Rhinology, 34, 78-82, 1996

Growth characteristics of the human nasal septum*

J. Van Loosen[1,2], G.A. Van Zanten[1], C.V. Howard[2], H.L. Verwoerd-Verhoef[1], D. Van Velzen[2,3], C.D.A. Verwoerd[1]

[1] Department of Otorhinolaryngology, University Hospital Dijkzigt, Rotterdam, The Netherlands
[2] Department of Fetal and Infant Pathology, University of Liverpool, United Kingdom
[3] Department of Pediatric Pathology, Dalhouse University, Halifax, Nova Scotia, Canada

SUMMARY

Using a specially designed algorithm for the measurement of the surface area of shapes with highly irregular contours, growth curves were developed for post-natal septal growth in humans using post-mortem specimens of a study population of 30 cases, distributed over the age range from birth to 62 years. From the results a rapid growth phase for the total septum is evident immediately after birth, lasting until the second year of life. Then, a gradual deceleration of growth is recognized with a plateau eventually being reached at the age of 36 years. Mathematical analysis of the growth curve shows that the curve for the total septum is the sum of two separate mathematical equations, representing the cartilaginous and bony contribution, respectively. It is demonstrated that the cartilaginous septum reaches adult dimensions (lateral surface area) at the age of two years. Subsequent growth of the septum is due to expansion of the perpendicular plate, i.e. the bony parts of the septum.

Key words: nasal septum cartilage, ossification, perpendicular plate, septum growth

INTRODUCTION

Effective nasal surgery is highly dependent on a comprehensive knowledge of the anatomy, physiology, and biodynamics of the mid-facial skeleton. The influence of the nasal septum and other parts of the nasal part of the naso-maxillary complex on the growth of the mid-facial skeleton has been debated for more than a century. Recently, however, long-term follow-up studies in the rabbit has clearly demonstrated an important role of the septodorsal cartilage with respect to the normal development of the nasal bones, (pre-)maxilla and orbit, which is responsible for the postnatal changes of the facial profile (Verwoerd et al., 1995; Verwoerd-Verhoef et al., 1995). Although much has been published since the introduction of radiographic cephalometry by Broadbent (1931) and Hofrath (1931) on the post-natal development of the human cranium, very little is known of the growth and development of the human nasal septum.

Schultz-Coulon and Eckermeier (1976) studied the post-natal changes in the human nasal septum from the neonatal period to ten years of age. In this study they multiplied height with length to obtain the lateral surface area of the nasal septum. They demonstrated a rapid decrease of nasal septal growth after birth and an extensive ossification process during the first 10 years of life.

No growth features of the human nasal septum, however, have been described after the age of 10 years. In view of the fact that many surgeons elect to postpone corrective nasal surgery until after the pubertal growth spurt, data on post-pubertal growth are very important. However, growth characteristics of the bony and cartilaginous part of the septum, respectively, are not available in the literature. Therefore, the purpose of this study is to analyze the growth characteristics of the separate parts of the human nasal septum from birth until the post-adolescent period.

In the adult, the nasal septum is composed of three parts: (1) the cartilaginous septum; (2) the perpendicular plate; and (3) the vomer. The perpendicular plate is the product of endochondral ossification of the cartilaginous septum during childhood. The vomer is formed by intramembranous ossification. In the neonate nearly all of the nasal septum is cartilaginous. The septal cartilage extends from the columella anteriorly to the sphenoid posteriorly, where it merges cranially with the cartilaginous "anlage" of the anterior cranial base.

The vomer is represented in the neonate by a thin bony lamella between the basal rim of the cartilaginous septum and palate. This inferior part of the vomer shows extensions on both sides of the cartilaginous septum. These "vomer blades" merge with the ossifying perpendicular plate (Verwoerd et al., 1989).

This study deals with the cartilaginous septum and the perpendicular plate and does not include the inferior part of the vomer which constitutes a minor, morphogenetically not

* Received for publication August 25, 1995; accepted November 8, 1995

related part of the septum. The immediate reason is that during preparation of the specimens a variable part remains fixed to the palate, whereas the other parts of the septum were obtained in their entirety.

MATERIAL AND METHODS

Nasal septum specimens of 30 Caucasians, with normal facial development, varying in age from birth to 62 years, were obtained at routine postmortem (Table 1). The specimens were acquired by a combined approach through the anterior cranial fossa and both nostrils (Van Loosen et al., 1988). After fixation in 4% formaldehyde in 0.1 M phosphate buffer (pH 7.4) for more than 24 h, all specimens were decalcified before processing to paraffin by routine tissue processing. Specimens were sectioned semi-serially in a frontal plane. Sections (5 μm) were mounted and stained with haematoxylin and eosin. All specimens were recorded on Kodachrome slides together with two orthogonal calibration rulers defining the distances in the plane of the specimen (Figure 1A). Most of the specimens (Table 1, Nos. 1-27) were also recorded on X-ray film, after direct placement of the specimen on top of the film-cassette and irradiation from a distance of 50 cm by a Senograph 500T (22 keV, focus at 0.3 mm; Verwoerd et al., 1989; Figure 1B).

Table 1. Overview of patient group and causes of death (n=30).

No.	age (years)	sex	cause of death
1	0	m	solutio placentae
2	0.6	m	tuberculosis
3	1	m	forensic case
4	1	f	meningitis
5	1.5	m	dehydration
6	2	f	forensic case
7	2	m	meningitis
8	2.5	m	forensic case
9	2.5	f	road traffic accident
10	3	f	forensic case
11	3	m	meningitis
12	3	m	forensic case
13	4	f	road fraffic accident
14	4	m	forensic case
15	8	f	drowning
16	9	f	road traffic accident
17	10	m	forensic case
18	12	m	road traffic accident
19	15	f	road traffic accident
20	15	m	forensic case
21	15	f	septicemia
22	17	f	accidental death
23	17	m	septicemia
24	17	m	forensic case
25	18	m	road traffic accident
26	20	m	road traffic accident
27	30	f	forensic case
28	40	m	road traffic accident
29	58	m	road traffic accident
30	62	m	glioblastoma

The slides and X-ray images were projected on a digitizing tablet (Genius 1212B) connected to a personal computer. For each septum the circumferential outline was digitized from the

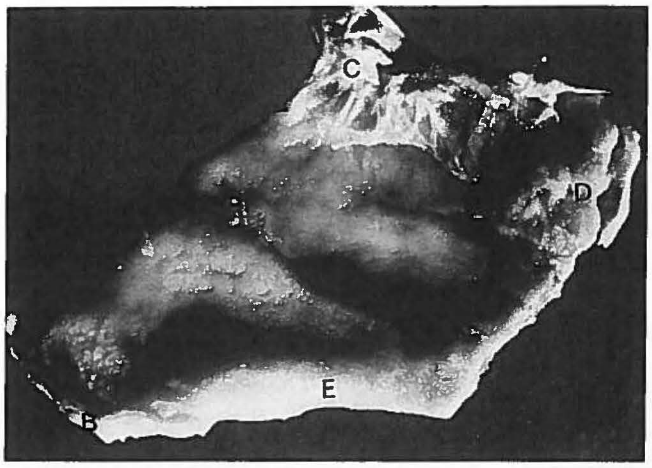

Figure 1A. Lateral aspect of fully prepared septum of a 30-year old male. A: nasal dorsum; B: anterior naris; C: crista Galli; D: sphenoid region; E: vomer bone region.

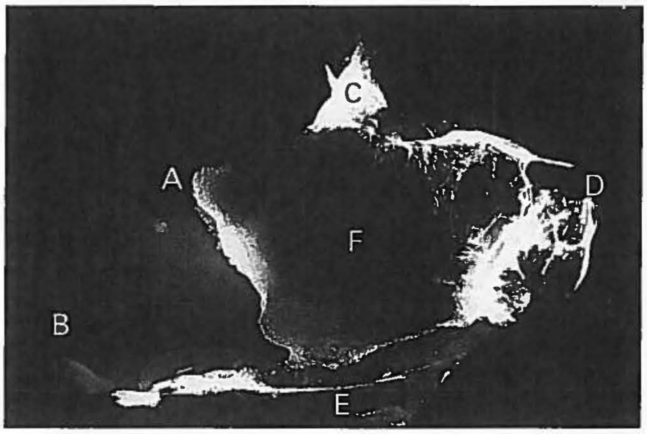

Figure 1B. Lateral X-ray of identical specimen. A: nasal dorsum; B: anterior naris; C: crista Galli; D: sphenoid region; E: vomer bone; F: perpendicular plate (Senograph 500t, film screen 22 keV, 0.3 m focus).

slide as well as from the X-ray image. Areas were calculated in numbers of pixels applying the trapezium rule for integration (with help of a custom-made programme). Using calibration rulers on the slide as a scaling factor, the number of pixels per cm^2 was calculated. The area of the preparation on the slide in number of pixels was divided by this scaling factor and by that converted to cm^2. Dividing this total preparation area (in cm^2) by its equivalent in pixels of the X-ray image projection, for each preparation an X-ray scaling factor was calculated. From the X-ray image the area fraction in numbers of pixels was measured of both the perpendicular plate (bony part) and the cartilaginous part, the latter including the cartilage between the vomer blades (Verwoerd et al., 1989) with exclusion of the sphenoid and premaxilla. The Relative Perpendicular Plate Area (RPPA) was - calculated by dividing the two areas. The total area of the septum was defined as the sum of these two areas and, after conversion to cm^2, called the Total Area (TA). The absolute Perpendicular Plate Area (PPA) was calculated by multiplication of RPPA with TA. From repeated measurements it was calculated that the measurement error in TA was below 0.02 cm^2. TA was plotted against age in a scattergram and subsequently a "growth function" was fitted through the data (Slidewrite V5).

RESULTS

The results of the measurements are summarized in Table 2. As is shown in Figures 2-3, the growth of the septal area (TA) diminishes continuously, more clearly so after the second year of life. Non-linear regression analyses of the data on a wide range of mathematical functions were tried. It appeared that total septum area data were described with the least amount of error by a summation of two similar simple growth functions, Y1 and Y2 in Figures 2-3.

Table 2. Surface parameters of nasal septum components related to age (TA: total septum area; RPPA: relative perpendicular plate area; PPA: perpendicular area).

No.	age (years)	TA (cm^2)**	RPPA (%)	PPA (cm^2)
1	0	0.68	0	0
2	0.6	5.99	2	0.12
3	1	8.15	12	0.98
4	1	8.46	11	0.93
5	1.5	9.73	16	.56
6	2	11.29	15	1.69
7	2	12.37	14	1.73
8	2.5	11.39	16	1.82
9	2.5	11.34	21	2.38
10	3	11.63	32	3.72
11	3	12.30	26	3.20
12	3	9.97	27	2.69
13	4	13.30	39	5.19
14	4	13.38	29	3.88
15	8	14.04	39	5.48
16	9	15.90	43	6.84
17	10	16.29	36	5.86
18	12	18.08	54	9.76
19	15	17.17	49	8.41
20	15	17.78	46	8.18
21	15	17.90	55	9.85
22	17	18.36	51	9.63
23	17	18.07	48	8.67
24	17	18.91	44	8.32
25	18	20.42	56	11.44
26	20	19.21	55	10.57
27	30	19.39	63	12.22
28*	40	20.95*		
29*	58	21.08*		
30*	62	20.86*		

*: due to fragmentation no further (X-ray) quantification
**: corrected for pre-maxilla, sphenoid and inferior part of the vomer

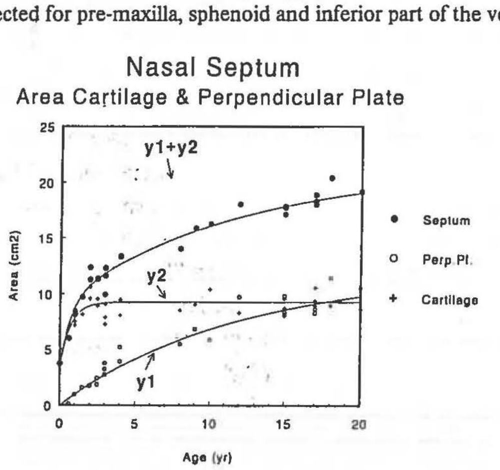

Figure 2. Area measurements of the total septum as a function of age (Y1+Y2) from 0-20 years. After mathematical analysis the curves for bone (Y1) and cartilage (Y2) are demonstrated.

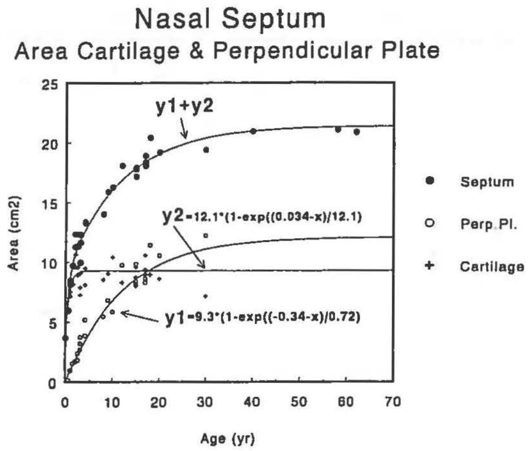

Figure 3. Area measurements of the total septum as a function of age (Y1+Y2) from 0-62 years. After mathematical analysis the curves for bone (Y1) and cartilage (Y2) are demonstrated.

The standard error of the fit is 0.8 cm^2. Given the much smaller error in the area measurements mentioned above, we conclude that the remaining spread of the data around the curve Y1+Y2 is due to interindividual anatomical variation and that the present data do not allow for assessment of more complex growth functions. The functions Y1 and Y2 happen to define the area growth of each of the separate parts of the septum. Y1 describes the growth of the cartilaginous part including the cartilaginous part between the vomer blades and concomitantly Y2 that of the perpendicular plate. From the parameters of the Y1 function it could be concluded that the growth of the cartilaginous part starts at about -0.34 year, i.e. at about 4 months of gestation. Furthermore, the time-constant of cartilage growth is 0.72 year, which means that by 2.2 year the area has reached 95% of its final value. Similarly, from Y2 it can be concluded that growth of the bony part starts at about term (0.034 year) and has reached 95% of the final area at 36 years of age. An impression of the growth rate of the various areas is obtained by taking the derivative of function Y1 and Y2 (Figures 4-5). Although similar in the pattern of age associated deceleration of growth, the overall capacity for growth of the cartilage is far greater than that for the ossified part of the septum.

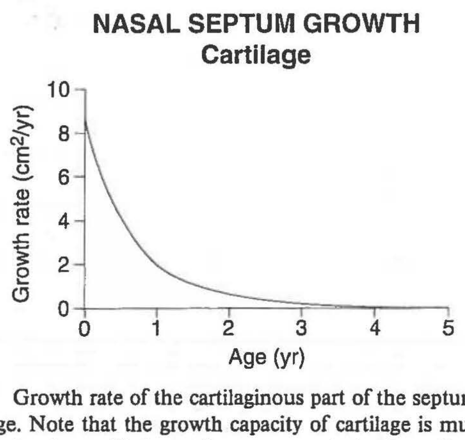

Figure 4. Growth rate of the cartilaginous part of the septum as function of age. Note that the growth capacity of cartilage is much higher than that for the ossified part (compare vertical axis scaling between Figures 4-5).

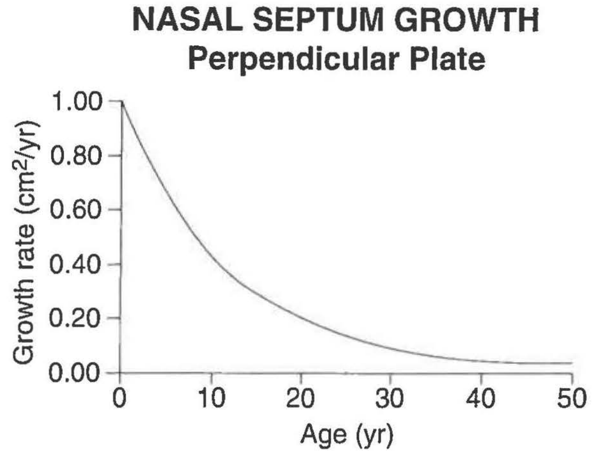

Figure 5. Growth rate of the ossified part of the septum as function of age. Note that the growth capacity of cartilage is much higher than that for bone (compare vertical axis scaling between Figures 4 and 5).

DISCUSSION

This study has been designed to evaluate postnatal growth of the human septum. The pattern of linear growth before birth (Bosma, 1986) is possibly continued into the first year of life (Figure 2). After this, in contrast to before birth, there is continuous deceleration of growth. Our data on the septal area, as demonstrated in Table 2 and Figure 2, show (although the pattern of change is comparable) lower values for the period from birth to the age of 10 years than the findings of Schultz-Coulon and Eckermeier (1976). This could be explained by the fact that they multiplied height with length of the septum to assess the pattern of change of the total area and, thus, a systemic bias may have been introduced. Area measurements as performed in this study more accurately reflect the surface area of the irregularly-shaped nasal septum. A second factor may be that we have excluded the variable inferior part of the vomer.

It was noticed that growth of the septum continues, even after puberty, albeit slowly. This confirms earlier cephalometric studies by Thompson and Kendrick (1964) and Sarnas and Solow (1980), who showed that even after the age of 20 years, a significant overall growth of the midfacial structures occurred. Our data suggest that, at least for the septum after the age of 36 years, this process comes to a virtual halt and near-final values are reached.

Until the present, it has not been noted in the literature that the sum total area of the cartilaginous part of the septum remains constant after the age of two years. It seems that in compensation to the newly formed cartilage an equal amount is transformed into bone, and thus the total area remains constant in this way. However, at the same time the septal cartilage shows changes in form and gradually assumes a more ventral position. In the adult situation the cartilaginous part of the nasal septum has become more anteriorly localized. This is reflected in a more prominent nose when compared to the newborn. However, the question of whether the reducing nasolabial angle solely results from septal growth as proposed by Wissner (1970) remains. Atrophy of the alveolar ridge in particular may well contribute to this appearance (Pirsig and Haase, 1986). Using our measurements and calculations, neither adolescence-associated growth-spurt/acceleration (Hinderer, 1970) nor growth spurts at the ages of three, six or seven years and adolescence (Reichert, 1963) could be demonstrated for the human nasal septum. Being a transversal study, differences as small as those noted in optimalized longitudinal cephalometric investigations (Pirsig and Haase, 1986) cannot be detected, especially since such small accelerations are known to vary greatly in age of onset (Rosenberger, 1934; Bergersen, 1972). The study of such individual accelerations additionally should take into account sex as systematic differences in age-dependency exist (Riolo et al., 1974; Prahl-Andersen et al., 1979; Engel et al., 1994).

Thus, as this investigation was of the transversal type, it does not completely exclude the existence of growth spurts. However, the narrow spread of the data around the regression line makes it improbable that significant deviations from the average growth pattern exist. Interindividual variation in time of onset and in size may well have been obscured in the present data set. Therefore, a longitudinal study, with regularly-spaced metallic implants in the nasal septum of an experimental animal as used by Björk (1955) for human skull growth, may be required to finally clarify any remaining ambiguity.

In summary, the results of this study demonstrate that:

(1) the growth rate of the nasal septum is highest in the newborn and slows down continuously, more clearly after the second year of life, but continues even after puberty to come to a halt after the age of 36 years;

(2) the cartilaginous part of the nasal septum increases rapidly in sagittal dimensions during the first years of life. After the age of two years the total area of the cartilaginous septum remains constant;

(3) endochondral ossification of the cartilaginous septum, resulting in the formation of the perpendicular plate, starts after the first half-year of life. The expansion of the perpendicular plate in the sagittal plane continues until after puberty;

(4) the development of the cartilaginous nasal septum after the age of two yearsis characterized by: (a) a balance between new formation of cartilage and loss of cartilage by the process of endochondral ossification, and (b) a constant remodelling and gradual shift to a relatively more anterior position;

(5) Surgery or trauma involving the nasal septum in children and adolescents can interfere with different morphogenetic processes (growth, remodelling, ossification) depending on the site of the lesions.

ACKNOWLEDGEMENTS

The authors are indebted to Prof.Dr. U.L. Wagholikar and Dr. D.N. Lanjewar, Department of Pathology, Grant Medical College, Bombay, India for their help in obtaining the specimens, to Mr. A.J.J. Maas, Department of ENT, University of Rotterdam for the design of the computer programme for area measurement, and to Professor Dr. W. Pirsig for his critical remarks in reading the manuscript.

REFERENCES

1. Bergersen EO (1972) The male adolescent facial growth spurt: Its prediction and relation to skeletal maturation. Angle Orthod 42: 319-338.
2. Björk A (1955) Facial growth in man, studied with the aid of metallic implants. Acta Odontol Scand 13: 9-34.
3. Bosma JF (1986) Anatomy of the Infant Head. John Hopkins University Press, Boston, USA.
4. Broadbent BH (1931) A new X-ray technique and its application to orthodontia. Angle Orthod 1: 45-66.
5. Engel T, Van Loosen J, Van Zanten GA, Howard CV, Van Velzen D (1994) Postnatal growth of the craniofacial skeleton: A transversal cephalometric study. Proc VIth Asean ORL Congress, Chiang Rai, Thailand.
6. Hinderer KH (1970) Fundamentals of Anatomy and Surgery of the Nose. Aescolapius Publishing, Birmingham, USA.
7. Hofrath TH (1931) Die Bedeutung der Röntgenfern- und Abstand-Aufname fur die Diagnostiek der Kiefer Anomalien. Fortschr Orthod 1: 232-258.
8. Pirsig W, Haase S (1986) Phasen des postnatalen Nasenwachstums: Ein kritische Übersicht. Laryng Rhinol Otol 65: 243-249.
9. Prahl-Andersen B, Kowalski CJ, Heydendael PHJM (1979) A Mixed Longitudinal Interdisciplinary Study of Growth and Development. Academic Press, New York.
10. Reichert H (1963) Plastic surgery of the nose in children. Plast Reconstr Surg 31: 51-56.
11. Riolo ML, Moyers RE, McNamara, JA, Stuart-Hunter W (1974) An Atlas of Craniofacial Growth. Center for Human Growth and Development, University of Michigan, Ann Arbor, USA.
12. Rosenberger HC (1934) Growth and development of the naso-respiratory area in childhood. Ann Otol Rhinol 43: 495-512.
13. Sarnas KV, Solow B (1980) Adult changes in skeletal and soft tissue profile. Eur J Orthod 2: 1-12.
14. Schultz-Coulon HJ, Eckermeier L (1976) Zum postnatalen Wachstum der Nasenscheidewand. Acta Otolaryngol (Stockh) 82: 131-142.
15. Thompson JL, Kendrick GS (1964) Changes in vertical dimensions of the human male skull during the third and fourth decade of life. Anat Rec 150: 209-214.
16. Van Loosen J, Verwoerd-Verhoef HL, Verwoerd CDA (1988) The nasal septum cartilage in the newborn. Rhinology 26: 161-165.
17. Verwoerd CDA, Van Loosen J, Schütte HE, Verwoerd-Verhoef HL, van Velzen D (1989) Surgical aspects of the anatomy of the vomer in children and adults. Rhinology Suppl 9: 87-93.
18. Verwoerd CDA, Mladina R, Nolst Trenité GJ, Pigott RW (1995) The nose in children with unilateral cleft lip and palate. Int J Ped Otorhinolaryngol Suppl 32: 45-53.
19. Verwoerd-Verhoef HL, Verwoerd CDA (1995) Sinonasal surgery and growth. An experimental study review. In: M. Tos, J. Thomsen, V. Balle (Eds.) Rhinology. State of the Art. Kugler Publications, Amsterdam, pp. 195-201.
20. Wissner G (1970) Alters Veranderungen von Gesichts- und Ohrmerkmalen. Anthrop Anz 32: 157-193.

Prof. C.D.A. Verwoerd
University Hospital Dijkzigt
Dr. Molewaterplein 40
NL-3015 GD Rotterdam
The Netherlands