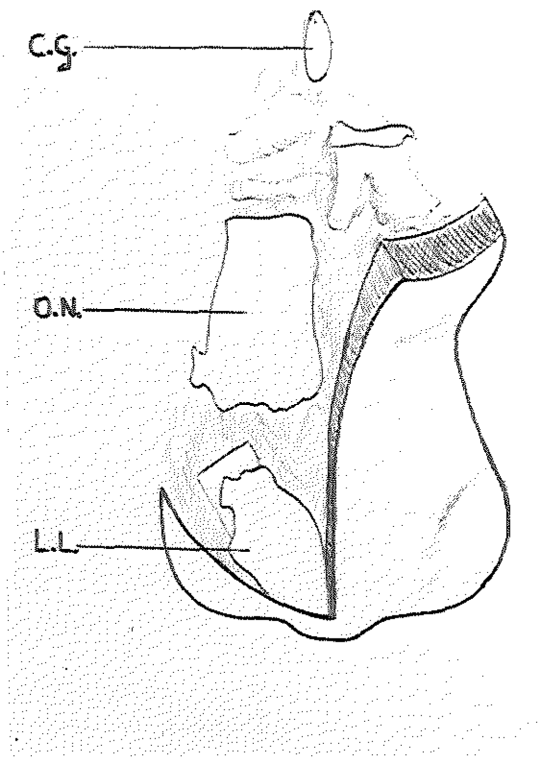


Fig. 3. Tracing of a cranial view of a specimen (human neonate after a pregnancy of 38 weeks) demonstrating the lower lateral cartilage (L.L.), the nasal bone (O.N.) under a thick subcutaneous layer and the crista galli (C.G.).

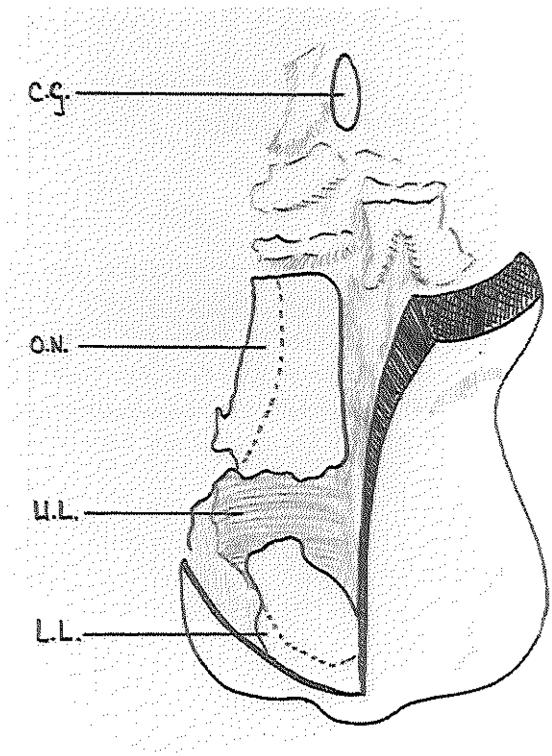


Fig. 4. *Tracing of a cranial view of a specimen (human neonate after a pregnancy of 38 weeks) demonstrating the outline of the upper lateral cartilage (U.L.), under the lower lateral cartilage (L.L.) and the nasal bone (O.N.).*

Exposing the nasal skeleton by a median incision over the nasal dorsum (fig. 3) a thick subcutaneous layer of fatty tissue was found, measuring 10 mm over the frontonasal suture and thinning out towards the tip of the nose. Thus the facial profile in the neonate is to a large extent determined by subcutaneous fat. The nasal groove (nasion) does not correspond with the frontonasal suture.

The bony part of the nasal dorsum is slightly shorter than the cartilaginous part. The internasal and frontonasal sutures are not yet ossified. The edges of the piriform aperture, formed by the frontal processes and the nasal bones on both sides, are rather irregular (fig. 4).

On both sides of the tip of the nose the alar cartilages partly encompass the nasal vestibule laterally. No cartilage is found in the most lateral part of the ala (fig. 4). The upper lateral cartilages forming the cartilaginous nasal dorsum appear to continue under the full length of the nasal bones and merge into the cartilaginous anterior skull base. The upper lateral cartilages are vaulted, fusing in the midline with the cartilaginous

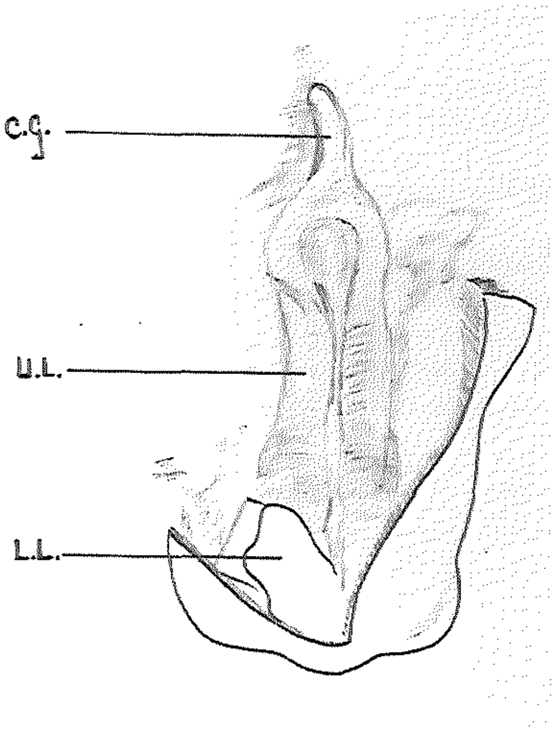


Fig. 5. *Tracing of a cranial view of a specimen (human neonate after a pregnancy of 38 weeks) demonstrating the lower lateral cartilage (L.L.) in the tip of the nose, partially covering the upper lateral cartilage (U.L.).*
The supraseptal groove can be distinguished in the median line between both upper laterals. This groove widens cranially forming a marked concavity in which the nasal bones are anchored. The upper laterals are in full contact with the skull base and the crista galli (C.G.).

septum. Both vaults are separated by the supraseptal groove (fig. 5). In cranial direction the convex shape of the vault is more pronounced as the supraseptal groove widens and deepens, ending in a concavity, in which the nasal bones were anchored by a terminal thickening on their inner surface.

Seen from a rhinosurgical point of view, the following conclusions are relevant:

1. In the neonate the cartilaginous nasal dorsum is still continuous with the cartilaginous skull base. Consequently it extends from near the tip of the nose for the full length under the nasal bones.

2. The anatomy of the upper lateral cartilages in the neonatal nose is similar to the foetal situation as described by Hamilton ('66), Patten ('68) and Bosma ('86).

3. The upper lateral cartilages do not show the extension and size of the adult shape as is suggested by Wen ('40).

4. The alar cartilages are present as separate structures, as seen in the adult.

5. Considerable changes in the morphology of the nasal cartilages - growth and regression or ossification of large parts - must occur during childhood. The postnatal development of the cartilaginous nasal dorsum remains to be studied. Judged from their size it may be expected that the upper lateral cartilages are more important during childhood than in the adult stage.

CHAPTER 4

THE GROWING RABBIT AS EXPERIMENTAL ANIMAL

4.1 Introduction.

In the early seventies the Amsterdam anatomist Van Limborg was interested in the postnatal development of the skulls of children with facial clefts. To investigate how a growing normal skull reacted to the presence of various clefts, experimental research was done in growing rabbits (New Zealand white females).
The initial reasons for choosing this experimental animal are simple. Young rabbits are of a convenient size for performing operations upon the facial skeleton; cavia, rat and mouse appear to be too small at the corresponding age. On the other hand, larger animals than the rabbit are too expensive for large series of experiments. In pilot studies the postoperative death-rate of animals, younger than 4 weeks of age, was very high. Growth studies of the skull demonstrated that by 24 weeks the definite skull form and size had been attained. So the experimental period was defined to be between 4 weeks after birth (experimental surgery) and 24 weeks after birth (the adult stage).

Successively various aspects of the growth of the facial skull in this experimental model have been investigated. The influence of unilateral or bilateral alveolar and/or palatal clefts (Verwoerd-Verhoef '74) have been examined, as have the growth-correcting effects of methods to repair facial clefts (Urbanus '74), the results of partial resection of the cartilaginous nasal septum (Mastenbroek '78), the growth after replacement of parts of the septum with autologous or alloplastic implants (Nolst Trenité '84), the effects of techniques used in nasal septum correction (Nijdam '85) and wound healing of growing septal cartilage (Meeuwis '85). The collection of carefully stored skulls (ENT department Rotterdam-AZR/Amsterdam-AMC) now serves for comparison with recent experimental results.

At first sight the anatomy of the rabbit is not favourable for experimental analysis of the role of the upper lateral cartilages, as the nasal dorsum is formed by the nasal bones for nearly the whole length, with only the last few millimeters near the tip being cartilaginous. The advantage of the link to the earlier work prevailed over this disadvantage.
The anatomy of the cartilaginous nasal dorsum in other mammals is dealt with in chapter 4.2. After a short description of materials and methods (chapter 6), the results of a series of experiments in growing rabbits are presented in chapters 8, 9, 10, 11, 12, 13 and 14.

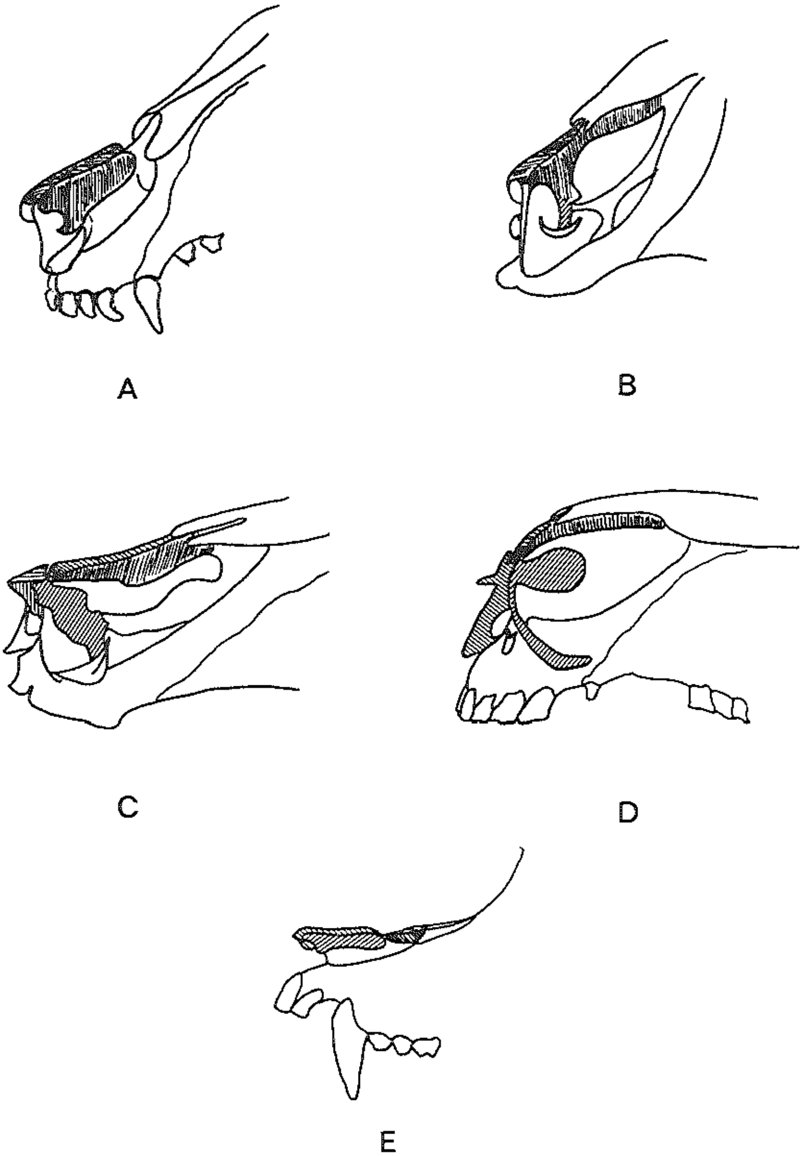


Fig 6. Impression of the structure and inter-relationship of the dorsal parietal cartilages (shaded) and the wing or alar cartilages (shaded) in some mammals (dog (A), sheep (B), cow (C), horse (D) and baboon (E)) according to Nickel '67 (modified).

4.2 Literature on the anatomy of the cartilaginous nasal dorsum in rabbits and other mammals.

No description of the anatomy of the cartilaginous nasal skeleton nor, in particular, of the lateral cartilage in rabbits and other smaller animals, has been found in the literature. Tonneyck-Müller ('82) and Meeuwis ('85) reported on some histological characteristics of the septal cartilage in the rabbit, but did not comment on other aspects of the anatomy of the nasal cartilage.

Only a limited amount of data is available on the cartilaginous part of the nasal skeleton in some larger adult mammals such as dog, sheep, cow, horse and monkey (fig. 6). Essentially it consists of the nasal septum (septal cartilage) with dorso-lateral extensions, which anteriorly merge into the lateral part and even into the floor of the nose. There it ends near the septum and forms the cartilaginous part of the vomeronasal organ of Jacobson (Nickel et al '67). Shape, size and extent of this complex structure vary considerably from one species to another.

In the dog the dorsal parietal nasal cartilage has no immediate contact with the bony part of the nose (Miller et al '68). It is wider anteriorly and gets narrower posteriorly. The thickness of the cartilage also decreases from anterior to posterior. Between the concave edge of the nasal bone and the dorsal nasal parietal cartilage lies a zone of dense connective tissue.

In the horse the dorsal cartilage is proportionately smaller, although it does extend as far as the nasal bone. There is no description of a further extension under the nasal bone (Nickel et al '67). In the tip of the nose a separate piece of cartilage, firmly fixed to the dorsal cartilage and surrounding the nasal aperture (nasal alar cartilage), is decribed (Getty '75).

Sheep and cattle have a prolonged dorsal cartilage. In both mammals the cartilage extends as far as the nasal bone where it is wider than near the tip of the nose. An extension under the nasal bones is not mentioned (Nickel et al '67). In both cases there are clear indications of a wing cartilage.

The shapes of the nasal cartilages in various primates have been extensively discussed in an article by Wen ('40). In the lower species of monkey (prosimians and platyrrhines) the separation between the wing cartilage and the lateral cartilage is incomplete, even in adults. A separate wing cartilage of conspicuous size is found in the higher species (catarrhines) soon after birth. In some species, such as the rhesus monkey and baboon, there is but little dorso-lateral cartilage left. Extension under the nasal bone is not reported in these animals either.

In conclusion :

1. There is no anatomical description available of the cartilaginous nasal dorsum in the rabbit.

2. No data pertinent to the postnatal development of the cartilaginous nasal skeleton in animals could be found in the literature.

3. The observations in the adult dog, sheep, cow and horse demonstrate that the cartilaginous nasal skeleton essentially consists of the septum with bilateral extensions in the dorsal cartilage and in some cases a separate wing cartilage of variable size and shape. The relation between the bony and cartilaginous nasal dorsum varies from direct contact in some animals to a connection via an intermediate zone of fibrous connective tissue in others.

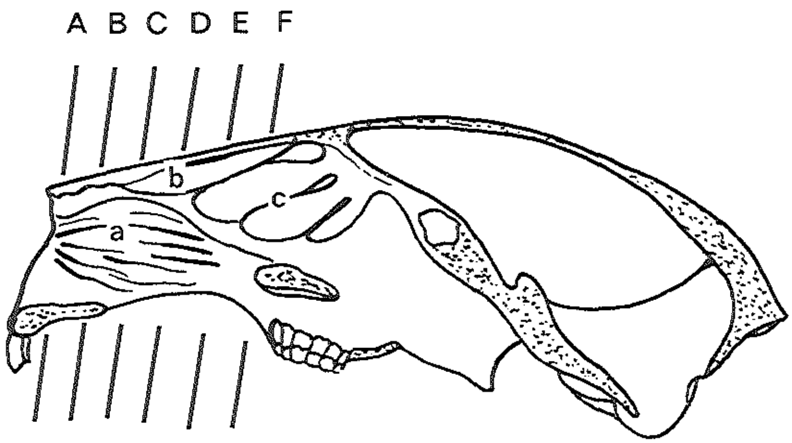


Fig. 7. Paramedian section of the rabbit skull with a view on the lateral wall of the nose with planes of dissection (A-F) seen in fig. 9.
(a) concha nasalis ventralis or maxilloturbinate, (b) concha nasalis dorsalis or nasoturbinate, (c) concha nasalis medialis or ethmoturbinate.

CHAPTER 5

ANATOMY OF THE CARTILAGINOUS NASAL DORSUM IN YOUNG AND ADULT RABBITS

5.1 The cartilaginous nasal skeleton in the 4 week old rabbit.

The cartilaginous nasal skeleton was studied by dissecting the nose of a 4 week old rabbit. Additional information was gained from a series of transverse microscopic sections through the nose of a young rabbit in the study by Meeuwis ('85) (fig. 7). The nasal dorsum consists for the greater part of bone i.e. the nasal bones bordering the frontal processes of the intermaxillary bone on either side. The nasal sutures (frontonasal, naso-intermaxillary and internasal) have not yet become ossified. The length of nasal bones, measured along the internasal suture is at this age approximately 18 mm.

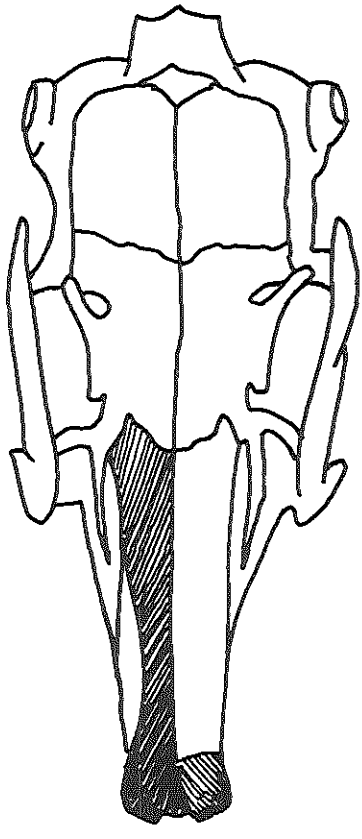


Fig. 8. *Cranial view of the rabbit skull (4 weeks old).*
The nasal bone on the right side is removed, giving view of the dorsal parietal cartilage or lateral cartilage (shaded).

Only at the tip of the nose is the nasal dorsum cartilaginous. In the mid-sagittal plane the antero-posterior length measures only 3 mm (fig. 8). At the level of the nasal vestibule the dorsal part of this cartilage curves with a medial convexity round and inwards to form the lateral nasal wall and even curves around in the nasal lumen. The (slightly V-shaped) anterior free edge of this lateral cartilage is joined to the free edge of the nasal bone by a dense layer of connective tissue. Medially both cartilages continue into the nasal septum. Laterally on both sides they widen out into a dome-shaped configuration thus forming a shallow Y-shaped supraseptal groove. There is no evidence of separate alar cartilages.

After removal of the nasal bone it can be observed that the cartilaginous nasal dorsum extends from the tip of the nose under the entire length of the nasal bones to merge into the cartilaginous base of the skull (fig. 8). The transverse diameter of these vaults decreases from the tip of the nose, to halfway along the nasal dorsum (fig. 9a-c). Laterally it extends as far as the ridge of the nasal turbinate, while in a more dorsal direction the lateral cartilage merges into the ethmoidal turbinate (fig. 9e and f). The supraseptal groove changes from a shallow Y-shape in the tip of the nose to a more distinct Y-shape halfway along the nose and is T-shaped at the base of the skull (fig. 9a-c and f).

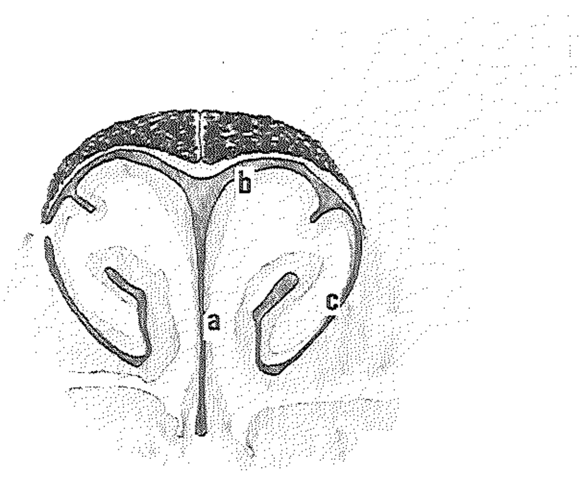


Fig. 9a. *Coronal section (A) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (c)ventral parietal cartilage, (d)nasal bone.*

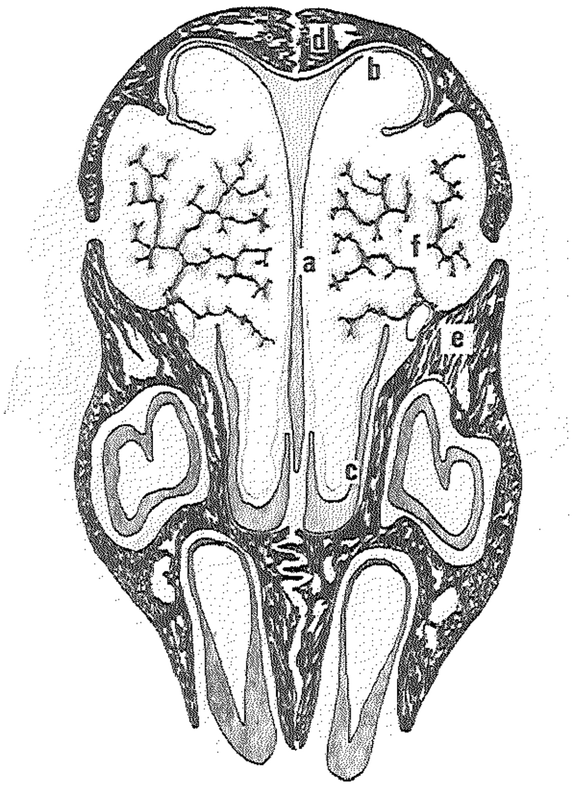


Fig. 9b. *Coronal section (B) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (c)ventral parietal cartilage or paraseptal cartilage, (d)nasal bone, (e)intermaxillary bone with incisors, (f)maxilloturbinate.*

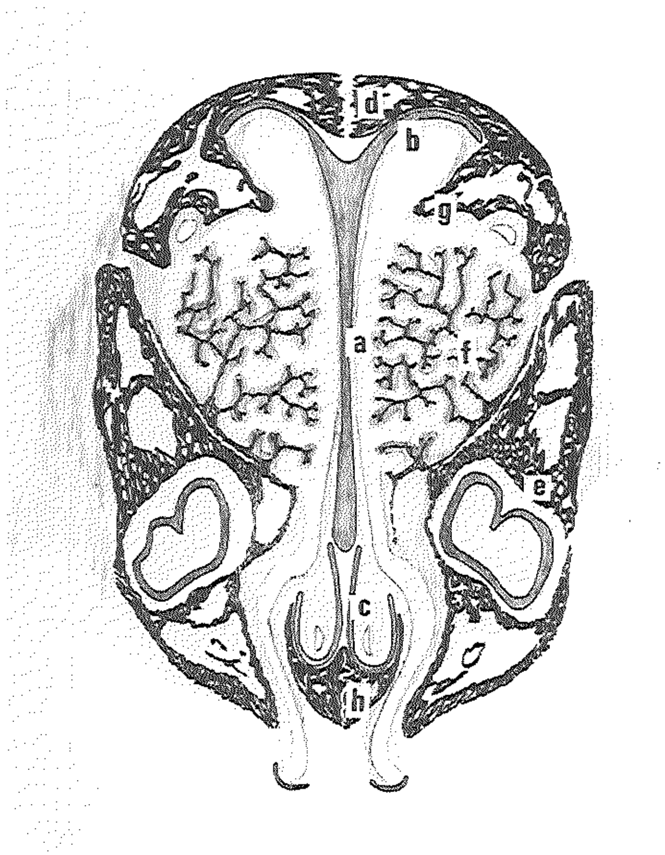


Fig. 9c. *Coronal section (C) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (c)paraseptal cartilage or vomeronasal organ of Jacobson, (d)nasal bone, (e)intermaxillary bone with incisors, (f)maxilloturbinate, (g)nasoturbinate, (h)medial process of the intermaxillary bone.*

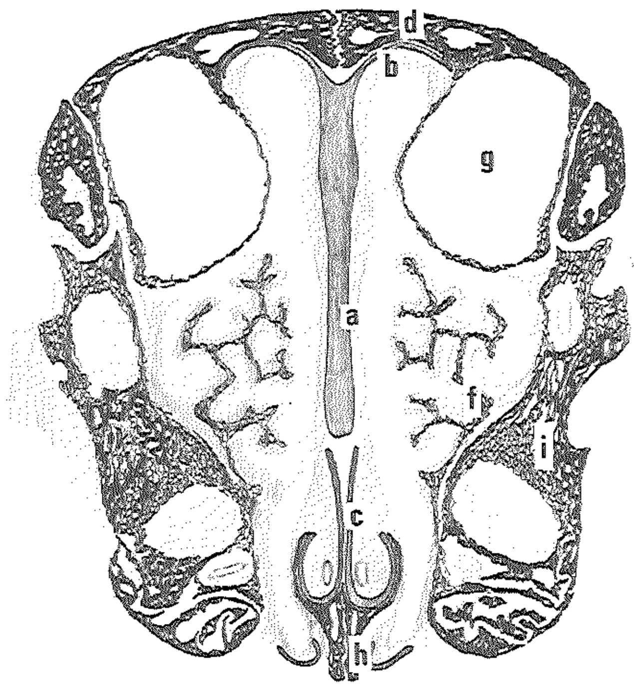


Fig. 9d. *Coronal section (D) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (c)paraseptal cartilage, (d)nasal bone, (f)maxilloturbinate, (g)nasoturbinate, (h)medial process of the intermaxillary bone, (i)maxilla.*

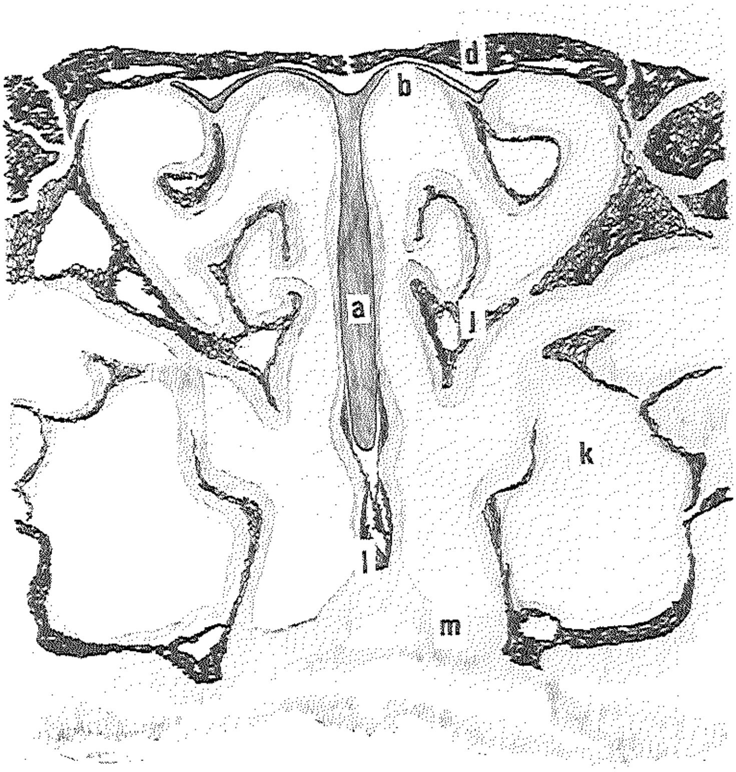


Fig. 9e. *Coronal section (E) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (d)nasal bone, (j)ethmo-turbinate, (k)maxillary sinus, (l)vomer, (m)palate (incisory foramina).*

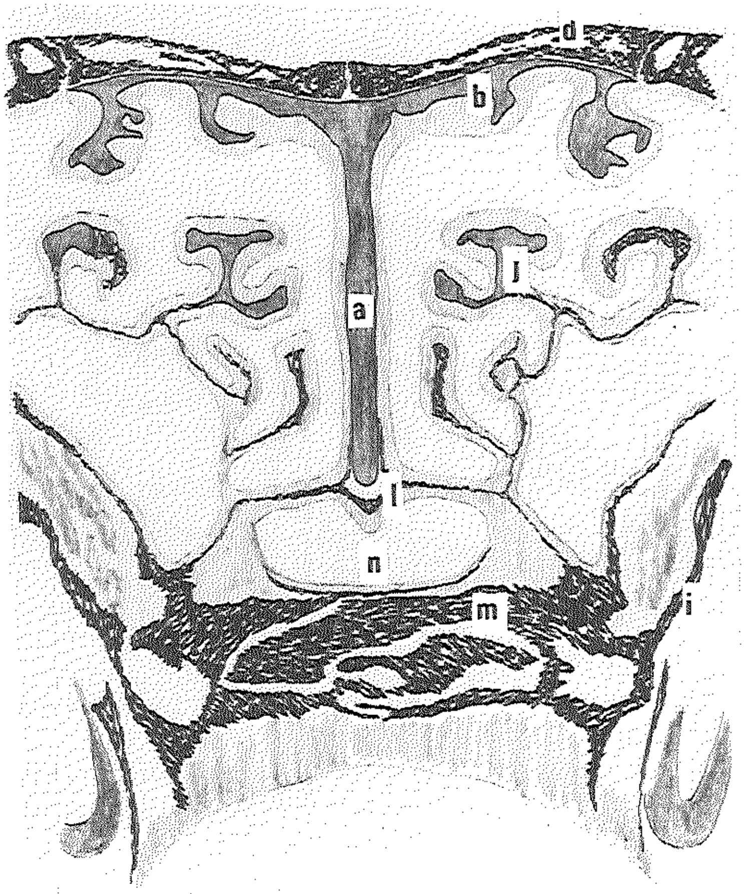


Fig. 9f. *Coronal section (F) through the rabbit skull at 4 weeks of age. (a)septal cartilage, (b)dorsal parietal cartilage, (d)nasal bone, (i)maxilla with molar complex, (j)ethmoturbinate, (l)vomer, (n)choana, (m)horizontal lamina of the palatine bone.*

In cranial direction the ventral parietal cartilages soon lose contact with the cartilage under the nasal dorsum. The lower and most medial part on both sides extends along the lower rim of the septal cartilage. Here they are known as the paraseptal cartilages of Jacobson's vomeronasal organ (fig. 9a-c, fig. 10).

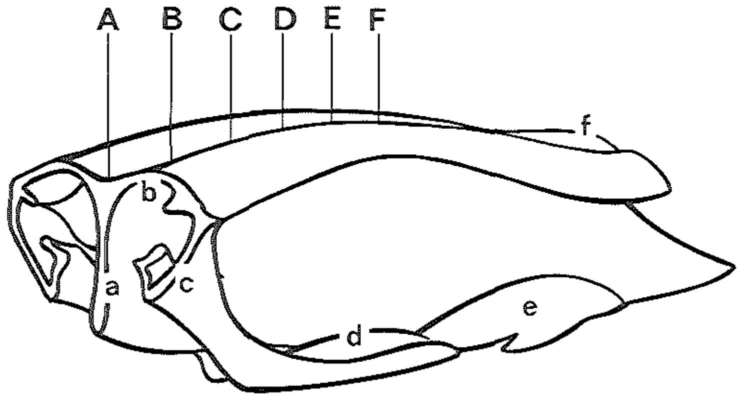


Fig. 10. Reconstruction of the cartilaginous nasal framework in rabbits at 4 weeks of age with planes of dissection (A-F) seen in fig. 9.
(a)septal cartilage, (b)dorsal parietal or lateral cartilage, (c)ventral parietal cartilage, (d)paraseptal cartilage or vomeronasal organ of Jacobson, (e)vomer, (f)crista galli.

The nasal septum, which is throughout continuous with the lateral cartilages, extends from the columella to the rostrum of the sphenoid and the crisa galli in the frontal skull base. The crista galli is, in fact, a cartilaginous intracranial extension of the septum. Only the extreme dorso-cranial part of the septum, near the sphenoid, is ossified (perpendicular plate).
In the most anterior section of the nose the basal septum "rests" on the medial process of the intermaxillary bone, separated from it by loose connective tissue (fig. 9b). This transition is bounded on either side by the paraseptal cartilages. Cranially the caudal part of the septum is eventually given real support by a bony groove in the vomer.

5.2 The cartilaginous nasal skeleton in the adult rabbit.

The dissection of the head of a 24 week old rabbit shows that it differs remarkably from that of a young rabbit in various aspects.
Compared with the 4 week old animal the skull has increased in size (in length, height

and width). The proportion between the neurocranium and the nose has changed as a result of the "extra growth" of the latter (fig. 11 and 12). Along the internasal suture, the nasal bone measures from 33 to 43 mm (mean: 37 mm).
The underlying cartilage extends about 6.5 mm beyond the nasal bone in the tip of the nose. The V-shaped free edge of this dorsal cartilage is now more pronounced while the conspicuous lateral convex curve at the tip (fig. 13) gives the impression that the ala contains a separate cartilaginous structure.
After removal of the nasal bone it can be observed that the lateral cartilage extends only halfway under the nasal bones (fig. 13), measuring 26 mm from the tip of the nose in cranial direction. It has thus lost contact with the base of the skull. The transverse diameter of the lateral cartilage decreases from the tip of the nose in cranial direction, resulting in a triangular shape (fig. 13). The lateral cartilage is still united with the septal cartilage in the median line. The transition is almost T-shaped, leaving a very shallow supraseptal groove.
The uppermost (dorso-cranial) part of the septum is ossified (perpendicular plate).

In conclusion, the cartilaginous and bony nasal skeleton of the young 4 week old rabbit correspond with that of an adult rabbit in various ways:

1. The nasal dorsum consists for the major part of bone. Only at the tip of the nose is the nasal dorsum cartilaginous.

2. The nasal bones overlap the lateral cartilages. The free edges of the bone have a fibrous connection with the anterior end of the extending lateral cartilages.

3. The lateral cartilage on both sides is continuous with the septal cartilage in the median line.

4. The cartilaginous nasal dorsum in the tip of the nose contains no separate alar cartilages.

There are also considerable differences between the young and adult rabbit as far as the nasal skeleton is concerned:

1. In the younger rabbit the cartilage extends under the entire nasal bone and merges into the frontal skull base. Only a triangular-shaped piece of cartilage under the nasal bone persists in the adult rabbit.

2. The transition from the lateral cartilages to the septal cartilage is Y-shaped in the young animal, and T-shaped in the adult rabbit.

3. The septum is almost totally cartilaginous in the young rabbit, whereas the dorso-cranial part of the septum in adult rabbits is ossified.

In chapter 15 a comparison is made between the anatomy and postnatal development of the cartilaginous nasal dorsum in rabbits and man.

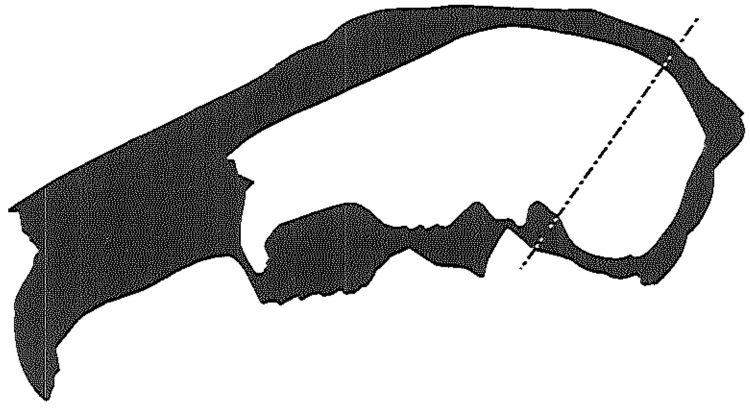


Fig. 11. Absolute increment in length and height from the 4 week old rabbit skull (in white) to the 24 week old rabbit skull (in black). Projection on SSO-SL (dotted line). SSO : the most caudal point of the spheno-occipital synchondrosis, SL : the most cranial part of the lambdoid suture.

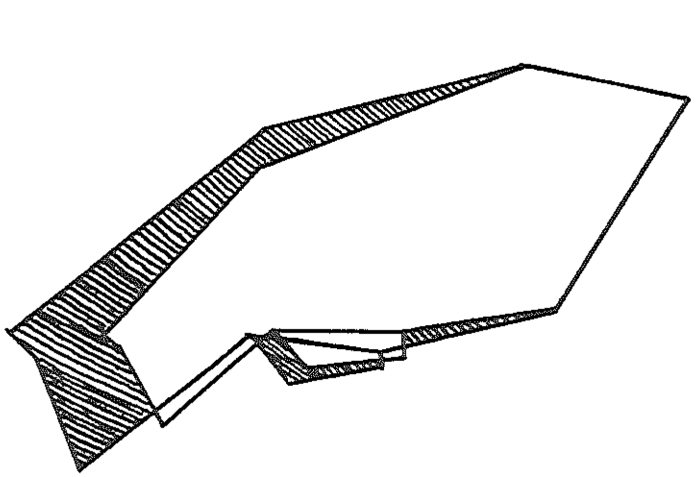


Fig. 12. Diagram of the skull of 4 week and 24 week old animals; SSO-SL has been made equal for both series and serves as a reference. The shaded part represents the extra growth of the facial skeleton with respect to the rest of the skull according to Verwoerd et al '79a (modified).

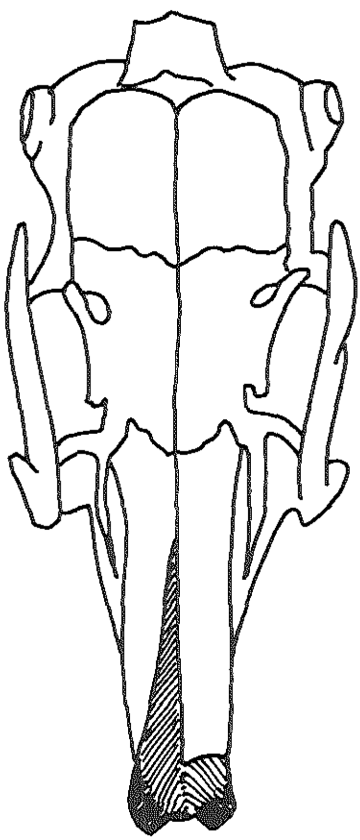


Fig. 13. Cranial view of the rabbit skull (24 weeks old).
The nasal bone on the right side is removed, giving view of the shaded dorsal parietal cartilage (lateral cartilage).

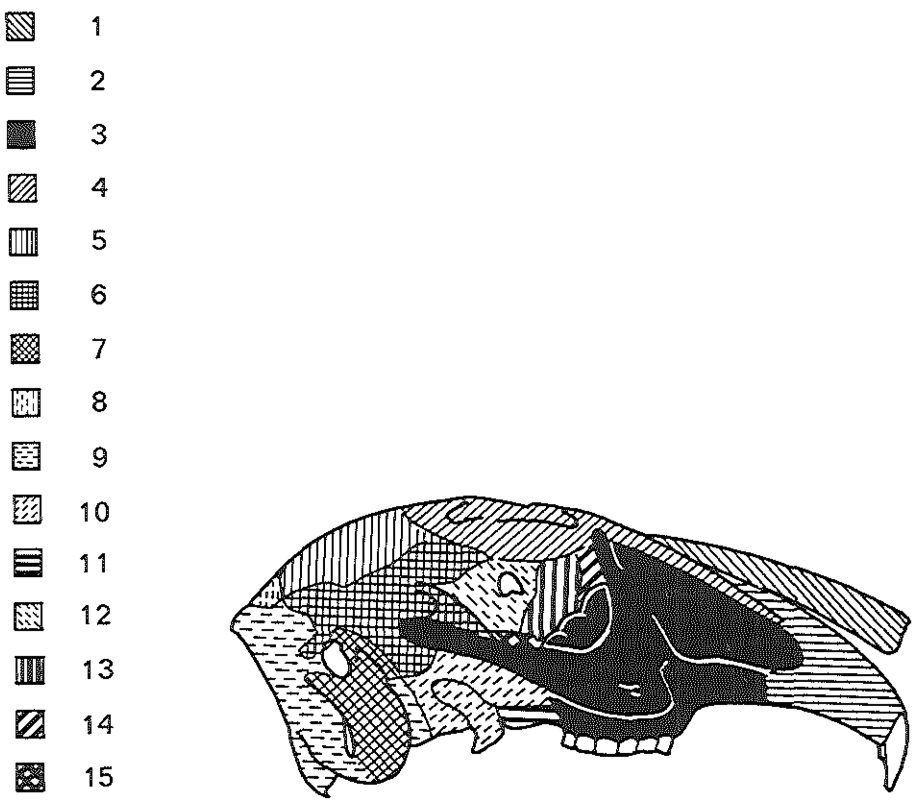


Fig. 14a. *Schematic drawing of a lateral view of a rabbit skull. The shaded parts on the skull correspond to:*
(1)nasal bone, (2)intermaxillary bone, (3)maxilla, (4)frontal bone, (5)parietal bone, (6)temporal bone, (7)tympanic bone, (8)interparietal bone, (9)occipital bone, (10)posterior sphenoidal bone, (11)palate, (12)anterior sphenoidal bone, (13)lacrimal bone, (14)ethmoid.

CHAPTER 6

EXPERIMENTAL STUDY: MATERIALS AND METHODS

6.1 Introduction.

The experiments are a continuation of previous work dealing with the postnatal growth of the facial skeleton as influenced by injury or surgery (Chapter 4.1). Thus in this study the experimental animal, the age of operation, the duration of the experiments and the methods used to study the skulls are the same as in the previous investigations reported elsewhere (Mastenbroek '78 and Nolst Trenité '84). Here they will be presented briefly.

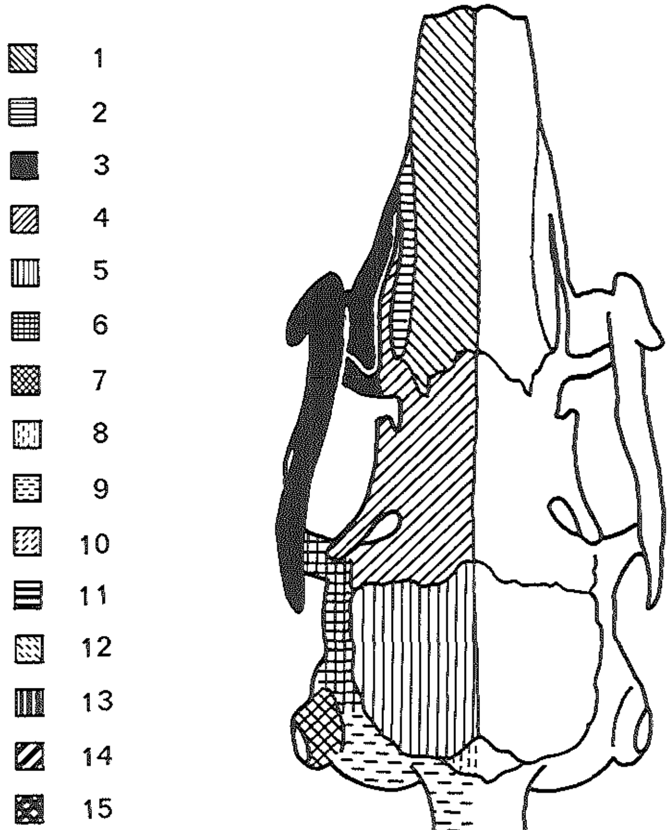


Fig. 14b. Schematic drawing of a cranial view of a rabbit skull. The shaded parts on the skull correspond to:
(1)nasal bone, (2)intermaxillary bone, (3)maxilla, (4)frontal bone, (5)parietal bone, (6)temporal bone, (7)tympanic bone, (8)interparietal bone, (9)occipital bone.

6.2 Experimental animal.

The experimental animals were rabbits (New Zealand whites) supplied by Harlan-CPB (Centraal Proefdierenbedrijf), Zeist, The Netherlands. Only females were used to eliminate the effect of sexual differences. At the start of the experiment the animals were 4 weeks of age and weighed between 400 and 500 grams. The duration of the experiment was 20 weeks and ended when the animals were 24 weeks old. Consequently the animals were sacrificed at the age of 24 weeks.

6.3 Methods.

6.3.1 Anaesthesia.

The muscle relaxant xylazine (Rompun R) 0.1 ml/100 mg was administered intramuscularly in combination with the anaesthetic ketamine chloride (Ketaset R) 0.1 ml/100 mg. In some cases a small supplementary dose was necessary.

6.3.2 Operating techniques.

In total 99 animals were used in this study; only one animal died during the surgical procedure. Twenty animals were sacrificed as controls. Description of the surgical procedures are given in the chapters dealing with the experiments.

6.3.3 Post-operative course.

Post-operatively all animals received intramuscularly 0.1 ml Penidural R (benzathine-penicilline G 300.000 E/ml). No signs of wound infections were observed. The general conditions, such as climate, feed and care were identical for all animals (Laboratory Animal Centre - Centraal Proefdierenbedrijf), Medical Faculty of the Erasmus University, Director: M.E.L. van Wassenaar). The developing deformations of the skull caused occlusal anomalies in some animals. To prevent the abnormally growing incisors from damaging the gums, they were cut back to normal proportions.

During the experimental period 21/99 or 21% of the animals died. Seventeen of these animals belonged to the experimental series described in chapter 12. The reason was a haemorrhagic enteritis.

6.4 Method of examination and analysis.

Before further processing, the septum was studied transorbitally (Nolst Trenité '84). The contents of the orbit, the papyrus lamina on the right, unoperated side and the ethmoidal cells were removed. Transorbitally, as much of the posterior part of the maxillary turbinate as possible was extracted to give a view of the septum. Only the dorsal part of the septum could be observed while the ventral part remained hidden. The condition of the mucous membrane and perforations or deviations of the septum were

described. The inspection was carried out using an operating microscope (magnification 16x).
Next the heads were prepared in the Department for Radiology of Small Mammals ("Röntgen Kleine Huisdieren") Faculty of Animal Medicine, Utrecht, The Netherlands* with the help of specific beetles (Dermestus vulpinus). At the larva stage this beetle, whose biotope is the South American rain forest, is able to consume large quantities of organic material. When a rabbit head is put in the terrarium it is eaten clean to the bone in a few hours. After removal from the terrarium the skulls were bleached in hydrogen peroxide 10% solution. General information on the anatomy of the rabbit skull is given in figs. 14 and 15.

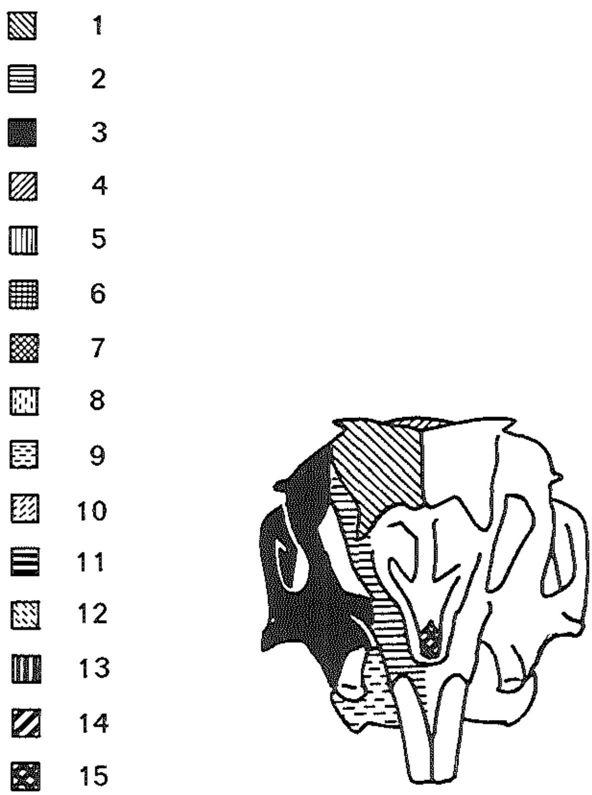


Fig. 15a. Schematic drawing of a frontal view of a rabbit skull. The shaded parts on the skull correspond to:
(1)nasal bone, (2)intermaxillary bone, (3)maxilla, (4)frontal bone, (8)interparietal bone, (15)vomer.

* The author wishes to express his appreciation of H. van de Brink's unique skill and thanks him for his cooperation.

Each skull was examined following the protocol described by Nolst Trenité ('84). Attention was paid to 19 characteristics, some of which are presented in tabular form in those chapters where the results of the experimental series are reported. A number of terms were used to specify the height and length of the skull components and the angles between the different parts of the skull. These are defined below. The numbers correspond with the numbers on the diagram (fig. 16).

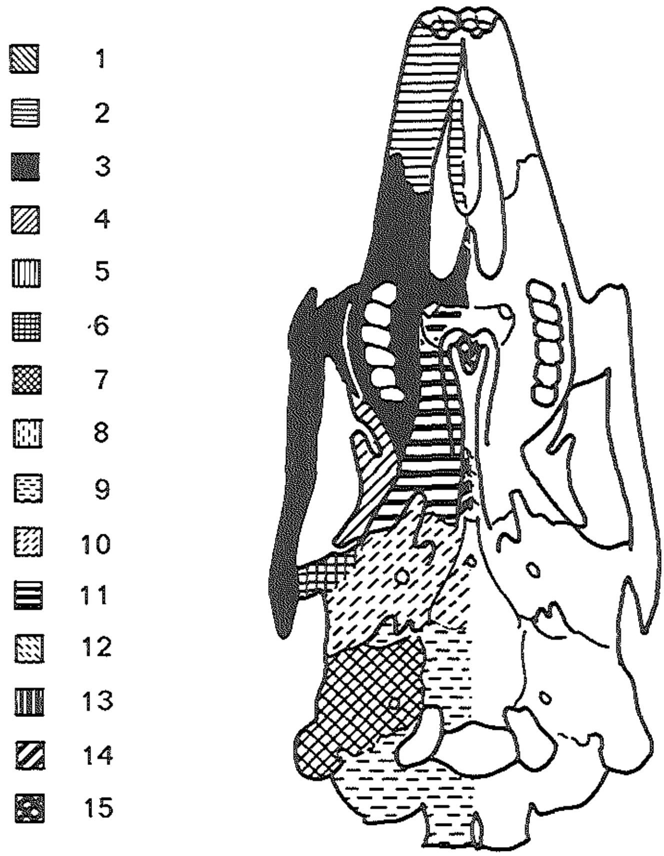


Fig. 15b. *Schematic drawing of a caudal view of a rabbit skull. The shaded parts on the skull correspond to:*
(2)intermaxillary bone, (3)maxilla, (4)frontal bone, (6)temporal bone, (7)tympanic bone, (9)occipital bone, (10)posterior sphenoidal bone, (11)palate, (14)ethmoid, (15)vomer.

- Length of the nose (1): the distance between the intersection of the frontonasal sutures and the internasal suture (nasion) and the most ventral point of the internasal suture.

- Length of the upper jaw (2): the distance between the most dorso-caudal point of the socket of the dorsal maxillary incisor and the dorso-caudal edge of the alveolar process of the third molar.

- Length of the maxilla (3): the distance between the intermaxillary-maxillary suture and the dorso-caudal edge of the alveolar process of the third molar.

- Length of the intermaxillary bone (4): the distance between the most dorso-caudal point of the socket of the dorso-maxillary incisor and the intermaxillary suture.

- Length of the zygoma (5): the distance between the masseteric spine and the most dorsal point of the zygomatic-temporal suture.

- Height of the maxilla (6): the distance between the most ventro-cranial point of the alveolar process of the first premolar and the intersection of the perpendicular line from this point with the lower edge of the frontal process of the intermaxillary bone.

- Height of the intermaxillary bone (7): the distance between a point on the lower edge of the intermaxillary bone halfway along the length of this bone and the point where a perpendicular line from this point (on the lower edge of the intermaxillary bone) intersects the upper edge of the frontal process of the intermaxillary bone.

- Angle between the maxillary process and the alveolar process of the maxilla (8): the angle between the tangent to the lower edge of the maxillary process and the tangent to the ventral edge of the alveolar process of the first premolar.

- Angle between the alveolar process and the pterygoid process (9): the angle between the tangent to the ventral edge of the pterygoid process and the tangent to the dorsal edge of the alveolar process of the third molar.

- Sagging of the nose: the contour of the nasal bones, which is normally curved convexly in cranial direction (in lateral view), has become straight or concave.

- Flattening of the nasal bone: the nasal bone which is normally curved convexly in cranial direction (in frontal view) has become straight.

- Two types of frontal malocclusion can be differentiated: an inverted horizontal overbite anteriorly (reversed overbite) and an end-to-end bite anteriorly (reduced overbite); in the former the lower incisors are more ventral than the upper incisors, in the latter both occlusion planes are in direct contact.

- Retroposition of the molar complex and zygoma is defined as a difference in the position of the corresponding left and right components with respect to the dorsal part of the skull.

- Rotation of the intermaxillary bone is judged by studying the frontal aspect of the skull. This rotation can be to the right (counter clockwise) or to the left (clockwise).

The term shortening used in the table is equivalent to the reduction in length.

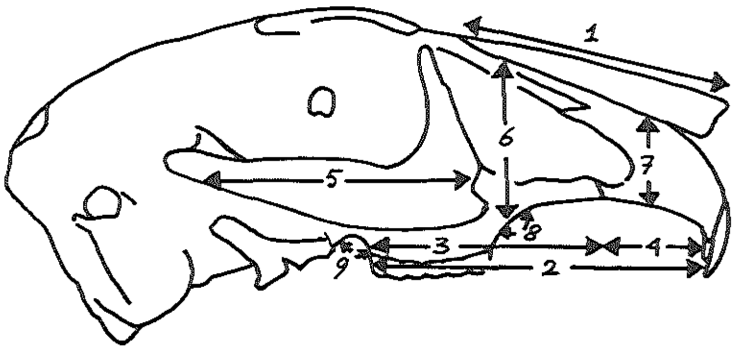


Fig. 16. Diagram of a lateral view of a rabbit skull (the numbers correspond to the numbers in the text).

6.5 Geometry.

The method has been described in detail by Urbanus ('74) and later by Nolst Trenité ('84). Essentially it entails calculating the position of specific points on the facial skull with respect to 2 reference points on the dorsal part of the skull. This dorsal part seems to be the least variable in morphology. It has never demonstrated reactive changes in cases of experimentally-induced abnormal development of the facial skeleton (Verwoerd-Verhoef '74, Urbanus '74, Mastenbroek '78, Nolst-Trenité '84 and Nijdam '85). Photographs were made of the lateral side of the skulls in a standardized manner (Audiovisual Services (Audiovisuele Dienst), Erasmus University, Rotterdam, The Netherlands**). A number of predetermined points were identified. The coordinates of these points were measured using an X-Y tablet (Summa Graphics bit/ped 1). The line through the most caudal point of the spheno-occipital sychondrosis (SSO) and the most cranial point of the lamboid suture (SL), both on the posterior part of the skull, serves as the Y-axis. The X-axis is constructed perpendicular to this line at point SSO.

** The author is very grateful to G. Maatje for his help and support.

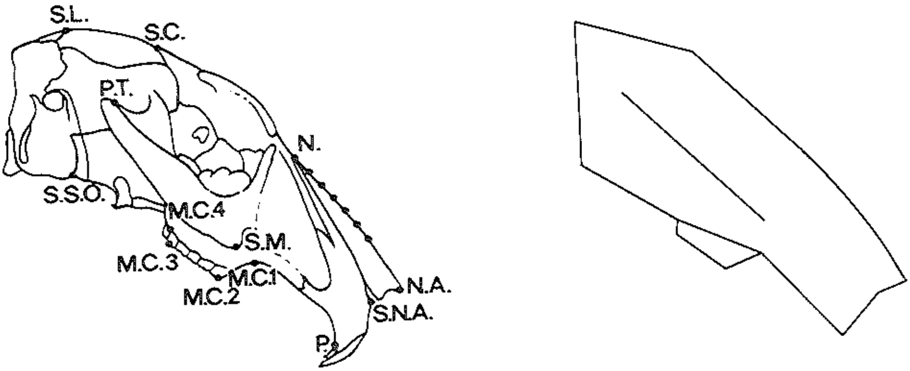


Fig. 17. Lateral view of a rabbit skull with 19 characteristic points (A) and diagram based on the mean coordinates of the measuring points (B).
SSO: the most caudal point of the spheno-occipital synchondrosis, SL: the most cranial point of the lambdoid suture, SC: the most cranial point of the coronal suture, N: nasion, N1-6: points on the internasal suture at respective distances of 5, 10, 15, 20, 25 and 30 mm from nasion, NA: the most ventral point of the internasal suture, SNA: the most lateral point of the piriform aperture near the anterior nasal spine, P: the most dorso-caudal point of the tooth-socket of the minor incisor, MC1: the most ventro-cranial point of the alveolar process of the first premolar, MC2: the most ventro-caudal point of the first premolar, MC3: the most dorso-caudal point of the second molar, MC4: the most dorso-caudal point of the alveolar process of the second molar, SM: the masseteric spine of the zygomatic process, PT: the most dorsal point of the connection between the zygomatic process of the temporal bone and the zygoma.

The effects of the difference in size between the skulls can be eliminated by standardizing all the coordinates on a skull with reference to the length of the line SSO-SL. The mean ($\overline{X},\overline{Y}$) and the standard error of the coordinates (SEM-$\overline{X}$, SEM-$\overline{Y}$) were determined for each point on the skull. The skull diagrams are graphic representations based on the averaged standardized coordinates (figs. 17a and b).

Hotelling's T^2 multivariate test (Morrison '76) was used, in the manner described by Nolst Trenité ('84), to demonstrate statistically significant differences between a corresponding set of points in two series. In this test the null hypothesis is accepted when the means of the standardized values for a given point show no significant difference in position (with a 95% significance level). The null hypothesis is rejected if the F-value exceeds the critical value (marked with *). Rejection of the null hypothesis does not give any other information about the relation of two points than that their position is not identical.

Thus on the skull diagram an ellipse was drawn round each point, in the way described by Nolst Trenité ('84). This ellipse can be described by its long and short axis (Diem et al '73), within the limit of confidence according to the following formula:

$$l1,l2 = \sqrt{k}\sqrt{SEM(\overline{X}) + SEM(\overline{Y}) +/- \sqrt{(SEM(\overline{X}) + SEM(\overline{Y}))^2 - 4(SEM(\overline{X}) \cdot SEM(\overline{Y}) - SEM^2(\overline{X}) \cdot (\overline{Y})}}$$

$$k = F/n(n-2)$$

The angle between the long axis of the ellipse and the X-axis can be described according to:

$$tg\ \alpha = \sqrt{1 + \frac{(SEM(\overline{Y}) - SEM(\overline{X}))^2}{4 \cdot SEM^2(\overline{X}) \cdot (\overline{Y})}}$$

The probability that the means ($\overline{X},\overline{Y}$) of one point are within the ellipse in both the X and Y directions is 95%. The lengths of the long and the short axes of the ellipse depend on both the size of and the spread within the series. If in two series the ellipses for the same point do not overlap it can be concluded that there is a significant difference between the means for the points.

To demonstrate a foreshortening of the nose and/or upper jaw in comparing two series, the Student-T test was used. The means and associated p-values can be calculated from measurements of the standardized lengths between certain predetermined points. A comparison can be made with similar measurements from another series, provided the series being compared are of the same size.

6.6 Short description of the experimental series performed.

Series 0. Control series (chapter 7).

Series 1. Lifting and replacement of the nasal bone on one side (chapter 8).

Series 2. Lifting and replacement of the nasal bone on both sides (chapter 9).

Series 3. Lifting of the left nasal bone, subtotal resection of the lateral cartilage on that side and replacement of the nasal bone (fig. 18a) (chapter 10).

Series 4. Lifting of the nasal bone on both sides, subtotal resection of the lateral cartilages and replacement of the nasal bones (fig. 18b) (chapter 11).

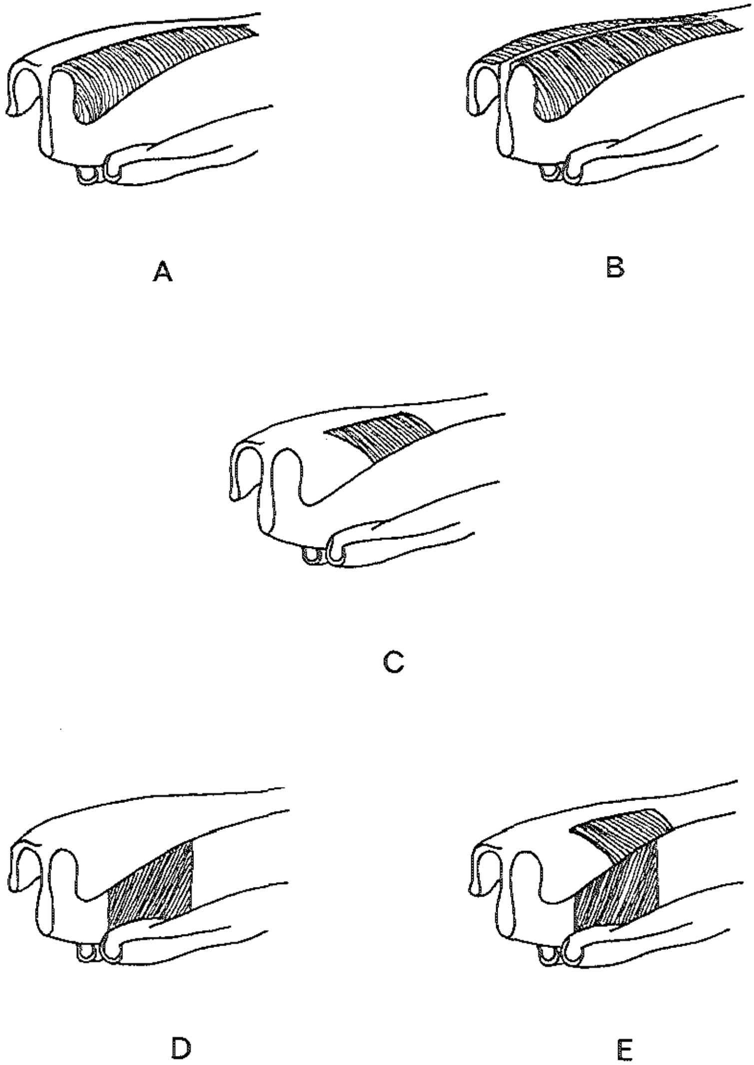


Fig. 18. Experiments on the cartilaginous nasal frame-work of a 4 week old rabbit; subtotal resection of the lateral cartilage on one side (A), bilateral subtotal resection of the lateral cartilage (B), partial resection of the lateral cartilage on one side (C), partial submucous resection of the septal cartilage (D), partial submucous resection of the septal and lateral cartilages (E).

Series 5. Lifting of the left nasal bone, resection of a 10 mm. long piece of cartilage corresponding to the middle third of the lateral cartilage on that side and replacement of the nasal bone (fig. 18c) (chapter 12).

Series 6. Lifting of the left nasal bone, submucous resection of a 10 mm long piece of septal cartilage corresponding to the middle third (being the medial support of the lateral cartilage) and replacement of the nasal bone (fig. 18d) (chapter 13).

Series 7. Lifting of the left nasal bone, submucous resection of a 10 mm long piece of septal cartilage corresponding to the middle third, together with the corresponding piece of the lateral cartilage on that side and replacement of the nasal bone (fig. 18e) (chapter 14).

CHAPTER 7

CONTROL SERIES (series 0)

7.1 Introduction.

Twenty rabbits, which were not operated upon were kept under the same conditions as the operated animals between the 4th and 24th week after birth. Not one animal died during the experimental period.
The skulls in this series were used as a control group for the experiments described in the following chapters.

7.2 Results.

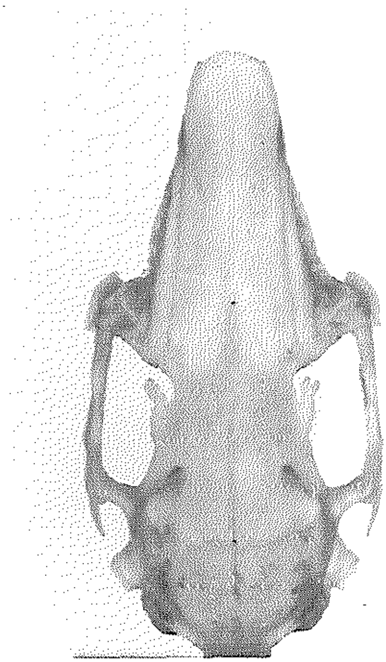
7.2.1. Morphology (table 1, fig. 19).

The skulls from this series are very uniform. A few deviations are found in only 4 of the 20 skulls. In one skull both the nose and upper jaw deviate slightly to the left. In another skull the intermaxillary bone shows a just visible rotation to the right which is combined with a slight deviation of the nose to the right.

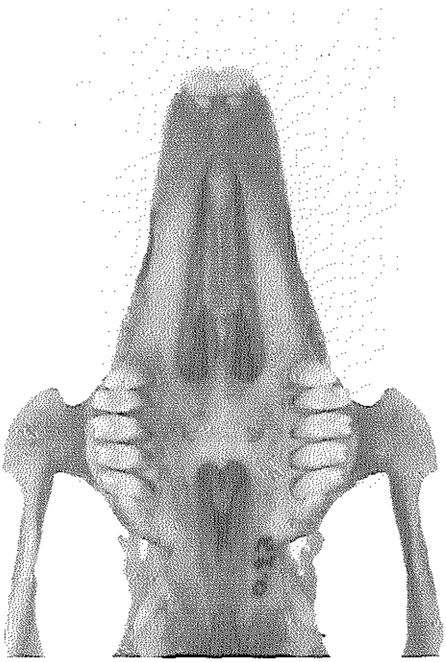
Table 1: Skull deformities in series 0; n=20; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial			20/20
	lateral			20/20
	narrowing			20/20
	sagging			20
	flattening			20/20
	deviation		1/1	18
Maxilla	shortening			20
	deviation		2/1	17
	rotation		-/1	19
Incisor malocclusion	reduced overbite			20
	reversed overbite			20

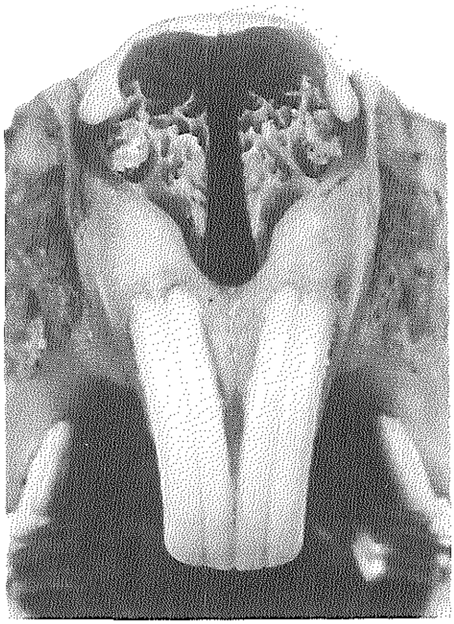
A



B



C



D

*Fig. 19: Skull of unoperated control rabbit (series 0).
(A, lateral view from the left; B, cranial view; C, caudal view; D, frontal view).
Note the normal length of the nose and upper jaw, the normal convexity of the nasal bones, the normal position of the incisors in the upper jaw and symmetry of the internasal structures.*

7.2.2 Geometry (table 2 and 3; fig. 20).

The data for the left and right side of the skull are presented in tables 2 and 3 respectively. From the means of standardized values of the coordinates for both sides and the calculated F-values, it can be concluded, using Hotellings T^2-test, that there is no significant difference between the left and right sides for a given point (table 3).

Diagrams of the left and right sides of the skull, obtained by joining together the averaged, standardized coordinates for each point, are shown in figure 20. The two sides are almost identical.

Table 2: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side of the skull in series 0.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)
SL	0.00	0.0000	100.00	0.0000
SC	64.40	0.7086	77.45	0.6707
N	141.30	1.1358	-9.20	1.5871
N1	147.85	1.2124	-21.95	1.6959
N2	154.55	1.3445	-34.60	1.8230
N3	161.40	1.5668	-47.30	1.8483
N4	168.15	1.5394	-59.80	1.9461
N5	174.40	1.5818	-72.05	2.0793
N6	180.25	1.6333	-85.40	2.1660
NA	192.85	1.8372	-122.95	2.6641
SNA	172.30	1.8696	-133.35	2.4573
P	139.50	2.0098	-159.85	2.1142
MC1	103.90	1.2626	-77.80	1.2410
MC2	84.05	1.2721	-86.35	1.1749
MC3	53.00	1.0736	-59.00	0.8046
MC4	54.95	1.0450	-54.70	0.8739
SM	98.05	1.3504	-70.95	1.3088
PT	31.90	0.7709	39.70	1.0714

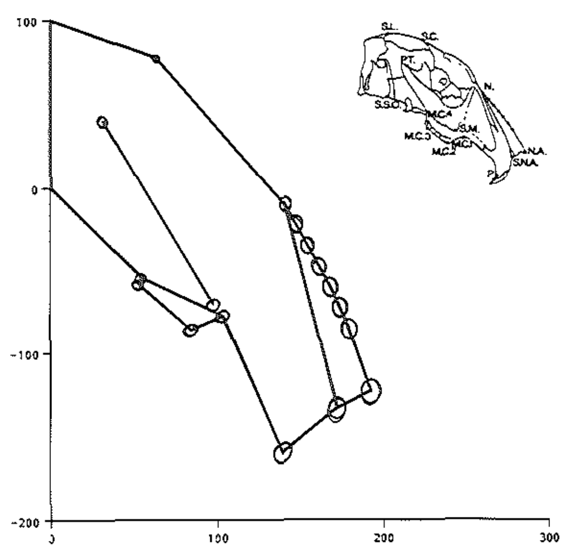


Table 3: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each point SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the right side of the skull in series 0. Included are the F-values, calculated from the means of standardized values for the right side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	64.90	0.8237	76.70	0.7000	0.3547
N	142.15	1.3064	-9.80	1.9863	0.1235
N1	148.35	1.3304	-22.15	2.0841	0.0382
N2	154.90	1.4490	-34.45	2.1367	0.0178
N3	161.90	1.5760	-47.10	2.2371	0.0284
N4	168.60	1.6818	-59.65	2.3093	0.0203
N5	174.70	1.7638	-72.45	2.3153	0.0158
N6	180.35	1.9266	-85.10	2.3440	0.0048
NA	192.45	2.1182	-123.10	2.7757	0.0103
SNA	173.30	2.1693	-134.20	2.6760	0.1091
P	139.60	2.2946	-161.55	2.5251	0.1525
MC1	103.95	1.4445	-77.60	1.3463	0.0058
MC2	84.90	1.4307	-85.65	1.2253	0.1423
MC3	53.95	1.0143	-58.70	0.9655	0.2393
MC4	55.90	1.0257	-54.70	1.0541	0.2049
SM	98.30	1.3690	-69.95	1.4170	0.2712
PT	33.50	0.9076	40.60	0.6130	1.0576

(according to Fisher's tables, the F0-value is: 3.26 for n-3=37 degrees of freedom, 2 variables and a level of significance of 5%).

Fig. 20: Diagram of the skulls of adult rabbits in series 0. The left and right side view are obtained by joining the averaged, standardized coordinates for each point.
SSO-SL has been made equal for both side views.

7.3 Conclusion.

1. The marked uniformity of the skulls of adult unoperated rabbits (New Zealand white) indicates that there is only a slight biological variation in the anatomy. Similar observations were described by Nolst Trenité ('84).

2. The geometrical data confirm the symmetry of the skulls.

3. From a histologic study by Meeuwis ('85) of the nasal septum in 25 non-operated rabbits (aged between 4 and 24 weeks) it was concluded that no septal deviations occurred. Thus no transorbital inspection was performed in this series.

CHAPTER 8

LIFTING OF THE NASAL BONE ON ONE SIDE (series 1).

8.1 Introduction.

In this experiment the nasal bone was rotated aside in order to expose the lateral cartilage (as necessary for experimental surgery on the nasal skeleton).
With the animal in a recumbent position the skin is incised over the nasal dorsum along the median line (fig. 21a). The periosteum is cut just paramedially to the right of the internasal suture. Cranially a transverse incision in the periosteum over the left nasal bone is made (fig. 21b). Then the periosteum can be elevated and moved aside. With a fine fraise a slit is made in the left nasal bone, perpendicular to the internasal suture and just ventral to the crossing of the internasal and frontonasal sutures (fig. 21c). After splitting the internasal suture, the nasal bone with the attached nasal turbinate can be rotated to the left, hinging on the naso-intermaxillary suture (fig. 21d). A good view is obtained of the cartilaginous nasal capsule, which remains untouched. The mucous membrane is carefully preserved. Thus the nasal fossa is not opened. Finally the nasal bone is put back in its original position. The wound is closed with nylon sutures (4-0).
The operation was carried out on 10 rabbits. All the animals remained alive for the duration of the experiment (20 weeks).

8.2 Results.

8.2.1 Transorbital inspection.

In all cases the septal mucosa appeared to be normal. No deviations or perforations were observed.

8.2.2 Morphology (table 4; fig. 22).

The nose and upper jaw have developed to the normal length, height and width in all skulls (fig. 22 A). There are slight deviations in the nose and/or upper jaw of a few skulls, always towards the left side.
The fraised slit is not always completely refilled with bone (fig. 22 B). In 6 of the 10 skulls there are still small defects of variable size (0.5 to 2 mm). In ventral direction from the fraised slit, however, the internasal suture has an uneven course; in a few cases it cannot be identified at all. The nasal bones are symmetrical and fit together well over the whole length of the nose. The naso-intermaxillary suture has a similar

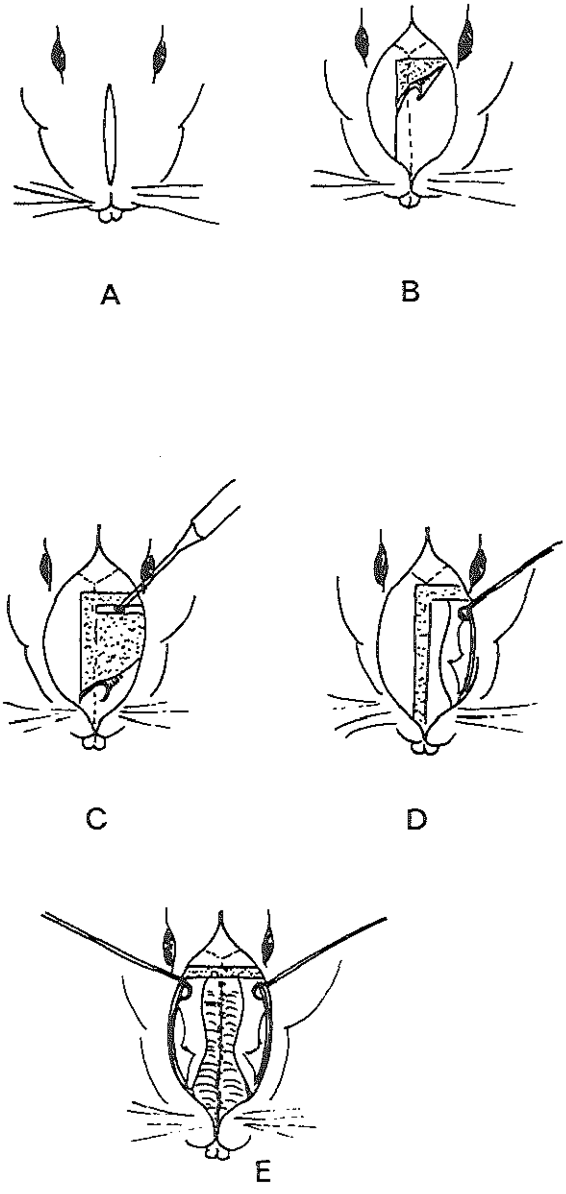
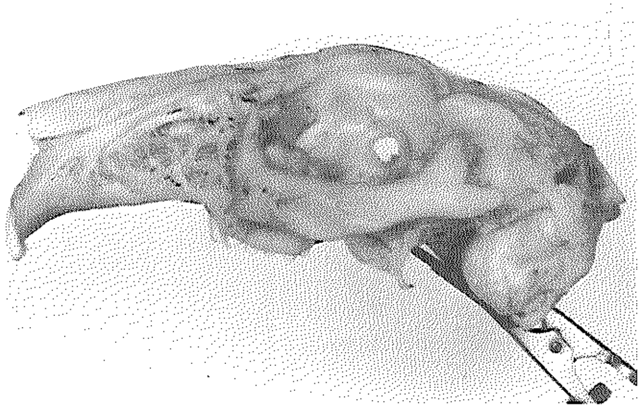


Fig. 21. Surgical technique: incision over the nasal dorsum in the median line (A), transverse incision in the periosteum over the left nasal bone (B), fraised slit in the left nasal bone perpendicular to the internasal suture (C), rotated left nasal bone with the attached nasal turbinate (D) and when both nasal bones are rotated aside (E).



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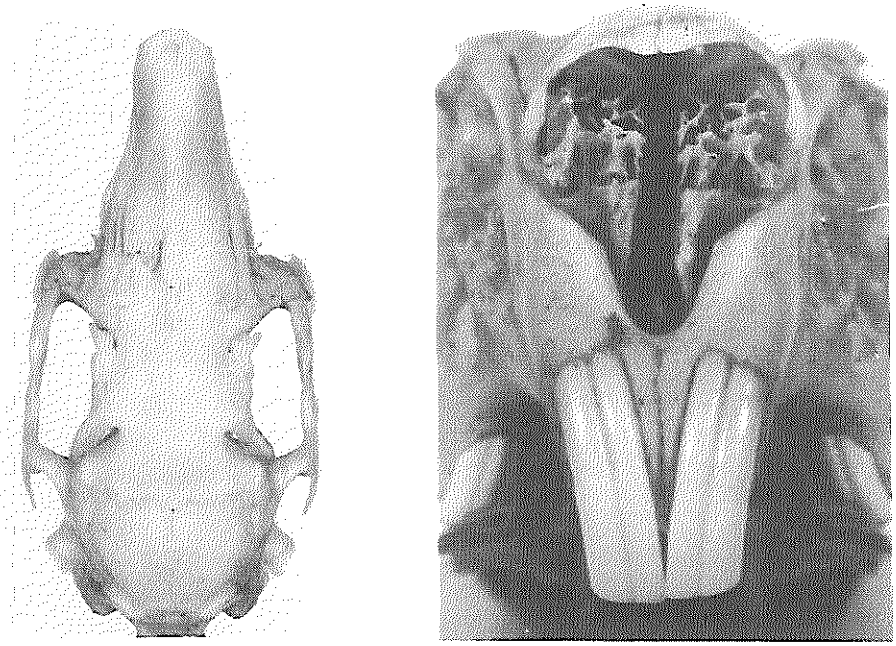


B C

Fig. 22: Skull of an adult rabbit after lifting the nasal bone on one side at the age of 4 weeks (series 1).
(A,lateral view from the left; B,cranial view; C,frontal view).
Note the normal length of the nose and upper jaw, the uneven course of the internasal suture, the irregularity of the former fraised slit and the normal complexity of the maxilloturbinate.

appearance on both the operated and the non-operated sides.
When viewed from the front it can clearly be observed that both the nasal and maxillary turbinates have developed completely symmetrically (fig. 22 C).

Table 4: Skull deformities in series 1; n=10; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial			10/10
	lateral			10/10
	narrowing			10/10
	sagging			10
	flattening			10/10
	deviation		3/-	7
Maxilla	shortening			10
	deviation		3/-	7
	rotation			10
Incisor malocclusion	reduced overbite			10
	reversed overbite			10

8.2.3 Geometry (table 5, figure 23).

From the means of standardized values of the coordinates for the left side view (table 5) and the F-values that have been calculated from them, it can be seen, using Hotellings T^2-test, that not a single point deviates significantly from series 0. No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

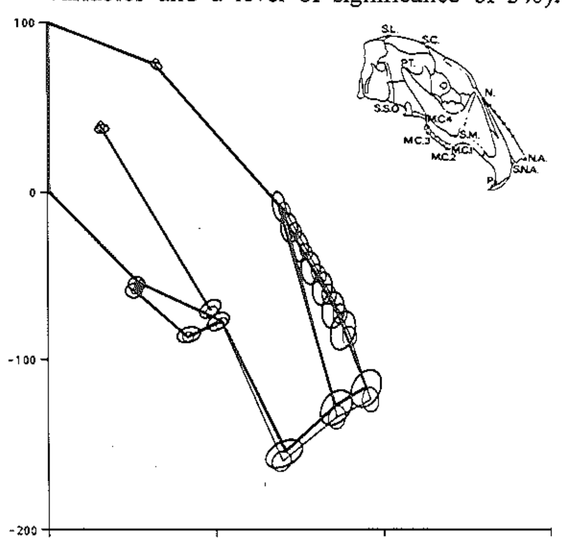
In figure 23 the skull diagram for series 1 is superimposed on that for series 0. It can be seen that the positions of the points in this series hardly differ from the positions in the control series.

Fig. 23: Diagram of the skulls of adult rabbits in series 1, in which the left nasal bone was lifted and rotated aside at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

Table 5: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side of the skull in series 1.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	65.90	0.9597	74.90	1.0376	2.5881
N	138.20	1.1907	-7.30	2.6752	1.4137
N1	144.20	1.3565	-19.80	2.8433	1.7327
N2	150.30	1.5279	-32.20	2.8821	1.8738
N3	156.90	1.6961	-44.80	2.9807	1.6298
N4	163.70	1.7892	-57.20	3.1048	1.6807
N5	170.30	2.0766	-69.70	3.2966	1.2787
N6	176.40	2.3295	-81.80	3.4538	1.3382
NA	190.30	3.0297	-116.70	3.7269	1.3055
SNA	171.70	3.2182	-127.60	3.0521	1.0973
P	141.10	3.5291	-154.90	2.6434	0.9477
MC1	102.20	1.9310	-76.70	1.5638	0.5220
MC2	84.50	2.0180	-85.20	1.4283	0.1768
MC3	52.00	1.4682	-58.60	1.3920	0.1686
MC4	53.80	1.4283	-54.80	1.3482	0.2034
SM	97.20	2.1124	-69.90	1.9462	0.2298
PT	33.00	1.4298	37.80	0.9978	0.8879

(according to Fisher's tables, the F0 value is: 3.36 for n-3=27 degrees of freedom, 2 variables and a level of significance of 5%).



8.3 Conclusion.

1. Lifting part of the nasal bone in young rabbits does not affect the length, height or width, shape or position of the bony nasal dorsum in the adult rabbit. There is only slight evidence of the operation: the uneven course of the internasal suture and the incomplete closure of the operative defect.

2. The approach used in this series seems suitable for experimental interventions involving the lateral cartilage on one side and/or the septum as it does not disturb the normal growth of the nose and upper jaw.

CHAPTER 9

LIFTING OF THE NASAL BONE ON BOTH SIDES (series 2).

9.1 Introduction.

It is necessary to lift both nasal bones to obtain a good view of the entire lateral cartilage in the rabbit as is necessary for bilateral experimental interventions. Both the nasal bones were lifted, rotated aside and replaced using the same technique as described in chapter 8 for only one side (fig 21e).
The operation was performed on 13 animals. One animal died from haemorrhagic enteritis.

9.2 Results.

9.2.1 Transorbital inspection.

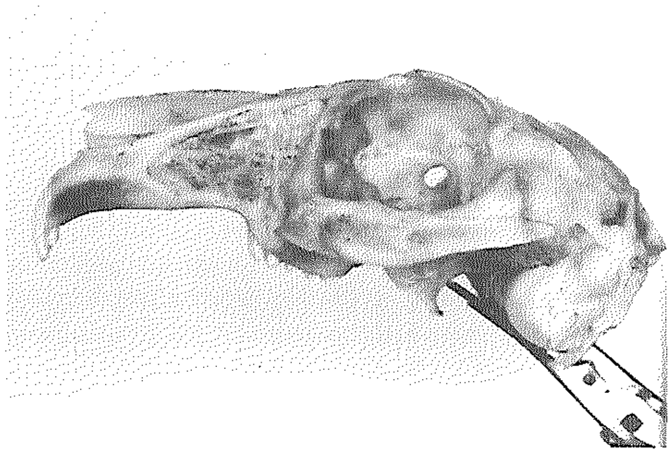
The dorsal part of the septum was located medially in all cases. There were no perforations. The mucosa appeared to be normal.

9.2.2 Morphology (table 6; fig. 24).

There are no marked malformations in any of the skulls.

Table 6: Skull deformities in series 2; n=12; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial			12/12
	shortening: lateral			12/12
	narrowing			12/12
	sagging		1	11
	flattening		-/1	12/11
	deviation		3/1	9
Maxilla	shortening			12
	deviation		2/-	10
	rotation			12
Incisor malocclusion	reduced overbite			12
	reversed overbite			12



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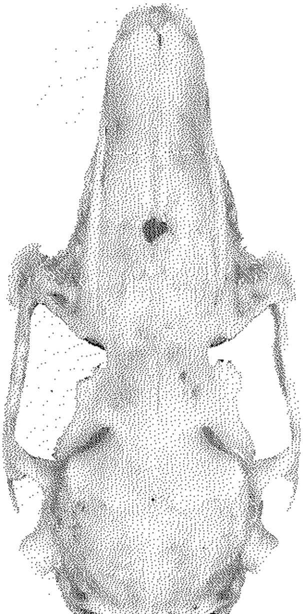


B

C

Fig. 24: Skull of an adult rabbit after lifting both nasal bones at the age of 4 weeks (series 2).
(A,lateral view from the left; B,cranial view; C,frontal view).
Note the normal length of the nose and upper jaw, the uneven course and widening of the internasal suture at the tip of the nose , the bony defect on the site of the former fraised slit and the normal complexity of the maxilloturbinate.

The nasal bones display their normal shape. There is no evidence of foreshortening of the nose or upper jaw (fig. 24 A). Only a few skulls show a slight deviation. The nasal and maxillary turbinates have a normal size and shape compared with the control skulls (fig. 24 C).
Minor deformities were found along the internasal suture and the fraised slit. In all skulls the internasal suture is irregular, being invisible in some places. The suture is lost at the anterior end of the nasal bones, which shows here a dehiscence not present in the control skulls (fig. 24 B). The regenerated bone along the transverse fraised slit is of variable quality and has an uneven surface. The bony defect is completely closed in only two skulls; in the others a medial defect persists, measuring up to 3 mm. It is possible that the incomplete regeneration of the bone is due to loss of periosteum. The non-rotated, cranial part of the nasal bone has a normal aspect in all cases.

9.2.3 Geometry (table 7; figure 25).

From the means of the standardized values of the coordinates for the left side view (table 7) and the F-values that have been calculated from them, it can be seen, using Hotelling's T^2-test, that the only points that differ significantly from those in series 0 are SC, MC2-4, SM and PT. There are no significant differences for points on the nose and upper jaw.
No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

In figure 25 the skull diagram for series 2 is superimposed on that for series 0. The nose and upper jaw in this series are not demonstrably shorter than those in the control series. The greater variation in the different points on the nose and upper jaw are probably due to the effects of this relatively minor operation.

Table 7: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side of the skull in series 2.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\bar{X}$ norm	SEM ($\bar{X}$)	$\bar{Y}$ norm	SEM ($\bar{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	67.83	0.8689	72.58	0.5833	17.6563*
N	143.33	1.8146	-14.50	2.0652	2.1218
N1	149.67	1.9746	-27.25	2.1537	1.9500
N2	156.08	2.1443	-39.75	2.2127	1.5628
N3	163.17	2.1171	-52.33	2.3784	1.4582
N4	169.83	2.0701	-65.17	2.5638	1.5027
N5	175.33	2.0163	-77.92	2.6670	1.5005
N6	180.33	1.9937	-91.25	2.8126	1.3233
NA	190.33	2.3656	-128.08	3.2321	1.0024
SNA	169.83	2.3576	-136.67	2.9189	0.5574
P	138.92	2.6981	-162.25	2.7056	0.2356
MC1	101.17	1.4026	-81.08	1.1178	2.0222
MC2	79.25	1.5331	-88.58	1.0763	3.4052*
MC3	48.33	1.0323	-59.00	0.6963	4.1193*
MC4	50.17	1.1135	-56.33	0.8379	5.1132*
SM	91.00	1.4873	-71.50	1.2216	5.6087*
PT	26.08	0.6681	38.17	0.3860	13.3547*

(according to Fisher's tables, the F0 value is: 3.36, for n-3=27 degrees of freedom, 2 variables and a level of significance of 5%).

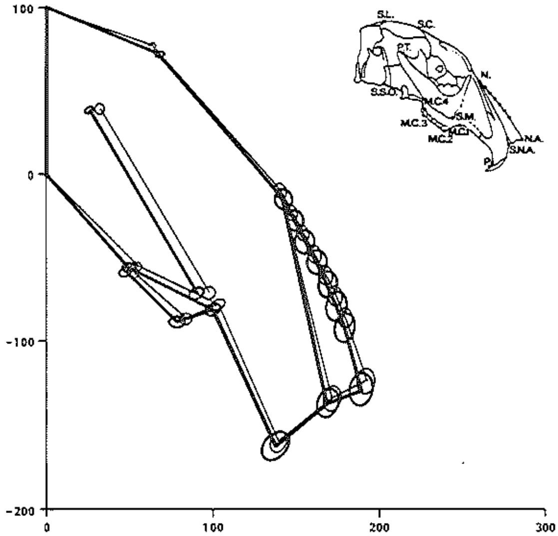
Fig. 25: Diagram of the skulls of adult rabbits in series 2, in which both nasal bones were lifted and rotated aside at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

9.3 Conclusion.

Lifting the nasal bone on both sides does not cause any obvious change in the shape of the adult skull. The results are similar to those obtained when the nasal bone is only lifted on one side. The transverse fraised slit, the transection of the internasal suture and the rotation at the level of the naso-intermaxillary suture do not interfere with the further development in length, height and width of those parts of the nasal bones that have been mobilized.

At the adult stage the internasal suture has an irregular course while the naso-intermaxillary suture appears to be normal. This difference may be due to a difference in the surgical procedure (such as transection vs. "hinging") or to the different properties of the two sutures.

Finally it can be concluded that the approach to the cartilaginous nasal capsule here described does not interfere with the further development of the nose and upper jaw.



CHAPTER 10

SUBTOTAL RESECTION OF THE LATERAL CARTILAGE ON ONE SIDE (series 3).

10.1 Introduction.

By removing one of the lateral cartilages an attempt was made to gain information about the significance of these cartilages for the further growth of the nose. The lateral cartilages in the 4 week old rabbit extend from the tip of the nose to the still cartilaginous frontal skull base. After lifting the nasal bone on the left side (chapter 8, fig. 21d) the section of cartilage between the transverse fraised slit and the tip of the nose was removed. Consequently the uppermost cranial part of the lateral cartilage remained undisturbed. The resection line on the medial side is close to the septum. Laterally, the cartilage can be easily separated from the underlying mucosa. Only near the tip of the nose are some parts of the cartilage left in place in the alar region.
The operation was performed on 12 animals. All survived during the experimental period.

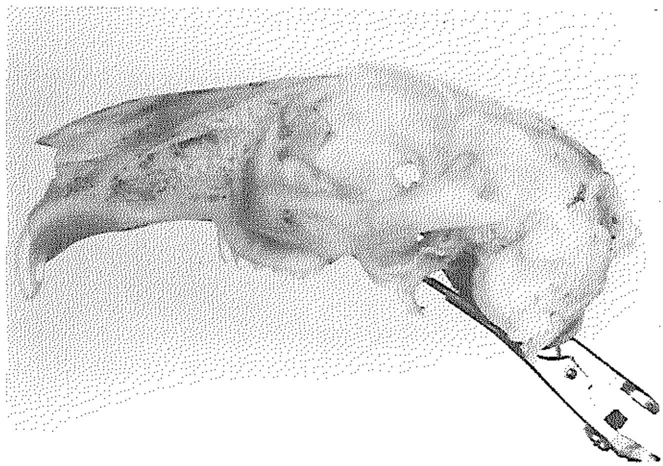
10.2 Results.

10.2.1 Transorbital inspection.

In all cases the nasal mucosa was intact and not encrusted. The septum was almost completely straight or showed a slight concavity on the right side.

10.2.2 Morphology (table 8; fig. 26).

Most conspicuous in the skulls in this series appears to be the deviation of the nose towards the non-operated side (in 9 of the 12 skulls) (fig. 26 B). This deviation is restricted to the anterior third of the two nasal bones. On the operated side the nasal bone is much shorter (especially on the lateral side), flatter and narrower. On the non-operated side the anterior part of the nasal bone curves laterally beyond the contour of the upper jaw (fig. 26 C). There is no evidence of sagging in the nasal dorsum (fig. 26 A).
In comparison with the control skulls, the internasal suture is uneven, something that was also observed when only the nasal bone was lifted (chapter 8). Moreover, halfway along the nose the suture bends towards the operated side while at the tip of the nose it crosses over to the unoperated side. As a result the right nasal bone forms the highest point of the nasal convexity (fig. 26 B and D).



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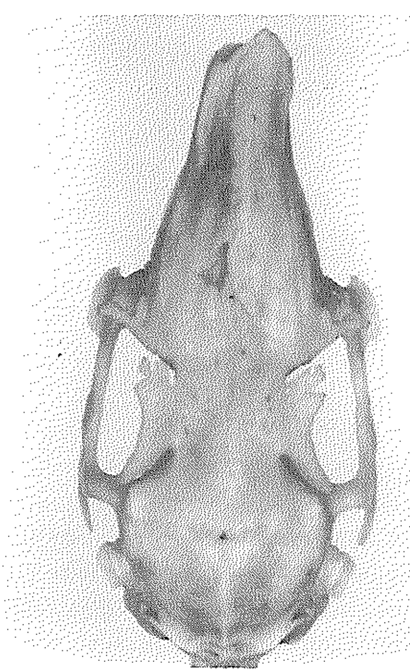

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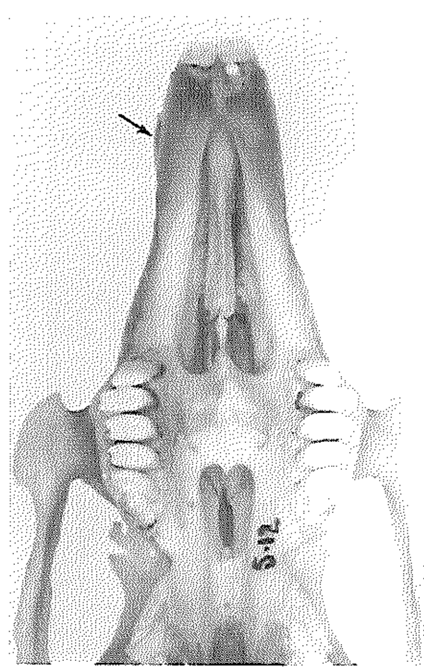


C

D

Fig. 26: *Skull of an adult rabbit after subtotal resection of the lateral cartilage on one side at the age of 4 weeks (series 3).*
(A,lateral view; B,cranial view; C,caudal view; D,frontal view).
Note the deviation of the nose to the right side without deviation of the upper jaw (arrow), the foreshortening and flattening of the left nasal bone, the uneven and bending course to the left of the internasal suture and the reduced maxilloturbinate on the left side.

Table 8: Skull deformities in series 3; n=12; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial	4/-	6/-	2/12
	lateral	6/-	4/-	2/12
	narrowing	7/-	3/-	2/12
	sagging		2	10
	flattening	9/-	3/1	-/11
	deviation	-/4	-/5	3
Maxilla	shortening			12
	deviation		1/1	10
	rotation	1/-	2/-	9
Incisor malocclusion	reduced overbite			12
	reversed overbite			12

The surface of the rotated part of the left nasal bone is rather irregular, which corresponds with the findings in series 1 and 2. The slit, fraised in the left nasal bone, is completely filled with bone in only 3 of the skulls. In all specimens the nasal bone fits perfectly with the frontal process of the intermaxillary bone.
Viewed from the front the height of the piriform aperture is apparently reduced on the operated side as a result of the flattening of the nasal bone. Here the maxillary turbinate is only half of its normal size or even less (fig.26 D). The nasal turbinate on the operated side is only rudimentally developed whereas the dorsal nasal meatus is narrower than in the control skulls.
The groove, formed by the two medial processes of the intermaxillary bone, is tilted to the left. From this oblique position and the curved fissure in the space between the two maxillary turbinates it can be inferred that the septum, lost by preparation, was bent to the operated side (fig 26 D).
On the palatinal side the fused medial processes of the intermaxillary bone are positioned in the midline, as normal (fig 26 C).
In two skulls the deviation of the nose is combined with a deviation of the upper jaw.

10.2.3 Geometry (table 9; fig. 27).

From the means of the standardized values of the coordinates for the left side view (table 9) and the F-values that have been calculated from them, it can be observed, using Hotelling's T^2-test, that no single point significantly differs from series 0. No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

In figure 27 the skull diagram for series 3 is superimposed on that for series 0. Here, too, it is demonstrated that the position of the points in this series do not significantly differ from those for the non-operated skulls.

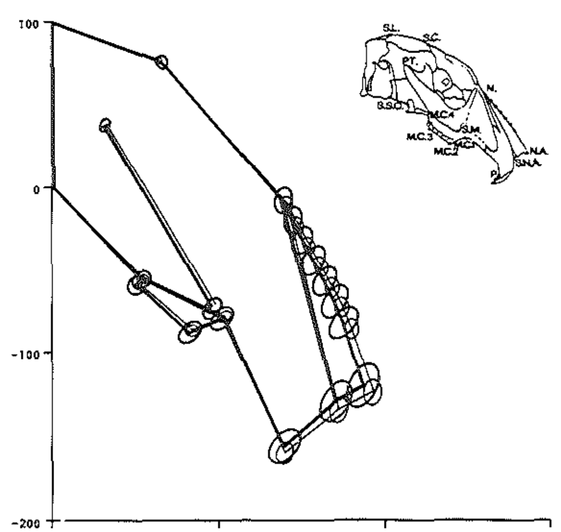


Table 9: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side of the skull in series 3.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	65.67	1.0964	75.58	1.1963	1.4963
N	137.33	1.6982	-7.75	2.4989	2.0314
N1	143.25	1.8955	-20.25	2.5469	2.4004
N2	149.17	2.0554	-32.67	2.6381	2.6975
N3	155.83	2.2891	-45.00	2.7386	2.3718
N4	161.92	2.3851	-57.25	2.9132	3.0173
N5	168.08	2.5568	-69.92	3.1005	2.7800
N6	173.67	2.7423	-82.67	3.1439	3.0093
NA	184.58	3.3016	-120.17	4.2441	3.1841
SNA	168.33	3.0977	-128.92	3.6793	1.6329
P	137.17	3.4659	-156.75	3.3487	0.7332
MC1	101.17	2.1350	-79.42	2.2545	0.7252
MC2	80.83	2.2825	-88.17	2.1526	0.9938
MC3	49.67	1.8518	-59.92	1.8235	1.4289
MC4	51.92	1.7428	-55.58	1.7899	1.2732
SM	95.08	1.8318	-73.83	2.2321	1.2241
PT	30.50	1.0335	37.67	1.2452	1.2027

(according to Fisher's tables, the F0 value is: 3.33 for n-3=29 degrees of freedom, 2 variables and a level of significance of 5%).

Fig. 27: Diagram of the skulls of adult rabbits in series 3, in which the lateral cartilage on one side was resected at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

10.3 Conclusion.

Compared to series 1, in which only the nasal bone was mobilized, the subtotal removal of the lateral cartilage on one side has far-reaching consequences for the further development of the nose. The important features are:

1. deviation of the anterior part of both nasal bones towards the non-operated side;
2. flattening, narrowing and foreshortening of the nasal bone on the operated side;
3. reduction of the nasal cavity with underdevelopment of the maxillary turbinate on this side;
4. marked deformation of the nasal turbinate and reduction in size of the dorsal nasal meatus;
5. tilting of the groove, formed by the medial processes of the intermaxillary bone to the operated side, suggesting a convex deviation of the anterior part of the nasal septum to the left;
6. no reduction in the length of the nasal bone on the non-operated side and/or upper jaw.

CHAPTER 11

SUBTOTAL RESECTION OF THE LATERAL CARTILAGE ON BOTH SIDES (series 4).

11.1 Introduction.

Following subtotal resection of the lateral cartilage on one side (chapter 10), in this experiment the lateral cartilage was resected for the greater part on both sides. Both nasal bones were lifted and repositioned as described in chapter 9. After a paramedian incision along both sides of the septum the lateral cartilages were mobilized and resected as described in chapter 10. Consequently the nasal fossa on either side was not opened and the septum was left undisturbed.
This operation was carried out on 10 animals at the age of 4 weeks. Two animals died from haemorrhagic enteritis before they reached the adult stage (24 weeks).

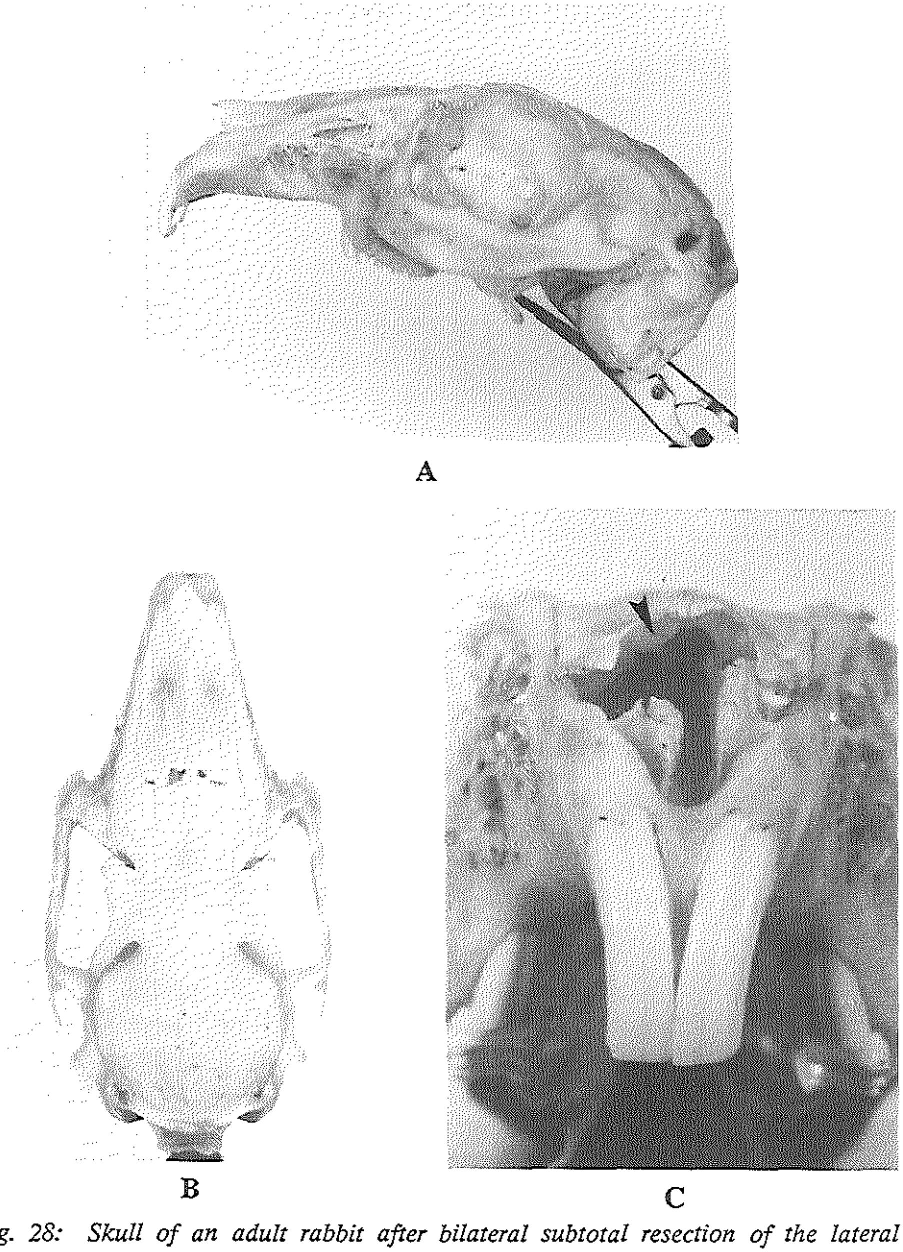
11.2 Results.

11.2.1 Transorbital inspection.

The mucosa covering the septum had a normal appearance. As far as could be observed the septum was straight and situated in the median line.

11.2.2 Morphology (table 10; fig. 28).

In addition to the uneven surface observed in earlier series, the two nasal bones of all skulls in this series show foreshortening on both medial and lateral sides. The nasal bones have lost their convexity and are flattened, leading to narrowing of the foremost part of the bony nasal pyramid (fig. 28 B). The nasal dorsum is reduced in height, with sagging at about one third of its length from the anterior edge of the nasal bone (fig. 28 A).
Another constant feature is the less demarcated internasal suture. A dehiscence near the anterior end of the nasal bone is only found in one skull. Also in this series the lateral part of the transverse slit is completely filled with bone. Medially bony defects (up to 3 mm) remain in the adult stage. Frontal inspection (fig. 28 C) shows that both maxillary turbinates are much smaller than in the control skulls. The crevice between the two turbinates is along the median plane. Another indication for a straight septum is found in the medial position of the groove formed by the medial processes of the intermaxillary bone. The two nasal turbinates are rudimentally developed whereas the dorsal nasal meatus is narrower and shallower than in the control skulls.



A B C

Fig. 28: *Skull of an adult rabbit after bilateral subtotal resection of the lateral cartilage at the age of 4 weeks (series 4).*
(A,lateral view; B,cranial view; C,frontal view).
Note the foreshortening of both nasal bones and their lack of convexity resulting in flattening (in frontal view) and sagging (in lateral view) of the nasal dorsum, the bony defect at the site of the former fraised slit and the reduced maxilloturbinate on the left side and the rudimentally developed nasal turbinates (arrow).

Table 10: Skull deformities in series 4; n=8; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial	8/8		
	lateral	8/8		
	narrowing	8/8		
	sagging	5	3	
	flattening	8/8		
	deviation	1/-	3/2	2
Maxilla	shortening		2	6
	deviation		2/1	5
	rotation		-/1	7
Incisor malocclusion	reduced overbite			8
	reversed overbite			8

Some slight nasal deviations were found in the majority of the cases, without any directional predominance. In 3 skulls the deviation of the nose is associated with a deviation of the upper jaw.

11.2.3 Geometry (table 11; fig. 29).

From the means of the standardized values of the coordinates for the left side view and the F-values that have been calculated from them (table 11), it can be seen, using Hotelling's T^2-test, that only one point (PT) differs significantly from those in series 0. No significant difference was found between the left and right sides. Only the data for the left side are presented.

In figure 29 it can be observed that the positions of most points in series 4 are almost the same as those in the non-operated series.

Table 11: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side view of the skull in series 4.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	67.00	1.0000	76.38	1.1792	2.3455
N	142.25	2.0938	-8.63	2.7642	0.1128
N1	149.38	2.3975	-21.87	2.8812	0.1887
N2	156.25	2.7951	-34.88	2.8688	0.1860
N3	161.88	3.0673	-47.88	2.8249	0.0242
N4	167.50	3.4641	-61.50	2.8536	0.1233
N5	173.00	3.7321	-74.63	2.9212	0.2837
N6	178.38	4.0749	-88.13	2.9182	0.3171
NA	189.13	4.6423	-116.00	3.3434	1.7677
SNA	174.25	5.0098	-124.38	3.2012	2.0425
P	147.75	5.6276	-152.88	3.0789	2.2502
MC1	102.38	3.5048	-78.50	1.3758	0.1442
MC2	81.00	3.2678	-86.75	1.2211	0.5479
MC3	48.38	2.4417	-58.50	0.9820	1.9984
MC4	49.88	2.3863	-55.75	1.0649	2.8741
SM	92.88	3.3617	-70.25	1.5207	1.7983
PT	22.38	1.2809	41.63	0.8224	21.0772*

(according to Fisher's tables, the F0-value is: 3.39, for n-3=25 degrees of freedom, 2 variables and a level of significance of 5%).

Fig. 29: Diagram of the skulls of adult rabbits in series 4, in which the lateral cartilage on both sides was resected at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

11.3 Conclusion.

There are both similarities and differences in the effects that unilateral and bilateral resections of the lateral cartilage have on growth.

They have in common:

1. reduction in length of the nasal bone; this is more pronounced laterally than near the midline, which explains the difference between the morphological observations and the geometrical results; the position of point NA is not significantly different from its position on the control skulls;

2. flattening of the nasal bone, resulting in a smaller nasal fossa with an equally reduced maxillary turbinate;

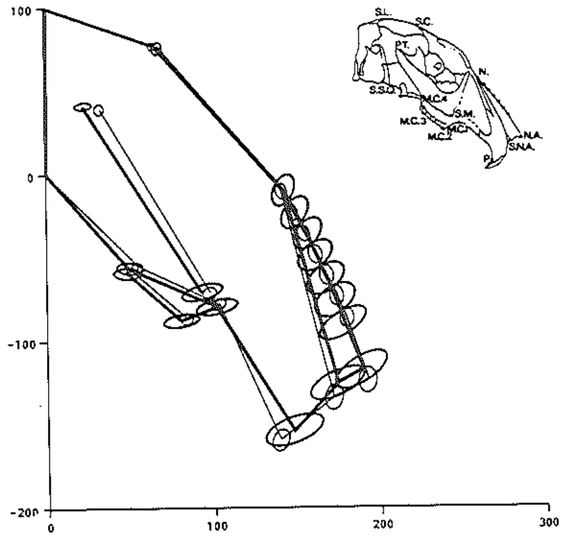
3. rudimentary development of the nasal turbinates.

Differences are:

1. after unilateral resection the nasal bones are deviated to the non-operated side in the majority of the skulls (9 of 12);

2. after bilateral surgery the nasal bones show a certain instability deviating either to the left or to the right; only 2 out of 8 noses have grown straight;

3. reduction in height with sagging of the bony nasal dorsum after resection of both the lateral cartilages, as opposed to the "normal" convexity of the dorsum formed by the nasal bone on the non-operated side after unilateral resection.



CHAPTER 12

PARTIAL RESECTION OF THE LATERAL CARTILAGE ON ONE SIDE (series 5).

12.1 Introduction.

In this experiment surgery was restricted to the middle third of only one lateral cartilage. In this way it was possible to study the effect on the further development of the nose after interruption of the antero-posterior continuity. Consequently the most anterior and posterior part of the cartilaginous vault was preserved. This operation was performed on 25 animals. Seventeen died as a result of an haemorrhagic enteritis.

12.2 Results.

12.2.1 Transorbital inspection.

The posterior part of the septum had a median position in all cases and was covered with normal mucosa.

12.2.2 Morphology (table 12; fig. 30).

In nearly all skulls the nose has developed asymmetrically. In 6 of the 8 skulls the nasal bone on the operated side is flattened halfway along its length. On the same side the lateral part of the nasal bone is shortened. The contra-lateral side has developed normally in length and convexity. As a result no sagging of the nasal dorsum is observed in a lateral view (fig. 30 A).

One skull shows a marked deviation of the nasal bones towards the operated side. The less demarcated internasal suture, uneven surface and the bony defect at the medial end of the fraised slit (less than 2 mm), as described in the previous series (chapters 8, 9 and 10) are also found in this series (fig. 30 B).
The shape and size of the nasal fossa and the anterior part of the maxillary turbinate are normal on both sides. The nasal turbinate on the operated side is only rudimentally developed (fig. 30 C).

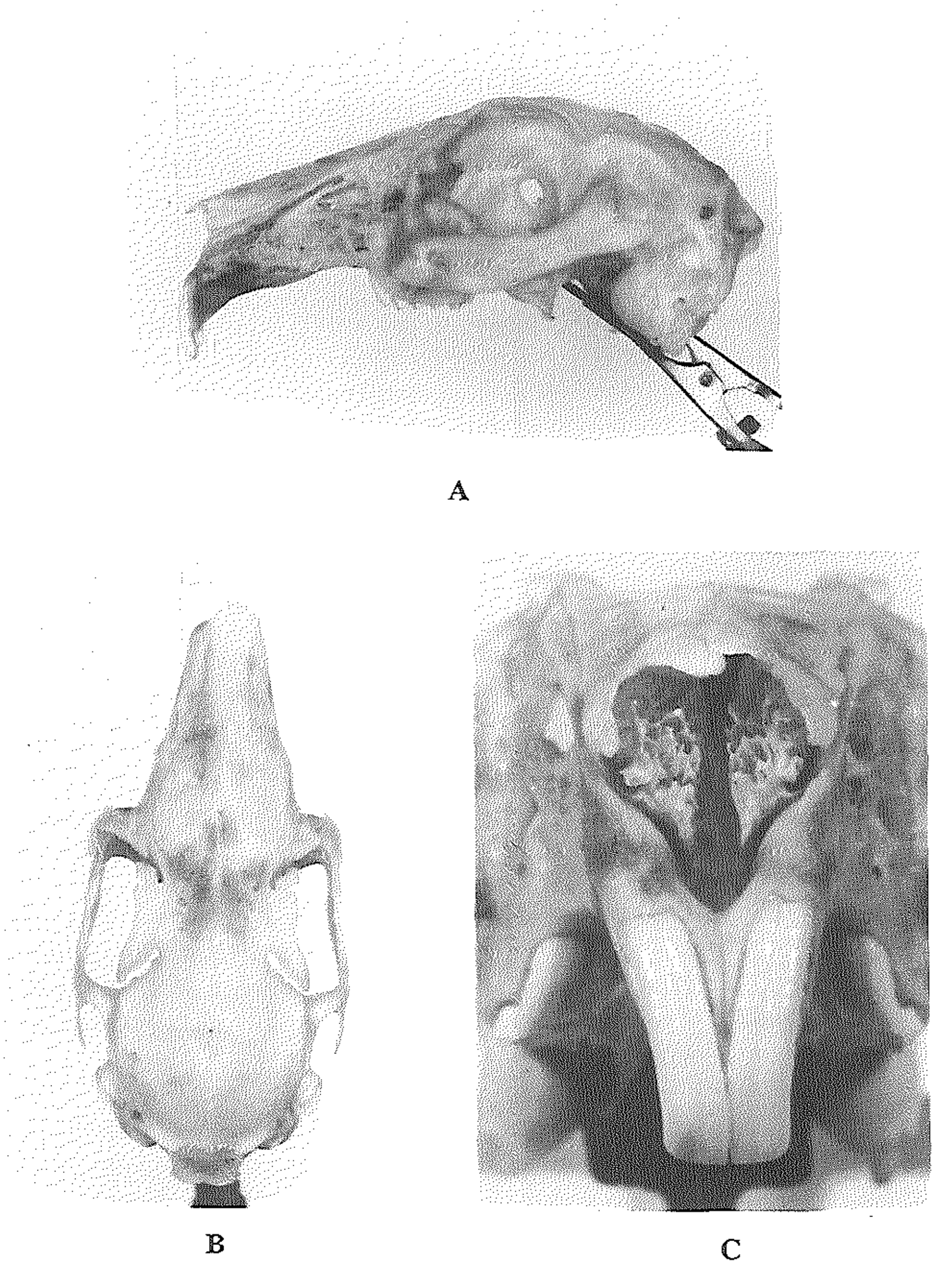


Fig. 30: Skull of an adult rabbit after partial resection of the lateral cartilage on one side at the age of 4 weeks (series 5).
(A,lateral view; B,cranial view; C,frontal view).
Note the foreshortening and flattening of the left nasal bone, the irregularity of the former fraised slit and the slight reduction of the maxilloturbinate on the left side.

Table 12: Skull deformities in series 5; n=8; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial	1/-	4/-	3/8
	lateral	4/-	3/-	1/8
	narrowing	2/-		6/8
	sagging			8
	flattening	3/-	3/-	2/8
	deviation	1/-	-/1	6
Maxilla	shortening			8
	deviation	1/-		7
	rotation			8
Incisor malocclusion	reduced overbite			8
	reversed overbite			8

12.2.3 Geometry (table 13; fig. 31).

From the means of the standardized values of the coordinates for the left side view and the F-values that have been calculated from them (table 13), it can be seen, using Hotelling's T^2-test, that the points MC2-4, and the points representing the zygoma are significantly different from series 0. No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

In figure 31 the skull diagram for series 5 is superimposed on that for series 0. It can be observed that the positions of the points on the nose and the upper jaw in this series are almost exactly the same as those for the same points in the unoperated series. The ellipses are larger mainly due to the increased variation within this series.

Table 13: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side view of the skull in series 5.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	67.63	1.0340	77.25	0.8183	2.9636
N	145.13	2.4599	-12.00	3.8266	1.4738
N1	151.13	2.7995	-25.50	4.1361	1.2324
N2	157.63	3.0644	-38.38	4.5393	1.0154
N3	163.63	3.2234	-51.75	4.6666	0.8508
N4	170.00	3.6302	-65.13	4.9477	0.9859
N5	175.50	4.0000	-78.75	5.2090	1.1878
N6	180.25	4.1047	-91.88	5.4623	0.9332
NA	191.50	5.3719	-131.00	4.3793	1.2283
SNA	170.50	5.5613	-140.00	3.9596	0.9962
P	137.38	5.8856	-166.25	2.9985	1.3291
MC1	99.50	2.8909	-82.50	1.8028	2.6631
MC2	76.38	2.7186	-89.88	1.4447	5.3988*
MC3	45.50	2.3261	-59.00	1.6583	5.8420*
MC4	46.87	2.2396	-56.00	1.6366	7.3774*
SM	87.13	3.1364	-73.63	1.4631	6.9491*
PT	25.13	1.1408	41.63	1.5577	11.3847*

(according to Fisher's tables, the F0-value is: 3.39, for n-3=25 degrees of freedom, 2 variables and a level of significance of 5%).

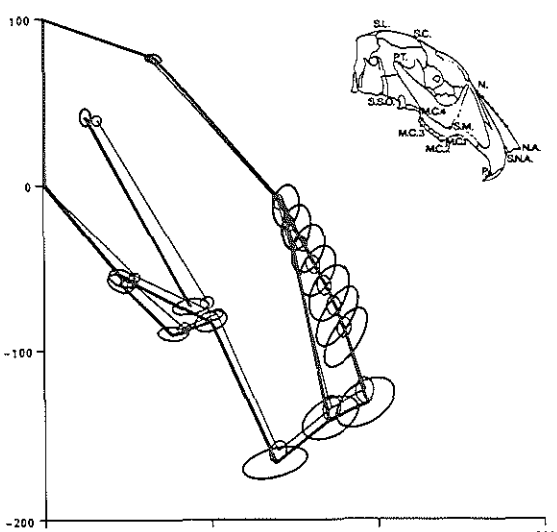
Fig. 31: Diagram of the skulls of adult rabbits in series 5, in which the lateral cartilage on the left was partially resected at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

12.3 Conclusion.

Noses where the middle third of one lateral cartilage has been resected differ from those for series 1, where the nasal bone was lifted (chapter 8) in three ways:

1. restricted flattening of the nasal bone halfway along its length, on the operated side,
2. slight foreshortening of its lateral side,
3. only rudimentary development of the nasal turbinate on the operated side.

The absence of a nasal deviation is the most important difference when compared with the series in which unilateral subtotal resection was performed (chapter 10).



CHAPTER 13

SUBMUCOUS RESECTION OF THE SEPTAL CARTILAGE (series 6).

13.1 Introduction.

The cartilaginous nasal dorsum is supported in the midline by the septal cartilage. The effects of partial resection of this medial support on the further growth is studied in this series. The nasal bone is lifted on the left side (chapter 8, fig. 22d). Paramedian incision on both sides, restricted to the middle third of the nasal dorsum, and elevation of the mucoperichondrium, gives an adequate access to the septal cartilage. The middle third of the latter is resected (10 mm) (fig. 19d). Finally the nasal bone is repositioned.
The operation was performed on 15 animals. All animals survived during the experimental period.

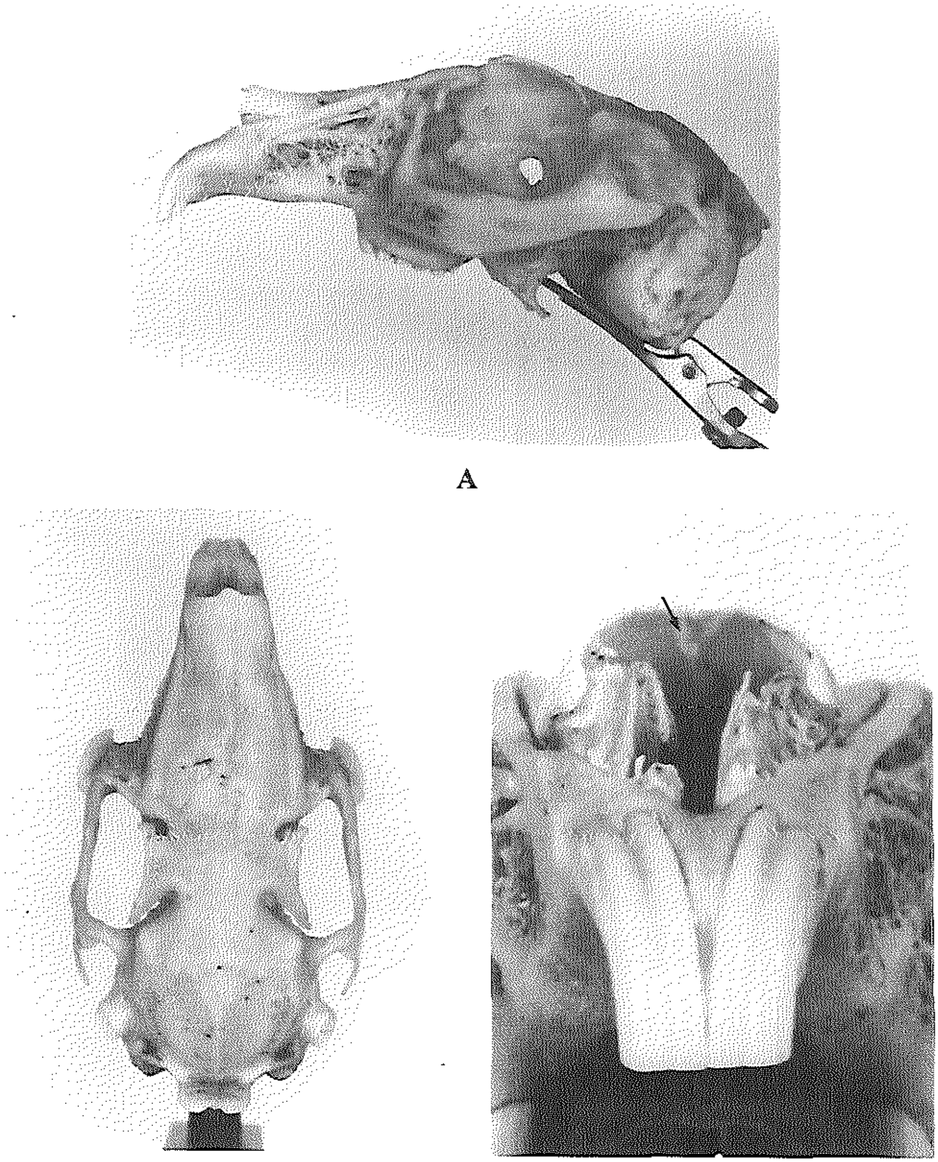
13.2 Results.

13.2.1 Transorbital inspection (table 14).

In all animals, except one (with a pinpoint perforation) the septum was intact. The mucosa had a normal appearance and synecchia were not observed.

Table 14: Observations of the septum (series 6) by means of transorbital inspection from the right side (n=15).

			Number
Mucosa	Normal		15
	Dry/encrusted		-
	Synecchia		-
Perforation	Absent		14
	Present		1
Septum	Median		9
	Deviation:	kinked	4
		convex	2
		concave	-



A

B

C

Fig. 32: Skull of an adult rabbit after submucous resection of the septal cartilage at the age of 4 weeks (series 6).
(A,lateral view; B,cranial view; C,frontal view).
Note the extreme foreshortening of nose and upper jaw, the lack in convexity of the nasal dorsum resulting in flattening and sagging halfway along the nose, the more rounded orbit, the horizontal position of the incisors in the premaxilla and the ridge halfway along the nose on the nasal side of the internasal suture (arrow).

A deviation of the septum occurred in 6 of the 15 animals. In 4 of these 6 cases the septum was distorted into a harmonica-shape with the posterior edge of the anterior part of the septum deviating to the left and the anterior edge of the posterior part of the septum deviating to the right. In the other 2 animals a convex deviation existed to the right.
The septum of the animal with a reversed overbite was straight and in the median position.

13.2.2 Morphology (table 15; fig. 32).

Most of the skulls have an extremely short nose and upper jaw.
Other specific deformaties are flattening of the nasal bones and sagging of the nasal dorsum. This sagging is especially conspicuous halfway along the nasal dorsum and gives the appearance of a rather turned-up nose. The reduction in length of the nasal bones is slightly greater in the midline than on the lateral side (fig. 32 B), resulting in an inclination in cranial direction of the plane of the piriform aperture (fig. 32 A).

Table 15: Skull deformities in series 6; n=15; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial	14/14	1/1	
	lateral		14/14	
	narrowing			15/15
	sagging	10	4	1
	flattening	10/9	4/5	1/1
	deviation		4/-	11
Maxilla	shortening	11	2	2
	deviation	2/-		13
	rotation			15
Incisor malocclusion	reduced overbite			15
	reversed overbite	1		14

The ratio of the vertical to the horizontal diameter of the orbit has changed, compared to the control skulls. In this series the orbit is rounded (fig. 32 A). The angle between the maxillary process and the alveolar process of the maxilla (as defined in chapter 6.4) has increased. This is accompanied by a change in the

position of the incisors in the upper jaw.
Apart from the previously described irregularity of the internasal suture, the nasal bones in this series do not diverge at the tip of the nose, and in 12 cases the transverse slit is completely filled with bone. A special feature is the bony protuberance (ridge) halfway along the nose on the inner side of the internasal suture (fig. 32 C). This ridge protrudes into the nasal fossa at the site of the cartilaginous defect, deviating either to the left (4 skulls), or to the right (3 skulls). The nasal turbinates have a normal appearance.
Slight deviations of the nasal bones are found in only 4 skulls with a preference for the left.

13.2.3 Geometry (table 16; fig. 33).

From the means of the standardized values of the coordinates for the left side view and the F-values that have been calculated from them (table 16), it can be seen, using Hotelling's T^2-test, that the position of all points (SC-PT) differ significantly from those in series 0.
No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

When series 6 is superimposed on series 0, the diagram confirms the observation that the upper jaw and especially the nose are foreshortened (fig. 33). Not only the most anterior points on the skull, such as NA, SNA and P are retropositioned, but likewise the points SC and N on top of the skull, and MC1-4 (molar complex). If the position of these points in the skull diagram is compared with the position of the corresponding points in the control series, it can be observed that the nose shows a deflection.

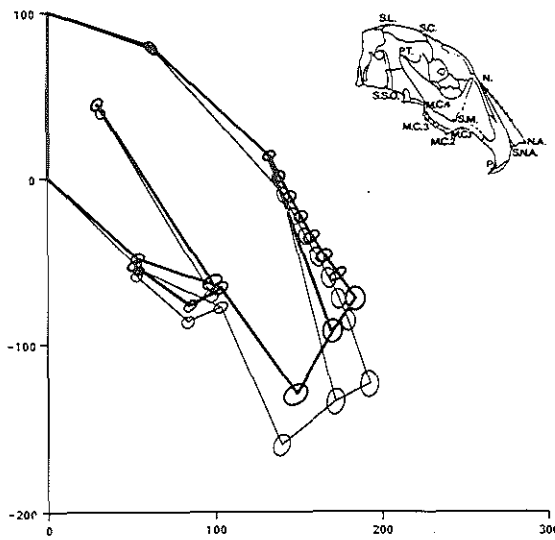


Table 16: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side view of the skull in series 6.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	61.87	1.0459	79.87	1.0992	3.3409*
N	132.73	1.0395	13.67	1.1616	62.2381*
N1	138.73	1.1607	1.47	1.1827	63.5010*
N2	145.13	1.2300	-10.80	1.1178	56.1603*
N3	152.00	1.3310	-22.87	1.0905	57.1403*
N4	158.80	1.4014	-34.80	1.1347	56.9515*
N5	166.20	1.4998	-46.60	1.2414	51.1724*
N6	174.47	1.5883	-57.87	1.3728	53.0886*
NA	184.67	1.9704	-72.60	2.4374	91.3104*
SNA	170.53	2.1333	-92.00	2.3073	70.5610*
P	148.93	2.3754	-129.33	2.0969	49.0481*
MC1	104.07	1.3074	-66.13	1.0368	24.5173*
MC2	85.67	1.4165	-76.80	1.1178	16.0009*
MC3	51.87	1.1333	-53.13	0.9704	11.1475*
MC4	54.13	1.1827	-48.53	0.9704	10.9740*
SM	98.80	1.7490	-62.93	1.4783	8.5931*
PT	30.00	1.1506	44.73	1.2401	6.2845*

(according to Fisher's tables, the F0-value is: 3.29, for n-3=33 degrees of freedom, 2 variables and a level of significance of 5%).

Fig. 33: Diagram of the skulls of adult rabbits in series 6, in which the middle third of the septal cartilage was resected submucously at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

13.3 Conclusion.

Resection of the middle third of the septal cartilage results in very severe deformities of the skull.
The major features are:

1. reduction in growth of the nasal bones: shortening, flattening, sagging and inclination of the piriform aperture;

2. reduction in length of the upper jaw with an increase in the angle between the maxillary process and the alveolar process of the maxilla (as defined in chapter 6.4), changed position of the incisors and retroposition of the molar complex;

3. rounded form of the orbit and retroposition of nasion;

4. bony ridge on the nasal (inner) surface of the internasal suture.

Minor details are the uneven surface of the nasal bone on the operated side, the irregular course of the internasal suture, the only partially-filled fraised slit and the slight deviation of the nasal bones to the left.

CHAPTER 14

PARTIAL SUBMUCOUS RESECTION OF THE SEPTAL AND LATERAL CARTILAGES ON ONE SIDE (series 7).

14.1 Introduction.

In this series the experimental operations described in chapters 12 and 13 are combined. In each of these experiments on the cartilaginous nasal skeleton a specific effect on the development of the skull was observed. In the following experiment the continuity of both the septal and lateral cartilages is interrupted in the longitudinal direction on one side, by resecting the middle third of both structures (fig. 18e). The aim is to study whether this combined operation, with loss of support in both the longitudinal and transverse directions, modifies the effects mentioned above. Surgery was performed on 15 animals. One animal died from haemorrhagic enteritis.

14.2 Results.

14.2.1 Transorbital inspection (table 17).

No perforations of the septum were observed. A deviation in the septum, with a slight preference for the left, was seen in 8 of the 14 animals.

Table 17: Observations of the septum (series 7) by means of transorbital inspection from the right side (n=14).

			Number
Mucosa	Normal		14
	Dry/encrusted		-
	Synecchia		-
Perforation	Absent		14
	Present		-
Septum	Median		6
	Deviation:	kinked	2
		convex	1
		concave	5

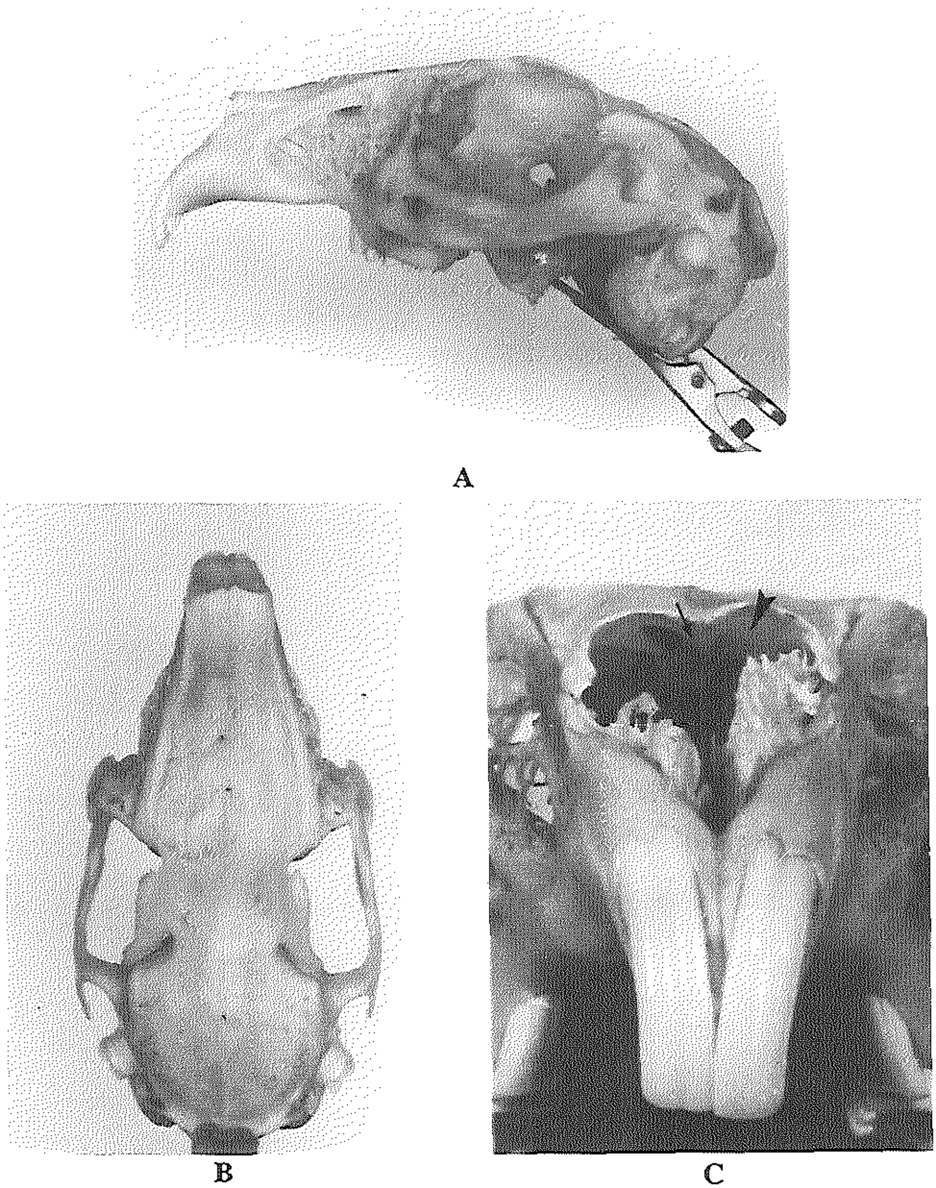


Fig. 34: *Skull of an adult rabbit after submucous resection of the septal cartilage with the corresponding middle third of the lateral cartilage on one side at the age of 4 weeks (series 7).*
(A,lateral view; B,cranial view; C,frontal view).
Note the extreme foreshortening of nose and upper jaw, the flattening and sagging of the nasal bones, the more rounded orbit, the horizontal position of the incisors in the premaxilla, the ridge halfway along the nose on the nasal side of the internasal suture (thin arrow) and the rudimentary development of the nasal turbinate (thick arrow).

In 5 cases the posterior part of the septum curved in the vertical axis to the left (concave) and once convexly to the right. Two septa showed a harmonica-shape with the posterior edge of the anterior part deviating to the left and the anterior edge of the posterior part deviating to the right. The other septa were situated in the median line.
In one animal with an inverted horizontal overbite anteriorly, the septum deviated strongly to the left.

14.2.2 Morphology (table 18; fig. 34).

All the skulls have a very short nose and upper jaw. The nasal bones are too short, flattened and have developed slightly asymmetrically; in particular the lateral side of the left nasal bone is slightly indented in 6 of the 14 skulls. The flattening is more pronounced on the left than on the non-operated right side. The plane of the piriform aperture inclines in a cranial direction (fig. 35 A). Sagging of the nasal dorsum with a reduction in the height of the piriform aperture can be observed in all skulls (fig. 34 A).

Table 18: Skull deformities in series 7; n=14; L/R= on or to the left or right side.

		Marked L/R	Slight L/R	Absent L/R
Nasal bone	shortening: medial	14/14		
	lateral		6/-	8/14
	narrowing			14/14
	sagging	13	1	
	flattening	10/8	3/1	1/5
	deviation		6/-	8
Maxilla	shortening	12	2	
	deviation	2/-	5/-	7
	rotation			14
Incisor malocclusion	reduced overbite			14
	reversed overbite	1		13

The orbits have a more rounded shape than the control skulls, resulting in a change of the ratio of the vertical and horizontal dimensions (compare fig. 34 A with fig. 19 A).

The angle between the maxillary process and the alveolar process (as defined in chapter 6.4) has increased. This means a change in the position of the incisors, whereas only one skull shows an inverted horizontal overbite anteriorly.
The internasal suture follows an irregular course and is sometimes indistinguishable from the surrounding bony tissue (fig. 34 B). On 3 skulls the nasal bones diverge at the tip of the nose. In the nasal bone a small defect remains at the site of the fraised slit in 6 out of the 14 skulls; it never exceeds 2 mm.
Halfway along the nasal (inner) side of the internasal suture a bony protuberance (ridge) of variable size exists (fig. 34 C). This ridge deviates in 7 cases to the left and in 2 cases to the right. The nasal turbinate on the operated side is only rudimentally developed and the dorsal nasal meatus is narrower and shallower than in the control skulls (fig. 34 C).
Deviations of the nasal bones to the left are found in a limited number of cases (in 6 of the 14 skulls), the deviation being mainly restricted to the foremost third. Some nasal deviations (4) are combined with a deviation of the upper jaw.

14.2.3 Geometry (table 19; fig. 35).

From the means of the standardized values of the coordinates for the left side view and the F-values that have been calculated from them (table 19), it can be seen, using Hotelling's T^2-test, that the position of 11 points (N-P and MC4) are statistically different from those in series 0.
No significant difference was found between the left and right sides. Only the data for the left (operated) side are presented.

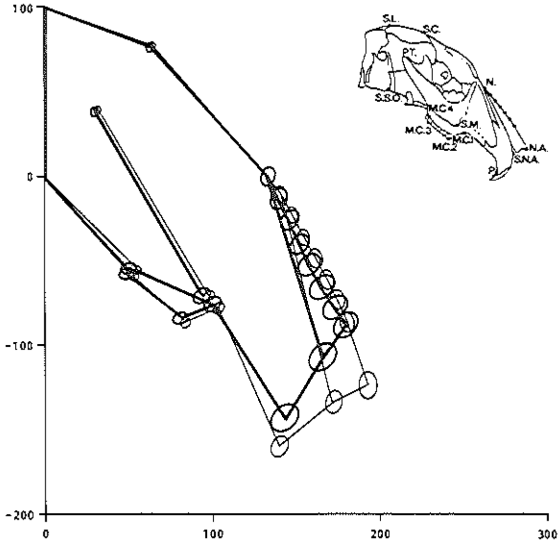
When series 7 is superimposed on series 0 the diagram confirms the observation that the nose and upper jaw are foreshortened (fig. 35). The foreshortening of the nose is more pronounced than in the diagram for series 6. The points representing the molar complex are not retropositioned, whereas the points N-SNA are displaced in cranial direction with respect to those in series 0.
The position of point P suggests a deflection of the upper jaw, although this has not led to deflection of the nose.

Fig. 35: Diagram of the skulls of adult rabbits in series 7, in which the middle third of the septal cartilage with the corresponding part of the lateral cartilage on the left side was resected at the age of 4 weeks, and the control skulls in series 0. The left side view is obtained by joining the averaged, standardized coordinates for each point. SSO-SL has been made equal for both series.

Table 19: The averaged, standardized coordinates and the corresponding standard error of the mean (SEM) for each of the points SL, SC, N, N1-6, NA, SNA, P, MC1-4, SM and PT. The data represent the left side view of the skull in series 7.
Included are the F-values, calculated from the means of standardized values for the left side of the skull using Hotelling's T^2-test.

	$\overline{X}$ norm	SEM ($\overline{X}$)	$\overline{Y}$ norm	SEM ($\overline{Y}$)	F-value
SL	0.00	0.0000	100.00	0.0000	0.0000
SC	63.14	0.9600	76.36	0.7233	1.0941
N	133.57	1.5749	0.50	1.9065	13.8197*
N1	139.79	1.8343	-12.93	2.0313	12.1520*
N2	146.14	1.9719	-25.86	2.0592	10.5727*
N3	151.93	2.1572	-39.21	2.1205	10.3521*
N4	158.21	2.3209	-51.86	2.2259	10.9136*
N5	165.29	2.4683	-65.29	2.3403	8.2550*
N6	173.29	2.3730	-77.29	2.4460	7.1628*
NA	180.07	2.5879	-87.71	2.8137	51.6010*
SNA	166.43	2.7451	-106.50	2.6762	31.8922*
P	143.21	2.9224	-142.57	2.6823	12.6753*
MC1	100.57	1.6162	-75.57	1.4477	2.5999
MC2	81.36	1.5640	-83.86	1.3862	1.8449
MC3	49.00	1.4412	-58.07	1.0025	2.5855
MC4	50.43	1.3856	-54.14	1.1136	3.4149*
SM	94.00	1.9555	-70.21	1.7703	1.8915
PT	30.07	0.8285	38.36	0.8555	1.7416

(according to Fisher's tables, the F0-value is: 3.31, for n-3=31 degrees of freedom, 2 variables and a level of significance of 5%).



14.3 Conclusion.

The results of interruption in the dorso-ventral continuity of both septal and lateral cartilages are similar to the effects observed when the experiments were performed separately (described in chapters 12 and 13), with some modifications such as:

1. only slight indentation or even absence of the lateral shortening of the nasal bone;

2. bilateral flattening of the nasal bone without any asymmetry.

There is hardly any evidence of disturbance in the growth of the nasal bone following partial resection of the lateral cartilage (in contrast to the results described in series 3, 4 and 5), probably due to the inability of the septal cartilage to grow sufficiently after partial resection.

CHAPTER 15

GENERAL DISCUSSION.

15.1 Introduction.

The nose is the most prominent part of the face. The transformation of the baby-face into the adult profile is the result of the disproportional growth of the two main parts of the skull. From birth to adulthood the facial skull, including the nose, increases much more in size than the brain skull. Surgeons dealing with congenital or acquired malformations in children face a two-fold task: ensuring the best possible form and function in the short term and in the long term promoting normal growth, or at least not disturbing further growth more than necessary. They are, therefore, interested in morphological and causal aspects of postnatal growth.
For the last three decades rhinologists have been interested in the role played by both the normal and the injured cartilaginous nasal septum in facial growth. However, this is the first study to focus on the cartilaginous nasal dorsum, which is made up of the two lateral cartilages.

The following questions were formulated in chapter 1:

1. What is the anatomy of the cartilaginous nasal skeleton and, in particular, the cartilaginous nasal dorsum in children?

2. What is the role of the cartilaginous nasal dorsum (upper lateral cartilages) in the postnatal growth of the nose?

To find answers to these questions an anatomical study in human neonates and a series of experiments in growing rabbits was carried out. The results of these two types of investigation will be discussed successively. Finally some remarks will be made on the relevance of this study for the rhinosurgical treatment of children.

15.2 The anatomy of the cartilaginous nasal dorsum in children.

In a survey of the literature on the cartilaginous nasal dorsum only data on the morphology in the foetal period and descriptions of the adult anatomy were found (chapter 2). Dissection of the nasal region in two stillborns without visible signs of congenital malformations (chapter 3), demonstrated that in the very young child:

1. the cartilaginous nasal dorsum extends from the tip of the nose for the full length under the nasal bones and merges into the cartilaginous skull base;

2. the upper lateral cartilages form two longitudinal vaults supported in the midline by the septal cartilage;

3. separate, small alar cartilages are present in the tip of the nose;

4. the nasal bones closely overlie the cranial part of the cartilaginous vaults.

It can be concluded that the observed cartilaginous nasal "framework" in newborns appears to be similar to the descriptions of the foetus at about 26 weeks (Patten '68, Bosma '86)). Septum and upper lateral cartilages are certainly not separate anatomical entities but part of an undivided cartilaginous structure.

The number of dissected specimens is small. On the other hand the observations in both neonates are identical and fit well in the development between foetal and adult morphology. From a comparison of the above-mentioned observations on the neonate with the anatomical data on adults it seems that the postnatal development of the nasal cartilage is characterized by a change in shape due to:

1. growth and, at the same time,

2. regression of the cranial part of the cartilaginous nasal dorsum resulting in a very considerable reduction in the extension of the adult upper lateral cartilage under the nasal bones;

3. ossification of the posterior part of the septum (perpendicular plate) and the lateral cartilages (lateral wall).

At what rate these changes occur has not yet been studied. Incidental observations during surgery on two children about two years old revealed that the upper lateral cartilage still extends as far as the glabellar region (Verwoerd and Bos, personal communication). Only further anatomical and histological investigation of specimens in various age groups can give definite information on the morphology and the mechanisms of this macroscopical regression. The different amount of overlap of nasal bone and upper lateral cartilage in adults (between 7 and 20 mm) as reported by Straatsma et al ('51), Converse ('55), Hinderer ('70) and Lessard ('85) can be explained by individual variation in the regression of the cartilage. For rhinosurgeons, especially those interested in acquired or congenital pathology of the nose in children, the conclusion is that the normal anatomy of the cartilaginous nasal dorsum is actually not yet known in this group of patients.

15.3 The anatomy of the cartilaginous nasal dorsum in the experimental animal compared to that in man.

The reasons for choosing the rabbit as experimental animal for a study of the role of the upper lateral cartilage in nasal growth were explained in chapter 4.1. However, no description of the cartilaginous nasal dorsum in rabbits was found in literature. Only a few data are available about the cartilaginous part of the nasal skeleton in some larger animals and these are confined to the adult stage. These anatomical descriptions (chapter 4.2) can be summarized as follows:

1. The lateral cartilages are bilateral extensions of the septum under the nasal dorsum.
2. There is no mention of an extension of the lateral cartilage under the nasal bone.
3. The lateral cartilage is either in direct end-to-end contact with the bony skeleton (sheep, cow, horse) or connected to the nasal bone via a zone of fibrous tissue (dog).
4. The alar cartilage can be distinguished as a separate entity in the tip of the nose in some animals (e.g. horse and some primates, Getty '75) and it is thought to be derived from the lateral cartilage (Wen '40); in other animals the undivided lateral cartilage extends into the ala.

The dissection of the rabbit nose at 4 weeks after birth (beginning of the experimental period), reported in chapter 5.1, demonstrates the following:

1. The septum and lateral cartilages in the young rabbit are undivided and form a partly vault-like structure on both sides extending from the tip of the nose as far as the cartilaginous base of the skull. In this respect the structure of the lateral cartilage in the young rabbit corresponds with the cartilaginous skeleton of the human neonate.
2. There is no separate alar cartilage in the tip of the nose.

By comparing these findings with data obtained by dissection of an adult rabbit (chapter 5.2) the following conclusions concerning the growth during the experimental period (4-24 weeks after birth) can be drawn:

1. Regression of the cranial parts of the cartilaginous nasal dorsum, leads to a great reduction in the extension of the adult cartilage under the nasal bone and the transformation from a long vault-like structure to a triangular structure on both sides.
2. Ossification of the septum remains restricted to a small dorso-cranial part, while the further cartilaginous septum shows extensive growth.

Comparison of the anatomical observations made on the young child and young rabbit shows that in both species the lateral cartilages are part of the double-vaulted or T-bar-like nasal cartilage and extend from the tip of the nose in cranial direction to merge with the cartilaginous skull base. A common feature in the postnatal

development of both child and rabbit is that the greater part of the cartilaginous nasal dorsum underlying the nasal bone disappears.
These similarities make the growing rabbit a suitable experimental model for experiments on the role of the lateral cartilage in the postnatal growth of the nose.

15.4 The effect of the surgical approach to the cartilaginous nasal dorsum on the postnatal growth of the nose in rabbits.

For experimental surgery on the cartilaginous nasal dorsum in rabbits it is necessary to mobilize the nasal bone on one or both sides.
In experiments in which the nasal bone was lifted and replaced without any damage to the lateral cartilage (chapters 8 and 9) it was observed that this procedure did not interfere with the full development of the nose of the rabbit in length or height. Only minor and local deformities (irregularities of the internasal suture and local defects at the site of the transverse fraised slit) were found in the adult stage. The difference between the very irregular internasal suture and the apparently normally developed naso-intermaxillary suture could be due to the difference in the surgical trauma (transection vs."hinging") or to the difference in the morphological structure. Further histopathological evidence is needed to clarify this problem.
Damage to the periosteum of the nasal bones with associated disturbances of the local vascularization could also lead to sutural changes (Hellquist '72). The dehiscence at the anterior end of the internasal suture after a bilateral approach could be caused in this way.

With reference to the experiments on the cartilaginous nasal dorsum involving the mobilization of the nasal bones, the question arises as to whether the observed abnormal nasal development is caused by:

a) surgery on the nasal cartilage alone or,
b) this operation in combination with mobilization of the nasal bone(s), necessary for the approach.

Operating on the cartilaginous nasal dorsum without mobilizing the nasal bones could give the answer to this question. Other types of approaches have been described: via the bucco-gingival fold in rabbits (Stenström et al '70), via the palate in cats (Freng in '81) and in beagles (Kremenak '71 and Wada '80) and via the columella (Freng '85) in cats. In all these experiments, however, only the septal part of the cartilaginous nasal skeleton was operated upon. With these methods of approach it is technically impossible to have a clear view of the dorsal nasal cartilage, especially in young rabbits.

Indirect evidence in favour of the first interpretation (a) can be derived from the following observations:

1. The pattern of abnormal growth is specific to the type of surgery on the cartilage (chapters 10, 11, 12, 13 and 14).
2. In experiments on the nasal septum both the mobilized and the other, untouched, nasal bone are equally affected by the growth anomaly (chapters 13 and 14), as the nasal septum is the median support of the nasal dorsum.
3. After resection of the middle third of the septal cartilage, parts of the skull (e.g. maxilla, orbit) at some distance from the place of surgery, develop in an abnormal way.

Furthermore, the clinical observation that loss of septal cartilage at a young age results in the underdevelopment of the nose suggests that mobilization of the nasal bone is not a prerequisite for visible effects on further nasal growth.

Thus, apart from effects caused by the mobilization of the nasal bones, the major anomalies in growth can be regarded as the result of surgery on the nasal cartilage.

15.5 The role of the cartilaginous nasal dorsum in the postnatal growth of the nose in rabbits.

Resection of any part of the cartilaginous nasal skeleton in young rabbits induces the development of specific abnormalities as observed in the adult skulls. These anomalies can be devided into 3 categories:

A. local (i.e. confined to those parts of the nasal bones immediately overlying the operated cartilaginous parts);
B. regional (i.e. nasal bones and septum);
C. other features on surrounding skeletal parts (i.e. upper jaw, orbit and nasion).

A. The *local* features (fig. 36), after partial or subtotal resection of the cartilaginous framework, are:
   1. flattening of the nasal bone on the operated side (chapters 10, 11, 12 and 14);
   2. flattening of the nasal bone on both sides (chapters 13 and 14);
   3. sagging of the nasal dorsum (chapters 11, 13 and 14);
   4. narrowing of the foremost part of the bony nasal pyramid (chapter 11);
   5. rudimentary development of the nasal turbinate (chapters 10, 11, 12 and 14);
   6. formation of a bony ridge on the inner (nasal) side of the internasal suture (chapters 13 and 14).

   With respect to points A.1, 2 and 3: The extent of the deformities on the nasal bone (flattening and sagging) correlates with the extent of the resected part of the lateral cartilage and/or cartilaginous septum. The deformities are thus not restricted to the side on which the nasal bone was mobilized, for the surgical approach of the cartilaginous dorsum.

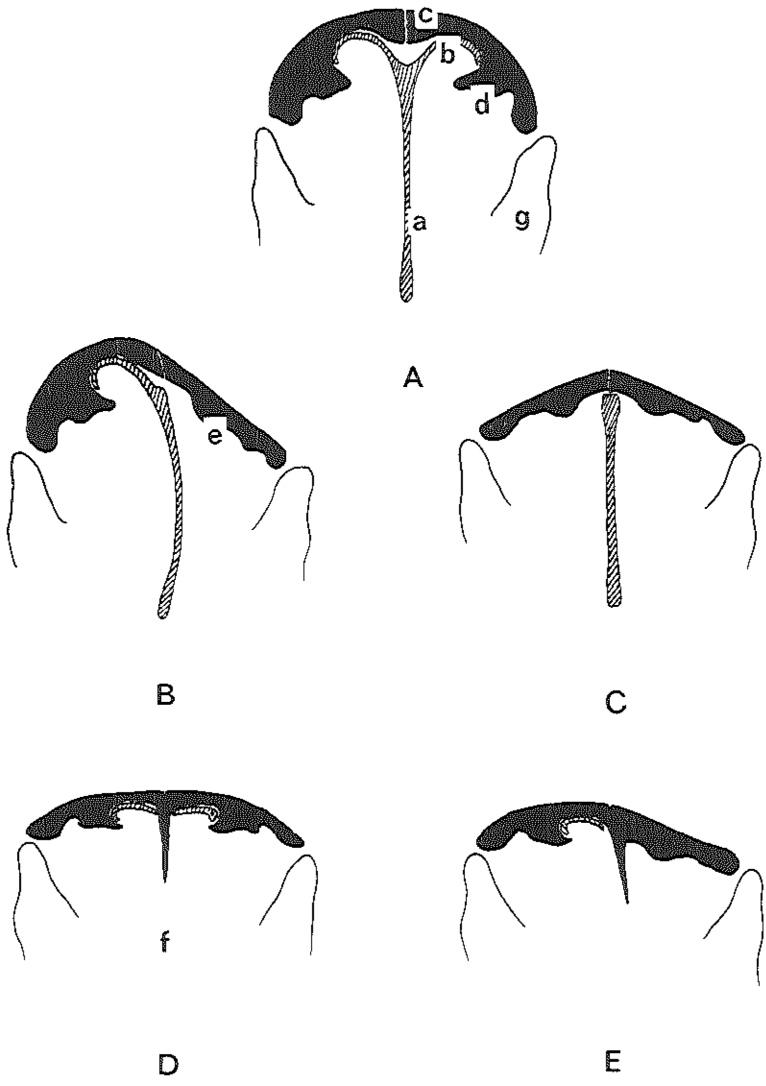


Fig. 36: *Impression of a coronal section halfway along the nose of the skull of an adult rabbit. (A) non-operated skull (series 0), (B) subtotal resection of the lateral cartilage on one side (series 3), (C) bilateral subtotal resection of the lateral cartilage (series 4), (D) submucous resection of the septal cartilage (series 6), (E) submucous resection of the septal cartilage with the corresponding part of the lateral cartilage on one side (series 7). (a)septal cartilage, (b)lateral cartilage, (c)nasal bone, (d)nasal turbinate, (e)remnant of nasal turbinate, (f)crest on the nasal side of the internasal suture, (g) frontal process of the intermaxillary bone.*

For an explanation of these disturbances in growth the normal anatomy of the nasal dorsum in the rabbit has to be considered (chapter 5.1). The 4 week old rabbit has a bilateral vault-like cartilaginous dorsum lying immediately under the nasal bone (fig. 36 a). Both lateral cartilages are continuous with the septum along the median line. Only medially does the bony skeleton not completely follow this cartilaginous vault, thus leading to a supraseptal groove filled with some loose connective tissue.
The flattening and sagging of the nasal bone(s) observed after partial or subtotal resection of one or both lateral cartilages (chapters 10, 11 and 12) demonstrate that when the underlying cartilaginous dorsum is absent the transverse convexity of the nasal bone disappears and the height decreases. The flattened nasal bone extends from the frontal process of the intermaxillary bone laterally to the cartilaginous septum, and medially to the unilaterally preserved cartilaginous vault (fig. 36 b/c). After subtotal resection of the lateral cartilage on one side the height of the nose is not reduced (fig. 36 b). However, the highest point of the bony nasal dorsum shifts from a medial to a paramedial position over the preserved nasal vault. After subtotal resection of the lateral cartilage on both sides the height of the nose is reduced to the level of the supraseptal groove (sagging) as a result of the resection of the cartilaginous vaults (fig. 36 c). Both flattened nasal bones meet in a slight prominence along the midline.
The deformity of the bony nasal dorsum, which develops in the area where the median support of both cartilaginous vaults was resected, is characterized by a loss of height and a reduction in the transversal convexity, but there is no external midline prominence (fig. 36 d).
Thus it can be concluded that interruption of the lateral cartilages and interruption of the septum lead in different ways to similar changes in the height and transverse convexity of the nasal dorsum.

With respect to point A.4: The flattening of the nasal bones after subtotal resection of both lateral cartilages is most conspicuous at the tip of the nose (narrowing). This appears to be associated with the pronounced dome-shaped structure of the lateral cartilage at this site.

With respect to point A.5: The nasal turbinate does not develop normally after partial or subtotal resection of the neighbouring lateral cartilage, whether or not this is combined with resection of the septal cartilage (fig. 36 b/c). The laterally convex curve is missing, as is the characteristic sharp crest extending into the nasal fossa. Moreover, the distance between the midline and the rudimentary nasal turbinate is smaller than in the non-operated control skulls. Apparently the lateral cartilage is necessary for the full development of the nasal turbinate and the transverse expansion of the dorsal nasal meatus during further growth.

In the case of partial resection of the septal cartilage a bony ridge is found (fig. 36 d/e) on the inner (nasal) side of the internasal suture. This ridge has its base exactly in the midline but shows deviations that correspond to the deviation of the septum, as revealed by transorbital inspection. It seems to be the result of the formation of new bone filling up the gap between the mucous membranes after submucous resection of the septal cartilage. Histological studies of wound healing processes in the septum following similar experiments (Meeuwis '85) confirm these observations.

In summary, it may be concluded that the nasal cartilage (lateral and septal), has to be intact for the normal development of:
1. the height and convexity of the nasal dorsum,
2. the specific form of the nasal turbinate and,
3. the transverse dimension of the dorsal nasal meatus between septum and nasal turbinate.

In this respect cartilage dominates bone.

B. The *regional* features (i.e. nasal bones and/or septum) in the adult skull, after partial or subtotal resection of the cartilaginous framework in young rabbits, are:

1. deviation of the nasal bones to the non-operated side (chapter 10),
2. deviation of the septum in a transverse axis towards the operated side (chapters 10 and 14),
3. reduction in the length of the lateral part of the nasal bone (chapters 10, 11, 12 and 14),
4. reduction in the length of the medial part of the nasal bone (chapters 10, 11, 12, 13 and 14).

With respect to point A.1: A deviation of both nasal bones with a directional predominance towards the non-operated (right) side develops after unilateral subtotal resection of the left lateral cartilage (series 3; table 20). This deviation only occurs in the anterior third of the nasal bone. The upper jaw is not affected by the deviation.
Judged from the normal convexity of the right nasal bone it can be concluded that the underlying right lateral cartilage also deviates to the right. After resection of the left lateral cartilage, the remaining parts of the nasal cartilage apparently grow asymmetrically, bending to the right side where the lateral cartilage is preserved. The two lateral cartilages seem to have a function in ensuring the straight growth of the nasal skeleton.

Table 20: Deviation of the nasal bone. L/R=to the left or right side. series 1: lifting of the nasal bone on one side; series 2: lifting of the nasal bone on both sides; series 3 subtotal resection of the lateral cartilage on one side; series 4:subtotal resection of the lateral cartilage on both sides; series 5: partial resection of the lateral cartilage on one side; series 6: submucous resection of the septal cartilage; series 7: partial submucous resection of the septal and the lateral cartilages on one side.

series	marked L/R	slight L/R	absent L/R	number
1	-	3/-	7	10
2	-	3/-	9	12
3	-/4	-/5	3	12
4	1/-	3/2	2	8
5	1/-	-/1	6	8
6	-	4/-	11	15
7	-	6/-	8	14

No deviation of the nasal bones occurs after unilateral resection of the middle third of the lateral cartilage. It can be assumed that in this respect the anterior part of the lateral cartilages are the most important, considering the normal regression of the cranial parts of the lateral cartilage after birth.
Deviations of the nasal bones, observed after bilateral subtotal resection of the lateral cartilage (series 4), do not show any preferential direction. The deviations are probably caused by a reduction in the stability of the growing nasal structures, due to the lack of transverse support by the lateral cartilages.
Deviations in the other series (partial resection of the septal cartilage, alone or in combination with partial resection of the lateral cartilage (series 6 and 7)), are only slight and incline towards the operated left side. The surgical approach used in all the series with surgery on one side (lifting of the left nasal bone) presumably causes the formation of scar tissue which prevents the straight growth of the nasal bones.

With respect to point B.2: The position of the anterior cartilaginous part of the septum can only be inferred indirectly as all the cartilaginous structures have been destroyed during preparation. This position is actually indicated by the gap (straight or curved) between the two maxillary turbinates, by the bony ridge on the inner side of the nasal bones (only after septal resection) and by the position of the medial processes of the intermaxillary bone (straight or tilted). From this indirect evidence it can be concluded that only after subtotal resection of the lateral cartilage on one side (series 3; chapter 10) does the anterior nasal septum show a deviation (curved) to the left, as observed in a transverse section. The convexly curved septum follows the deviation of the nasal bones to the right. Thus it is curved in two directions at the same time. In all other experiments the anterior septum seems to have a midline position.

With respect to point B.3: Partial or subtotal resection of the lateral cartilages (chapters 10, 11 and 12) has shown specific consequences for the growth in length of the nasal bones but does not influence the proportion of the upper jaw. On the operated side the nasal bone is foreshortened, more on the lateral than on the medial side (table 21 and 22) resulting in a change in the form of the piriform aperture (fig. 37). After bilateral subtotal resection of the dorsal cartilage (series 4) this disturbance in growth is found on both sides in all skulls. It seems that the full development of the lateral part of the nasal bone only depends on the continuity of the lateral cartilage being intact, whereas for the medial part it is much more important that the cartilaginous septum be intact.

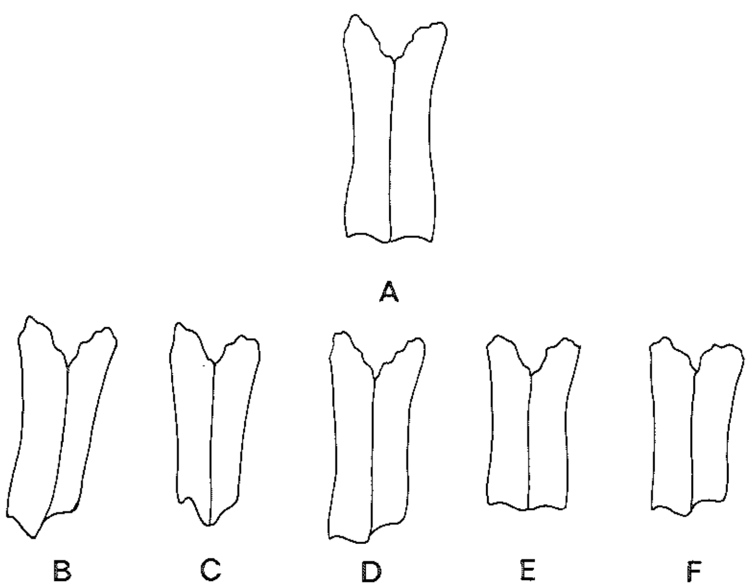


Fig. 37: Impression (cranial view) of the anterior aspect of the nasal bones in rabbit skulls. (A) non-operated skull (series 0), (B) subtotal resection of the lateral cartilage on one side (series 3), (C) bilateral subtotal resection of the lateral cartilage (series 4), (D) partial resection of the lateral cartilage on one side (series 5), (E) submucous resection of the septal cartilage (series 6), (F) partial submucous resection of the septal and lateral cartilages on one side (series 7).

Table 21: Relative foreshortening of the lateral part of the nasal bone (compared to the medial side of the nasal bone). Series are as listed in table 20. L/R = on the left or right side.

series	marked L/R	slight L/R	absent L/R	number
1	-	-	10/10	10
2	-	-	12/12	12
3	6/-	4/-	2/12	12
4	8/8	-	-	8
5	4/-	3/-	1/8	8
6	-	1/1	14/14	15
7	-	6/-	8/14	14

Presumably disruption of the connective fibrous tissue between the free edge of the nasal bones and the cartilaginous vault in the tip of the nose after subtotal resection of the lateral cartilage leads to distortion in the growth of the nasal bone on the affected side (shortening or slight indentation) during further development. In the mid-sagittal plane the septal cartilage will compensate for this disturbance in growth thus enabling the medial growth of the nasal bone to be relatively normal on the affected side.

With respect of point B.4: Shortening of the medial part of the nasal bone(s) was observed after resection of any part of the lateral cartilage but was restricted to the side of the resection (table 22, fig. 37).

Table 22: Medial foreshortening of the nasal bone(s). Series are as listed in table 20.

series	marked L/R	slight L/R	absent L/R	number
1	-	-	10	10
2	-	-	12	12
3	4/-	6/-	2	12
4	8/-	-/-	-	8
5	1/-	4/-	3	8
6	14/14	1/-	-	15
7	14/14	-/-	-	14

Only after bilateral resection (series 4) there was a significant reduction in length of the nasal bone (as determined by the distance between N and NA), according to the Student T-test (table 23).

Table 23: The averaged, standardized length of the distance N-NA with the corresponding standard deviation (st.dev.), the standard error of the mean (SEM) of the skulls in series 0-7 and the p-value calculated with Student T-test ($\alpha<0.05^*$). Series are as listed in table 20.

series	N-NA	st.dev.	SEM	p-value
0	125.66	8.91	1.99	-
1	121.72	9.30	2.94	0.2687
2	124.05	10.26	2.96	0.6419
3	122.77	8.84	2.55	0.3797
4	117.39	6.90	2.18	0.0158*
5	128.63	7.98	2.82	0.4217
6	101.32	6.58	1.70	0.0000*
7	100.54	4.45	1.19	0.0000*

The discrepancy between these data and the morphological findings can be explained by the method of depicting the skull. On the photograph of the skull in profile the point NA is the most ventral point of the internasal suture. It is thus not possible to specify to which of the nasal bones point NA belongs. The geometrical analysis fails to distinguish between the growth of the two separate nasal bones. Another disadvantage is that no point on the skull can be identified to represent the most lateral end of the nasal bone. The morphological observation has to suffice as evidence.

After partial resection of the cartilaginous septum (series 6 and 7), however, the disturbed growth in length of the nasal bones, on both their medial and lateral sides, is much more pronounced and symmetrical than after subtotal resection of both lateral cartilages. (tables 22, 23 and fig. 37). Thus interruption of the dorso-ventral continuity of the septal cartilage reduces the further growth of the nasal bones and the lateral cartilages are unable to compensate for this disturbance in growth. This observation concerning the nasal bones again stresses the important role that the cartilaginous septum plays in the further growth of the nose (Verwoerd '80, Nolst Trenité '84).

In summary, it can be concluded from these observations that the cartilaginous nasal skeleton (lateral and/or septal) has to be intact for:
1. the straight growth of septum and nasal bones,
2. the nasal bones to attain a normal length and,
3. the anterior free edge of the nasal bones to have a normal appearance.
Obviously the characteristic vault-like structure of the lateral cartilages is able to give the nasal bones their normal curve. The T-bar shape of the cartilaginous nasal skeleton with the septal cartilage in the midline not only supports the nasal dorsum but guarantees the delicate balance necessary for the straight growth of the nasal bones.

C. *Other effects* on the surrounding skeletal parts of the adult skull, after partial or subtotal resection of the cartilaginous framework in young rabbits, are:

1. a reduction in the length of the upper jaw with changes in occlusion after septal resection (chapters 13 and 14),
2. a change in the shape of the maxillary turbinate; retroposition of nasion; the rounded form of the orbit (chapters 10, 13 and 14).

With respect to point C. 1: Partial resection of the septum (series 6 and 7) also causes serious disturbance in the further growth of the upper jaw such asan extreme foreshortening (table 24).

Table 24: The averaged, standardized length of the distance MC1-P with the corresponding standard deviation (st.dev.), the standard error of the mean (SEM) of the skulls in series 0-7 and the p-value calculated with Student T-test (α<0.05*). Series are as listed in table 20.

series	MC1-P	st.dev.	SEM	p-value
0	89.56	4.94	1.11	-
1	87.57	3.64	1.15	0.2690
2	89.73	4.87	1.41	0.9257
3	85.50	4.82	1.39	0.1897
4	86.91	4.29	1.52	0.1952
5	92.01	4.69	1.70	0.2419
6	77.77	5.12	1.32	0.0000*
7	79.65	5.70	1.52	0.0000*

Occlusive abnormalities were observed in all skulls after septal resection in the young stage (chapters 13 and 14). Besides the retroposition of the molar complex, the position of the foremost incisors in the upper jaw is altered and the

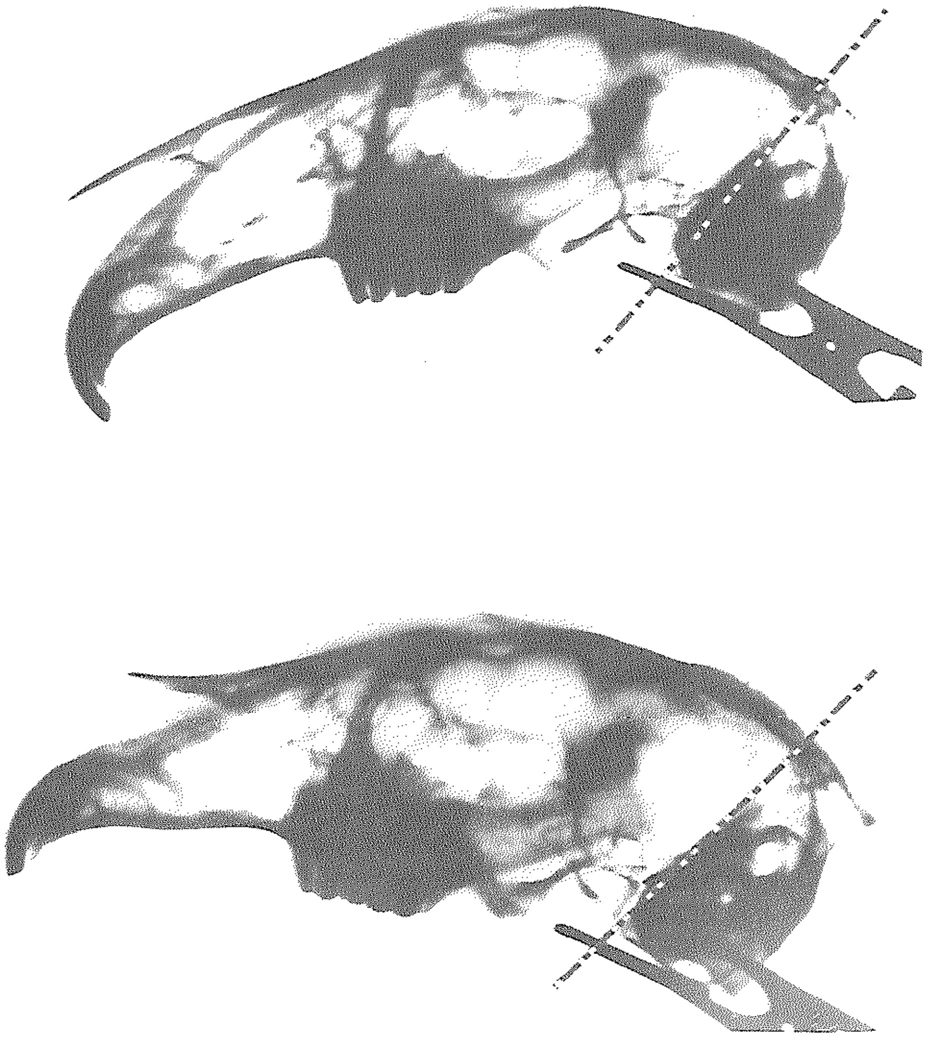


Fig. 38: Lateral roentgenogram of a rabbit skull in series 0 and series 6. Note the more horizontal position of the premaxilla and the less inclined incisors. (dotted line represents SSO-SL).

premaxilla is less curved in the caudal direction (fig. 38). The latter phenomenon (deflection) is most evident in the skull diagram from the displacement of point P in the cranial direction, compared with the control series.

Both the position of the teeth and the foreshortened upper jaw give the impression that the upper teeth are trying to remain in occlusion with the lower ones. During gnawing a constant pressure is exerted on the incisors of the upper jaw and this could be the reason for its deflection.
In both series (partial resection of the septal cartilage or in combination with partial resection of the lateral cartilage on one side) there is one skull with an inverted horizontal overbite anteriorly. No skulls were observed with an end-to-end overbite. It is noteworthy that in comparable experiments Nolst Trenité ('84) and Nijdam ('85) recorded, respectively, 1 and 7 skulls with an inverted horizontal overbite and 3 and 0 skulls with an end-to-end reduced overbite. The larger number of occlusive abnormalities are probably related to the large number of septal perforations both researchers observed in their experiments (9/12 and 8/10 respectively). Only one microperforation was found in the 29 skulls that were examined in this study (series 6 and 7). A septal perforation is presumably the result of damage to, and infection and necrosis of, the mucoperichondrium. The healing process which involves the formation of scar tissue will lead to an extra disturbance in growth.

With respect to point C.2: A striking feature after subtotal resection of one lateral cartilage (series 3) is the smaller dimensions of the maxillary turbinate on the affected side. This phenomenon could be the result of the smaller nasal cavity due to the flattening and sagging of the nasal bone as well as the convex bending of the nasal septum to the operated (left) side.
Retroposition of nasion (defined as point NA or the intersection of the frontonasal sutures and the internasal suture) and the rounded form of the orbit are observed after partial resection of the septal cartilage (series 6 and 7). These features must be considered as part of the generalized disturbance in growth of the structures bordering the surgical site. Further investigation on this subject is needed to clarify the causal factors.

15.6 Conclusions and clinical implications.

The nasal cartilage in the young (4 week old) rabbit forms a complex structure and may be considered as an extension of the, at that age, still cartilaginous skull base. It is composed of two longitudinal vaults which are fused in the midline forming the cartilaginous septum. The cranial parts of the cartilaginous vaults underlying the nasal bones disappear during postnatal growth, resulting in a bilateral triangular expansion of the dorsal side of the nasal septum in the adult stage.

In this study it was demonstrated that resection of parts of the cartilaginous framework (septum as well as lateral cartilage) in young animals (chapters 10-14) induce an abnormal development of the nasal bones and/or maxilla and other parts of the facial skull, leading to specific malformations in the adult animals.

In growing rabbits the lateral cartilages appear to be necessary for:
1. the development of the normal height and convexity of the nasal bones, the transverse expansion of the dorsal nasal meatus and the normal development of the nasal turbinates,
2. the straight forward outgrowth of the nasal bones,
3. the definite length of the lateral side of the nasal bones.

The cartilaginous septum has been demonstrated to be essential for:
1. the normal increase in length of the nasal bones,
2. the normal height and convexity of the nasal bones,
3. the normal development of the maxilla and to a lesser extent of other parts of the facial skull.

These observations suggest that the postnatal development of the bony nasal skeleton is controlled by the cartilaginous nasal framework.

In the literature it has already been postulated that growth of cartilage is almost exclusively dominated by intrinsic (genetic) factors (Van Limborg '70), whereas the development of the desmal parts of the skull is to a large extent determined by extrinsic (epigenetic) factors such as the expanding brain or eye balls. The hypothesis can be put forward that the growing nasal cartilage, defined by genetic factors, itself acts as an epigenetic factor on the desmal facial bones.

The way cartilage dominates bone is not yet known and needs further investigation. It is possible that the T-bar shape gives the growing nasal cartilage such strength that it is capable of exerting a pressure on the overlying or neighbouring bony parts of the skull.
It is interesting to note that lesions of the nasal cartilage also affects the development of parts of the skull at some distance such as the orbit and the maxilla. How these anomalies are formed deserves further analysis.
The lateral cartilages change during growth from a long double-vaulted structure underlying the entire nasal bones to a much smaller bilateral triangular structure only supporting the anterior part of the nasal bones. So, it can be concluded that at a certain moment during postnatal growth, the bony nasal skeleton becomes independent from the support of the underlying cartilaginous structure.

Growth regulation, as described above does not explain the change in dimension of the maxillary turbinate. The smaller size of this structure after subtotal resection of the lateral cartilage must be related to the reduced space in the nasal cavity and consequently reduced nasal passage. In this respect form and function are closely related (Moss '68, '76). It seems less probable that a disturbance in vascularization is the cause of diminished growth.

In this study, for the first time, the anatomy of the cartilaginous nasal dorsum in the neonates is described accurately. Subsequently, the similarity is demonstrated between the morphology of the child's nose and that in the young rabbit: T-bar shaped bilateral vaults fused in the midline to the septum, extending from the tip of the nose under the entire nasal bone and merging into the cartilaginous skull base. The macroscopical regression of the cranial parts of the lateral cartilage during further growth up to adulthood appears to be a second common feature in both species.
So, one has to face the question whether similar deformities will occur in children when parts of the cartilaginous framework are damaged by trauma or surgery.

A careful study of the nasal (facial) development in case of trauma or congenital anomaly will hopefully provide definite evidence. Furthermore, the nasal anatomy observed in the newborn, being apparently different from the adult state, demands additional anatomical investigation in later stages of development.
The results of this study may have specific implications for clinical work.

1. The lateral cartilages in the neonate differ from the adult; they extend from the tip of the nose into the cartilaginous skull base.

2. In the evaluation of acquired and congenital nasal deformities the cartilaginous structure has to be considered more important than the bony elements. Further knowledge has to be amassed concerning growth and wound healing processes in cartilage.

3. In young children mobilization of (parts of) the nasal bones with or without sutural involvement may be expected to cause no serious malformations of the developing skull provided the underlying cartilage remains undisturbed.

4. Surgery on the nasal bones will give rise to negative effects when the growth potential is diminished by irreversible loss of sutural tissue.

5. The frequently observed straight nasal dorsum combined with a basal septal deviation fits well with the function of the cartilaginous nasal dorsum in controlling the growth direction of the nose.

6. The experimental results suggest that traumatic or surgical damage to the upper lateral cartilage will lead to an asymmetrical growth of the nose.

7. In young children the cartilaginous septum still extends to a variable degree under the nasal bones. Therefore, medial osteotomies will separate the cartilaginous septum from the lateral cartilage. As a result the free dorsal edge of the septal cartilage, growing "unhindered" by the lateral cartilages, could induce a prominence on the nasal dorsum.

CHAPTER 16

SUMMARY

In numerous discussions and in anatomical literature on rhinosurgery in children hardly any data were found on the specific anatomy of the child's nose. In particular the upper lateral cartilages (the cartilaginous nasal dorsum) has been completely ignored (chapters 1 and 2).
In view of the development of nasal surgery in children, this is to be considered as a serious lacuna. Therefore this study focusses on the following questions:

1. What is the anatomy of the cartilaginous nasal skeleton and the cartilaginous nasal dorsum in children?

2. What is the role of the cartilaginous nasal dorsum (upper lateral cartilages) in the postnatal growth of the nose?

To answer these questions an anatomical study was performed of the child's nose and experimental investigations were carried out in growing animals.

A description of the anatomy of the nose as observed in two stillborns is given in chapter 3. The most important findings are that:
1. the lateral cartilage on either side of the septum widens laterally in a vault shape under the nasal dorsum,
2. the lateral cartilage extends from the tip of the nose to the still cartilaginous base of the skull.

From these observations it is apparent that at birth the cartilaginous nasal skeleton is still almost identical to that in the early foetal period and distinctly different from that in adults.

Chapter 5 deals with the normal growth of the cartilaginous nasal skeleton in rabbits, between the age of 4 weeks and the adult stage of 24 weeks after birth. The lateral cartilage in young rabbits was demonstrated to extend under the nasal dorsum from the tip of the nose to the cartilaginous base of the skull, just as in human neonates. In the adult animal, however, only a small piece of cartilage remains, showing a close similarity to the triangular cartilage in human adults.

To investigate the role of the lateral cartilages in the growth of the nose, the following experimental operations were carried out in series of young rabbits, 4 weeks of age:

1. subtotal resection of the lateral cartilage on one side (chapter 10),
2. bilateral subtotal resection of the lateral cartilage (chapter 11),
3. partial resection of the middle third of the lateral cartilage on one side (chapter 12),
4. submucous resection of the middle third of the septal cartilage (chapter 13),
5. partial submucous resection of the septal and lateral cartilages on one side (chapter 14).

The effects of surgery on the growth of the nose and facial skull were studied 20 weeks later, at the adult stage.

The lateral cartilages appear to be necessary for:
1. the development of normal height and convexity of the nasal bones, the transverse expansion of the dorsal nasal meatus and normal development of the nasal turbinates,
2. the straight forward outgrowth of the nasal bones,
3. the definite length of the lateral side of the nasal bones.

The cartilaginous septum has been demonstrated to be necessary for:
1. the normal increase in length of the nasal bones,
2. the normal height and convexity of the nasal bones,
3. the normal development of the maxilla and to a lesser extent of other parts of the facial skull.

From these observations in young growing rabbits it can be concluded that the cartilaginous nasal framework (septum and lateral cartilages on both sides) has a significant influence on the postnatal development of the bony nasal skeleton and some other parts of the facial skull (chapter 15). Dealing with rhinosurgical problems in children it has to be considered that:
1. the exact anatomy of the cartilaginous nasal dorsum is not yet known as it changes from the specifically neonatal to the adult morphology and no data are available on the postnatal development,
2. the cartilaginous complex (septum and upper lateral cartilages) has a controlling influence on the growth of the nasal bones, as may be concluded from observations in experimental animals.

CHAPTER 17

SAMENVATTING

In discussies over neuschirurgie bij kinderen zowel als in anatomische handboeken wordt weinig aandacht geschonken aan de specifieke anatomie van de kinderneus. Een beschrijving van de laterale kraakbeentjes ontbreekt zelfs geheel (hoofdstuk 1 en 2). Gezien de ontwikkelingen van de neuschirurgie bij kinderen heeft deze constatering geleid tot de formulering van de volgende vragen:

1. Hoe is de kraakbenige neus bij pasgeborenen opgebouwd en hoe verandert deze van vorm tijdens de verdere groei?
2. Welke rol spelen de laterale kraakbeentjes in de morfogenese van de neus?

Ter beantwoording van bovenstaande vragen vond een anatomische studie plaats van de kinderneus en is een experimenteel onderzoek verricht bij groeiende proefdieren.

In hoofdstuk 3 wordt de anatomie beschreven zoals die bij twee pasgeborenen gevonden is. De belangrijkste waarnemingen zijn dat:
1. het laterale kraakbeen zich ter weerszijden van het septum koepelvormig onder de neusrug naar lateraal toe uitbreidt en
2. zich van de neuspunt uitstrekt tot in de nog kraakbenige schedelbasis.

Hieruit blijkt dat het kraakbenige neusskelet bij de geboorte nog vrijwel overeenkomt met dat uit de vroeg-foetale periode en hierdoor sterk afwijkt van de volwassen vorm.

In hoofdstuk 5 wordt de normale groei van het kraakbenige neusskelet bij konijnen tussen het jonge stadium van 4 weken en de volwassen leeftijd van 24 weken besproken. Opvallend is dat het laterale kraakbeen bij jonge konijnen zich eveneens onder de neusrug uitstrekt van de neuspunt tot in de kraakbenige schedelbasis, zoals bij de neonaat werd gevonden. Bij het konijn resteert op de volwassen leeftijd nog slechts een restant, dat grote overeenkomst vertoont met het triangulaire kraakbeen bij de volwassen mens.

Om de invloed te bestuderen van het laterale kraakbeen op de groei van de neus vonden bij series konijnen op de leeftijd van 4 weken de volgende ingrepen plaats:
1. subtotale resectie van het laterale kraakbeen aan één zijde (hoofdstuk 10),
2. bilaterale subtotale resectie van het laterale kraakbeen (hoofdstuk 11),
3. partiele resectie van het laterale kraakbeen aan één zijde overeenkomend met het middelste 1/3 deel (hoofdstuk 12),

4. submuceuze resectie van het septumkraakbeen overeenkomend met het middelste 1/3 deel (hoofdstuk 13),
5. submuceuze resectie van het middelste 1/3 deel van het septumkraakbeen, gecombineerd met het overeenkomstige deel van het laterale kraakbeen aan één zijde (hoofdstuk 14).

De effecten op de groei van neus en aangezichtsschedel werden 20 weken later in het volwassen stadium bestudeerd.

De laterale kraakbeentjes blijken van belang te zijn voor:

1. de ontwikkeling van een normale hoogte en convexiteit van de neusrug, de breedte van de meatus nasalis dorsalis en de normale ontwikkeling van het turbinatum nasale,
2. de rechte uitgroei van het os nasale,
3. de uiteindelijke lengte van het laterale deel van het os nasale.

Het kraakbenige neustussenschot blijkt van belang te zijn voor:

1. de normale ventraalwaartse uitgroei van het os nasale
2. de normale hoogte en convexiteit van de neusrug,
3. de normale ontwikkeling van de bovenkaak en in mindere mate van de overige delen van de aangezichtsschedel.

Op grond van deze observaties bij jonge, groeiende konijnen kan worden geconcludeerd dat het kraakbenige neusskelet (septum en laterale kraakbeen beiderzijds) een essentiële rol speelt in de postnatale ontwikkeling van het benige neusskelet en overige delen van de aangezichtsschedel (hoofdstuk 15).

Bij de behandeling van neusafwijkingen bij kinderen dient men zich te realiseren dat:

1. de exacte anatomie van het kraakbenige neusdak bij kinderen nog steeds onbekend is, terwijl de neonatale en volwassen morfologie zeer duidelijk verschillen,
2. het kraakbenige neusskelet een belangrijke invloed heeft op de groei van het benige neusskelet, gezien de uitkomsten van experimenteel onderzoek.

REFERENCES.

Barone R.(1973): Atlas d'anatomie du lapin. Masson & Cie, Editeurs, Paris.

van Beest H.(1977): Morfologie en groei-activiteit van faciale suturen. Een morfologische, röntgenologische en histologische studie naar de groei-activiteit van craniofaciale suturen in relatie tot het periosteum bij konijnen. Acad.Proefschrift, Nijmegen.

Björk A.(1955): Cranial Base Development. Am.J.Orthod. 41: 198-225.

Bosma J.F.(1986): Anatomy of the Infant Head. John Hopkins University Press.

Converse J.M.(1955): The cartilaginous structures of the nose. Ann. Otol. Rhinol. Laryngol. 64: 220-229.

Dehneke H.J. & Meyer R.(1967): Plastic surgery of head and neck: corrective and reconstructive rhinoplasty. Vol I. Springer Verlag, New York.

Diem K. & Lentner C. (1973): Wissenschaftliche. Tabellen. 7. Auflage CiBA-geigy AG, Basel.

Drumheller G.W.(1973): Topology of the lateral nasal cartilages: the anatomical relationship of the lateral nasal cartilage to the greater alar cartilage, lateral crus. Anat.Rec. 76: 321-327.

Freng A.(1981): Mid-facial sagittal growth following resection of the nasal septum-vomer. A Roentgencephalometric Study in the Domestic Cat. Acta Otolaryngol.92: 363-370.

Freng A. & Haye R.(1985): Experimental nasal septoplasty; influence on nasomaxillary development. A roentgencephalometric study in growing domestic cats. Acta Otolaryngol. 100:309-315.

Getty R.(1975): The anatomy of the domestic animals. W.B.Saunders Comp.

Goodman W.S. & Zorn M.L.T.(1982): The unilateral cleft lip nose. J.Otolaryngol. 11: 198-203.

Gray L.P.(1965): The deviated nasal septum -II- prevention and treatment. J.Laryngol. 79: 806-816.

Gray L.P.(1977): Prevention and treatment of septal deformity in infancy and childhood. Rhinology XV: 183-191.

Gray L.P., Dillon P.I., Brogan W.F. & Henry P.J.(1982): The development of septal and dental deformity from birth. Angle Orthod. 52, No.4: 265-278.

Hafferl A.(1969): Lehrbuch der topographischen Anatomie. Dritte Auflage.

Hafferl A.(1969): Lehrbuch der topographischen Anatomie. Dritte Auflage. Springer Verlag Berlin.

Hamilton W.J., Boyd J.D. & Mossman H.W.(1966): Human Embryology. Prenatal development of form and function. W.Heffer and Sons Ltd, Cambridge.

Hellquist R.(1972): Facial skeleton growth after periosteal resection. An osteometric, roentgenographic and histologic study in the rabbit and guinea pig. Scand.J.Plast.Reconstr.Surg. Suppl.10.

Hinderer K.H.(1970): Fundamentals of anatomy and surgery of the nose. Aesculapius Publishing Company, Birmingham.

Hollinshead W.H.(1967): Textbook of Anatomy. Second ed. Hoeber Medical Book, Harper and Row Publishers.

Jost G., Meresse B. & Torossian F.(1973): Etude de la jonction entre les cartilages latéraux du nez. Ann.Chir.Plast. XVIII,No 2:175-182.

van der Klaauw C.J.(1946): Cerebral skull and facial skull. Arch.Neerl.Zool. 7: 16-36.

Kremenak C.R. & Searls J.C.(1971): Experimental manipulation of midfacial growth: a synthesis of five years of research at the Iowa Maxillofacial Growth Laboratory. J.Dent.Res. 50: 1488-1491.

Landsberger R.(1929): Die treibene Kräfte zur Dehnung und streckung des Gesichtsschädels. Zahnartzliche Rundsch. 23: 977-989.

Lessard M-L. & Daniel R.K.(1985): Surgical anatomy of septorhinoplasty. Arch.Otolaryngol. 111: 25-29.

van Limborgh J.(1970): A New View on the Control of the Morphogenesis of the Skull. Acta Morphol.Neerl.-Scand.8: 143-160.

van der Linden F.P.G.M.(1981): Gelaatsgroei en gelaatsorthopedie. Instituut voor Orthodontie, Kath.Universiteit Nijmegen.

Malek R.(1974): Nasal deformities and their treatment in secondary repair of cleft lip patients. Scand.J.Plast.Reconstr.Surg. 8: 136-141.

Mastenbroek G.J.(1978): De invloed van partiële resectie van het neustussenschot op de uitgroei van bovenkaak en neus. Acad.Proefschrift, Amsterdam.

Meeuwis C.A., Verwoerd-Verhoef H.L., van der Heul R.O. & Verwoerd C.D.A.(1985): Morphological changes of the cartilaginous nasal septum after partial resection in young rabbits. Clin.Otol.10:231-232.

Miller M.E.(1968): Anatomy of the dog. W.B.Saunders Comp.

Morrison D.F.(1976): Multivariate statistical methods. Second edition. McGraw-Hill, New-York.

Moss M.L., Bromberg B.E. & Eisenman G.(1968): The passive role of nasal septal cartilage in mid-facial growth. Plast.Reconstr.Surg. 536-542

Moss M.L.(1976): The role of nasal septal cartilage in midficial growth. In: Factors affecting the growth of the midface. Monograph No.6. Craniofacial Growth Series. edt. J.A.McNamara, Michigan.

Natvig P., Sether L.A., Gingrass R.P. & Gardner W.D.(1971): Anatomical details of the osseous-cartilaginous framework of the nose. Plast.Reconstr.Surg. 48: 528-532.

Nickel R., Schummer A. & Seiferle E.(1967): Lehrbuch der Anatomie der Haustiere. Band II, zweite Auflage. Paul Parey, Berlin-Hamburg.

Nolst-Trenité G.J.(1984): Implantaten in een groeiend neustussenschot. Acad.Proefschrift, Rotterdam.

Nijdam D.C.(1985): Schedelgroei na partiële submuceuze resectie van het neustussenschot. Acad.Proefschrift, Amsterdam.

Parkes M.L. & Kanodia R.(1981): Avulsion of the upper lateral cartilage: etiology, diagnosis, surgical anatomy and managment. The Laryngoscope 91: 758-764.

Patten B.M.(1968): Human Embryology. Third ed. The Graw-Hill Book Company.

le Pesteur J. & Firmin F.(1977): Reflexions sur l'auvent cartilagineux nasal. Ann.Chir.Plast. 22: 1-9.

Pirsig W.(1986): Open questions in nasal surgery in children. Rhinology, 24, 37-40.

Roskjaer M.(1977): Sutures and periosteum of growing intramembranous bone. An investigation of the nasal bone of the rabbit. Acad. Proefschrift, Nijmegen

Schaeffer J.P.(1910): The lateral nasal wall of the cavum nasi in man, with especial reference to various developmental stages. J.Morfology 21: 614-707.

Schaeffer J.P.(1916): The genesis, development and adult anatomy of the nasofrontal region. Am.J.Anat. 20:125-146.

Schaeffer J.P.(1920): The nose, paranasal sinuses, nasolacrimal passageways and olfactory organ in man. P.Blakiston's Sons and Co.

Scott J.H.(1953): The cartilage of the nasal septum. British Dental Journal, Vol.95: 37-43.

Scott J.H.(1959): The growth of the nasal cavities. Acta Otolaryngol. 50: 215-223.

Siegel M.I.(1974): The role of the cartilagenous nasal septum in mid-facial growth in Papio cynocephalus. Am.J.Phys.Anthrop. 11: 503.

Siegel M.I. & Sadler D.(1981): Nasal septum resection and craniofacial growth in a chimpanzee animal model: implications for cleft palate surgery. Plast.Reconstr. Surg. 849-853.

Sobotta J. & Becher H.(1967): Atlas der Anatomie des Menschen. Urban & Schwarzenberg, München.

Spalteholz W. & Spanner R.(1961): Handatlas der Anatomie des Menschen. 16.Auflage. Scheltema & Holkema N.V., Amsterdam.

Stenström S.J. & Thilander B.L.(1970): Effects of nasal septal cartilage resections on young guinea pigs. Plast. Reconstr.Surg. 45: 160-170.

Straatsma B.R. & Straatsma C.R.(1951): The anatomical relationship of the lateral nasal cartilage to the nasal bone and the cartilaginous nasal septum. Plast.Reconstr. Surg. 8: 443-455.

Tonneyck-Müller I, van der Werf F.(1982): Die Entwicklung des Septum nasi beim Kaninchen. Seine Beziehungen zu den benachbarten Teilen des Schdels. Acta Morphol.Néerl.Scand. 20:93-109.

Urbanus N.A.M.(1974): Schedelgroei na sluiting van lip-, kaak- en gehemelte-spleten. Acad.Proefschrift, Amsterdam.

Urbanus N.A.M., Verwoerd C.D.A., Tonneyck-Mller I. & Verwoerd-Verhoef H.L.(1977): Een kwantitatief onderzoek naar de groei van de schedel van het konijn. N.T.v.G. 121, No.15: 656.

Verwoerd C.D.A., Urbanus N.A.M. & Verwoerd-Verhoef H.L.(1979a): Growth mechanisms in skulls with facial clefts. Descriptive and Experimental studies on the Facial Skeleton. Acta Otolaryngol. 87: 335-339

Verwoerd C.D.A., Urbanus N.A.M. & Nijdam D.C.(1979b): The effects of septal surgery on the growth of nose and maxilla. Rhinology, XVII: 53-63.

Verwoerd C.D.A., Urbanus N.A.M. & Mastenbroek G.J.(1980): The influence of partial resections of the nasal septal cartilage on the growth of the upper jaw and the nose: an experimental study in rabbits. Clin.Otolaryngol.5: 291-302.

Verwoerd-Verhoef H.L.(1974): Schedelgroei onder invloed van aangezichtsspleten. Acad.Proefschrift, Amsterdam.

Wada T., Kremenak Ch.R., Myazaki T.(1980): Midfacial growth effects of surgical trauma to the area of the vomer in beagles. J.Osaka.Univ.Dent.Sch. 20: 241-276.

Walker W.F.(1967): A study of the cat. W.B.Saunders Comp.

Wen I.C.(1940): Ontogeny and phylogeny of the nasal cartilages in primates. Carnegie Institution. Contributions to Embryology No.130. John Hopkins University.

Williams P.L. & Warwick R.(1980): Gray's Anatomy. 36th ed. Churchill-Livingstone. New York.

Zelnik J. & Gingrass R.P.(1979): Anatomy of the Alar Cartilage. Plast. Reconstr. Surg. Vol.64, No.5: 650-653.

CURRICULUM VITAE

The author of this thesis was born in Makassar (former the Dutch East Indies) in 1949. After completing secondary school (HBS-B) he graduated in 1975 at the Medical Faculty of Leiden State University. He served as medical officer RNR in the internal medicin ward (head: Th.J.J.van Baar) of the Royal Naval Hospital at Overveen.
From 1977 until 1981 he was resident at the ENT department (head: Prof.E.H.Huizing, later Prof.C.D.A.Verwoerd), Dijkzigt Hospital, Erasmus University Rotterdam. Since 1981 he has been a staff member of the ENT department, from 1983 as head of the in-patient section and from 1986 as head of the out-patient section.

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