Growth of maxillary structures after palatal surgery on dogs

Maarten GGM Wijdeveld

Growth of maxillary structures after palatal surgery on dogs

GROEI VAN MAXILLAIRE STRUCTUREN
NA PALATUM-OPERATIES BIJ HONDEN

PROMOTOR : PROF. DR. F.P.G.M. VAN DER LINDEN

CO-REFERENTEN: DR. A.M. KUIJPERS-JAGTMAN
DR. J.C. MALTHA

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Growth of maxillary structures after palatal surgery on dogs

een wetenschappelijke proeve op het gebied van geneeskunde en tandheelkunde

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A.J. Peters
P.H.G. Philipsen
H.C.M. Reckers
H.H. Veen
Dr. G.E.A.M. Wijdeveld

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CHAPTER 1

General introduction

General introduction

Clinical considerations

Clefts in lip, alveolus and/or palate are congenital malformations of the face which occur during the embryonic development with an incidence of 1.4 to 1.9 per thousand (Van den Akker et al., 1986). In a number of countries in the western part of the world teams of specialists, i.e. plastic and reconstructive surgeons, orthodontists, E.N.T.-specialists, speech pathologists, dentists, maxillofacial surgeons and social workers, treat these patients from birth until adulthood. These clinicians are justifiably proud of the modern habilitation process for such clefts that transforms an infant with severe functional and aesthetic handicaps into an adult who is close to normal. Indeed differences from non-cleft populations in facial morphology can in general not be fully eliminated as has been demonstrated in many studies (Ross, 1987a).

The abnormal facial morphology is caused by three factors: intrinsic developmental deficiencies, functional distortions and iatrogenic factors. Ross and Johnston (1972) and Ross (1987a) theorized about the contribution of these factors: the intrinsic deficiencies are invariably mild and are rarely of clinical significance; the growth potential seems to be normal. Functional distortions are usually reversible by surgical repair of the cleft. Iatrogenic factors are, therefore, implicated as the major source of the midfacial deficiencies reported in patients with clefts.

It is difficult to prove that treatment influences facial growth. This would require a controlled study in which groups of individuals with clefts who have not received treatment are compared with identical groups who have. There are, however, sufficient studies available, showing that individuals with untreated facial clefts show a relatively normal facial growth (DeJesus, 1959; Ortiz-Monasterio et al., 1966; Bishara et al., 1976, 1985). If the intrinsic and functional factors have not diminished facial growth, it is probably true that surgical treatment inhibits facial growth.

The initial surgical procedures consist of repair of the cleft lip, alveolus and/or palate. Ross (1987 a-f) concluded from a large clinical study firstly that lip repair with variable timing and technique has little impact on facial or dentoalveolar growth, secondly that alveolus repair, with or without bone grafting, inhibits vertical growth of the anterior maxilla and thirdly that palate repair with variable timing and technique appears to be the major influence on maxillary and dento-alveolar growth.

Surgical repair of the hard and soft palate has two aims: to provide a soft palate that will achieve velopharyngeal closure and to separate the oral and nasal cavities, attended with a minimal growth inhibition. Literature is confusing on the best way to accomplish these goals. The major areas of contention are the timing and the technique of surgery. Until quite recently the traditional timing of hard and soft palate surgery has been between 12 and 24 months of age. This appears to have been an empiric decision that evolved and was maintained as a good compromise between speech and growth requirements. The theory of early repair of the soft palate for speech requirements, combined with delayed repair of the hard palate for reduced growth inhibition, was introduced into clinical practice by Schweckendiek in the 1940's; he delayed hard palate repair until the adolescent years (Schweckendiek, 1978). Hotz and Gnoinsky (1976) have made the delaying of hard palate repair until the early mixed dentition a widely used practice. The theory of delayed hard palate repair is based on the assumption that the more growth that has occurred, the less there remains to interfere with. Witzel et al. (1984) opposed this theory and concluded that there has been no evidence to support that growth will be improved by delaying surgery for several years.

The traditional techniques of hard palate repair consist of mobilization and displacement of palatal and/or nasal soft tissue flaps (for a review see Millard, 1980). Between these techniques no significant differences were found with respect to velopharyngeal closure, speech or hearing (Witzel et al., 1979) and facial growth (Ross, 1987e). Compared with other procedures, the Von Langenbeck technique requires less manipulation of the mucoperiosteum in the anterior palate, which seems to permit a more favourable incisor adjustment (Ross, 1987e).

It can be concluded that with regard to the timing and the technique of cleft palate surgery, a universal philosophy has not evolved. This might be due to an important limitation of clinical studies caused by the large number of variables. Due to these variables, i.e. patient, surgeon, type and extension of the cleft, number, timing and technique of surgery, presurgical orthopedics and orthodontics, the demonstration of significant differences between treatment procedures is strongly impeded. In animal experiments the number of variables can be limited to some extent.

Animal experiments

The animals used in such studies vary between rodents such as rats, rabbits, guinea pigs and non-rodent mammals such as cats, dogs and monkeys. The choice of the animal for the experiments depends on the aim of the study, e.g. if dentition

variables are studied, an animal with a deciduous and a permanent dentition is preferred. The type and extension of the cleft should be adjusted to the aim of the study, but since the breeding of non-rodent mammals with identical clefts appeared to be impossible, many investigators created their clefts surgically. These studies can, however, give conflicting results because of the extensive trauma of creating such a cleft. Freng (1979, 1981) reported a reduction of about 50% of transverse maxillary growth after creating an isolated bony palatal cleft which was left open. Other investigators restricted their surgery to soft tissue manipulation, e.g. by creating mucoperiosteal excisional wounds on the hard palate. Kremenak et al. (1967, 1970), Kremenak and Searls (1971) and Kremenak (1984) concluded in a series of macroscopic studies on dogs, based on the classic work of Herfert (1958), that unilateral excision of a strip of mucoperiosteum adjacent to the posterior deciduous teeth resulted in inhibition of maxillary growth. They also concluded that the contraction in the healing excisional wound initiated this growth inhibition. Their experimental design has, however, important limitations. The surgery was performed at one side of the palate only, the other side serving as a control. Surgery might, however, have an effect on the unoperated side as well. Furthermore, their conclusions about maxillary growth were based on measurements between posterior teeth and the mid-palatal raphe and suture. The surgery might have different effects on either the teeth, the mucoperiosteum or the suture.
Only few animal experiments have been found in which the effect of variation of timing of surgery was investigated. Kremenak et al. (1985a, b) performed their above-described surgery on four groups of Beagle dogs at the age of 3, 5, 8 and 10 weeks respectively, which is prior to the eruption of the permanent teeth. Although the 10 weeks-surgery group was the least affected, these studies provide no information comparable to the human situation in which the hard palate closure is delayed until the beginning of the eruption of the permanent teeth (Hotz and Gnoinski, 1976) or even until the permanent dentition has been completed (Schweckendiek, 1978).

Aim of the study

The aim of the present study was to investigate the growth and development of craniofacial and especially maxillary structures in Beagle dogs after palatal soft tissue surgery at different stages of development of the dentition.

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CHAPTER 2

Wound healing of the palatal mucoperiosteum in Beagle dogs after surgery at different ages

Wijdeveld, Maarten G.M.M.
Grupping, Ellen M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.

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Abstract

The aim of this study was to investigate macroscopic wound healing after palatal surgery at three different ages A total of 37 Beagle dogs was used, divided into three experimental groups, a sham group and a control group.
Palatal surgery was performed at the age of 6, 16 or 25 weeks respectively The animals of the sham group and the control group were studied from the age of 6 weeks on. All animals were studied longitudinally over a period of six weeks. The three experimental groups were compared mutually and the youngest experimental group was compared with the sham group and the control group.
Clinically, the wound healing in the medial region was complete after two weeks in all animals In the denuded areas the wound healing continued for the youngest experimental group for 2 to 3 weeks after the operation and for the two older age groups for 4 to 5 weeks after the operation.
The wound contraction in the denuded areas, recorded as the increasing approximation of opposite tattoo points, was larger in the two older age groups than in the youngest one and was restricted mainly to the first week after the operation. This effect seemed to be permanent because no compensating increase in distance was found later on.
It was concluded that shortly after the operation wound contraction was mainly responsible for the reduction of the surface area of the denuded bone, but later on epithelial cell proliferation was the predominant factor.

Introduction

The effects of primary surgical treatment in children with cleft lip and/or palate are initially beneficial. However, later on the results of surgery seem to have an unfavourable effect and to be responsible for disturbances in maxillary growth. In relation to this growth disturbance, controversial points of view are expressed with respect to the technique and the timing of palatal closure (Witzel et al , 1984). Palatal surgery on growing children seems to interfere with the growth of the soft tissues and the bony structures. It has been assumed that the wound healing process of the palatal mucoperiosteum can be regarded as an important post-surgical variable, which is age-dependent. Therefore, the present study deals with wound healing after surgery at different ages.

The wound healing process was studied mainly in animal experiments. Several studies in this field were carried out by Kremenak et al. (1967, 1970), Kremenak and Searls (1971) and Kremenak (1984). They concluded from experiments on Beagle dogs that mucoperiosteal denudation of palatal bone adjacent to the posterior deciduous teeth was the major factor in post-surgical growth disturbance. They stated that contraction of the healing excisional wound was the primary event that initiated the growth inhibition.

Using the same experimental set-up, Olin et al. (1974) studied the migration of the wound margins after excision of a strip of the palatal mucoperiosteum adjacent to the posterior teeth by means of tattoo points placed near the opposite wound margins. These tattoo points approached each other for about 20 days. Thereafter, they moved apart slowly. Analogous points in non-wound (control) areas always moved apart until maturity was reached.

Kahnberg and Thilander (1982) made standardized circular mucoperiosteal excisional wounds in the medial region of the palate in 3-month-old rats. They found an almost 50% reduction of the excisional wound surface between 7 and 10 days after the operation, while clinical healing was completed after 21 days. However, in this study no conclusions could be drawn about the migration of the wound margins during healing, as no mucoperiosteal measuring points were placed.

All studies mentioned deal with the effect of certain surgical techniques on wound healing and on maxillary growth. Only a few experimental studies are reported in which the effect of different timing of surgery has been investigated. Kremenak et al. (1985a) analysed wound contraction and post-surgical growth after unilateral excision of a strip of palatal mucoperiosteum adjacent to the posterior teeth in Beagle dogs at the age of 3, 5, 8 and 10 weeks. They found significantly less transverse growth of the maxilla in the experimental groups than in the control group. The 10-week surgery group was the least affected; arch width and jaw width increased by 95% and 87% compared with the control group. No significant differences were found between the younger age groups. Also less wound contraction was found in the oldest experimental group (Kremenak et al., 1985b).

The experimental design of the above-mentioned studies, in which the so-called 'canine one-sided strip model' of Kremenak was used, has an important limitation. The surgery was performed on one side of the hard palate only and the effect on operated and unoperated sides was compared mutually and occasionally with a control group. However, this unilateral procedure not only had an effect on the growing tissues of the operated side of the maxilla but on the other side as well. Therefore, it was concluded that more reliable results could be obtained from a study in which the surgery is performed symmetrically on both sides of the palate. Furthermore, in the experiments of Kremenak et al. (1985a,b) surgery was performed at ages from 3 to 10 weeks, i.e. prior to the transition of the dentition. No data on older age groups are available. These studies provide no information which corresponds to the human situation in which hard palate closure is delayed until later stages and particularly not until after completion of the permanent dentition as proposed by Schweckendiek (1978) and others (For a review see Witzel et al., 1984).

It was felt that meaningful information could be provided by an experimental design in which the surgical technique is standardized and the variation in timing of surgery corresponds with different approaches used in human cleft palate surgery.

The aim of this longitudinal study was to investigate macroscopically the wound healing in Beagle dogs after palatal surgery at different stages of development, i.e. during the eruption of the deciduous dentition, during the transition of the teeth and after completion of the permanent dentition.

Material and methods

A total of 37 Beagle dogs was used, divided at random into five groups. In the experimental groups palatal surgery was performed at the age of 6 weeks (group 1: during the eruption of the deciduous dentition), at the age of 16 weeks (group 2: during the period of the transitional dentition) and at the age of 25 weeks (group 3: completed permanent dentition). The animals of the sham group and the control group were 6 weeks old at the start of the study (table 1).

Table 1: Groups and number of dogs within each group. Ages are given in weeks.

age	group	number
6	1	10
6	Sham	7
6	Control	6
16	2	7
25	3	7

Prior to the operation all animals were weighed and premedicated with 0.5 ml Thalamonal® (Fentanyl 0.05 mg/ml + Droperidol 2.5 mg/ml) and 0.5 ml Atropine (Atropine Sulphate 0.5 mg/ml). Surgery was performed under general anaesthesia which consisted of 30 mg/kg Narcovet® (Sodium Pentobarbital 60 mg/ml). Next the oral mucosa and the dentition were cleaned with Chlorhexidine Digluconate 1% in water. In addition 1.8 ml Xylocaine® (Lidocaine Hydrochloride 0.4 mg/ml + Adrenaline 0.0125 mg/ml) was injected into the palatal mucoperiosteum to avoid excessive bleeding during surgery.
In the experimental groups 1, 2 and 3 a soft tissue defect was created in the medial region of the palate by incising, elevating and removing an elliptical-shaped mucoperiosteal flap which had been drawn on the mucosa with Bonney's Blue ink. This flap extended from a line just behind the cuspids to the caudal margin of the hard palate (figure 1). In groups 1 and 2 the maximum width of the flap was one third of the transverse distance between the second deciduous molars; in group 3 this was one third of the transverse distance between the fourth premolars. On both sides relaxation incisions adjacent to the posterior teeth were made and the remaining palatal mucoperiosteum was elevated from the underlying bone with a small raspatory. The major palatine neurovascular bundle was not damaged during the operation. The soft tissue defect was closed in the medial region of the palate and sutured in one layer with 4-0 Vicryl®. The denuded bony surfaces adjacent to the posterior teeth were left open to heal by secondary epithelialization.

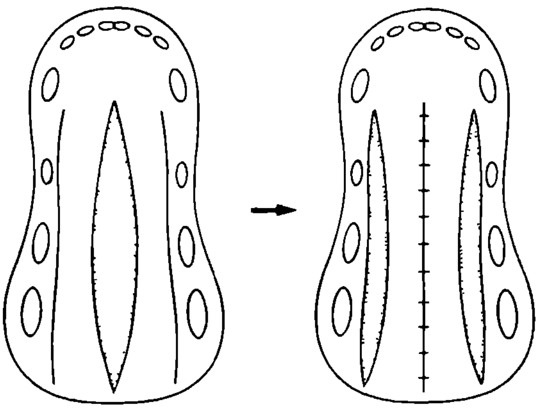

Figure 1: Schematic drawing of the palate and the operation in groups 1, 2 and 3. A mucoperiosteal flap was removed in the medial region of the palate and two relaxation incisions were made. The remaining palatal mucoperiosteum was elevated, repositioned and sutured in the midline

In the sham group a comparable procedure was followed, but no flap in the medial region of the palate was removed. In this group only an incision in the medial region and two lateral incisions were made after which the mucoperiosteum was elevated, replaced and sutured. In the control group no surgery was performed.

After surgery tattoo points were placed in the mucoperiosteum at a distance of about 1 mm from the wound margins at opposite sides of the denuded bone and one at each side of the incision in the medial region of the palate, using a Hedström® file and Hauptner® spezial Tätowierfarbe (figure 2). Tattoo points were also placed posteriorly on the palatal mucoperiosteum but during wound healing many points in that area faded away, so they could not be incorporated in the data analysis. In the sham group and the control group tattoo points were placed in corresponding areas of the palatal mucoperiosteum.

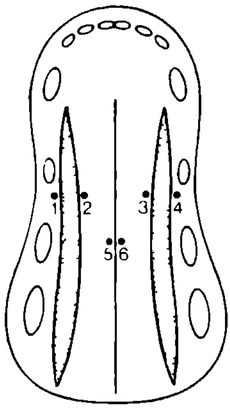

Figure 2: Schematic drawing of the palate after surgery with the tattoo points (numbers 1 to 6) placed near the wound margins.

Under general anaesthesia standardized photographs of the palate were taken every week until 6 weeks after the operation. A Nikon® F Body and a Medical Nikon® fixed focus lens (1:5.6, f=200 mm) with an integrated ringflash and Kodak® Ektachrome film (200 ASA) were used. The reproduction ratio was 2/3. A plane intraoral mirror was positioned behind the tuberosities of the maxilla at an angle of 45 degrees to the palate. Focussing was carried out by moving the camera until optimal sharpness was obtained. Four exposures were made at each occasion. The resulting slides of each occasion were projected on an electronic measuring table and the best of the four slides was selected. Subsequently, the centres of the tattoo points were digitized. The error of the photographic procedure was studied in three dogs of 6, 16 and 25 weeks old respectively. The procedure was performed five times immediately after the operation at 5 minute intervals. To determine the error of the measuring method, 24 slides were randomly selected, representing different groups and different stages of wound healing. These slides were digitized twice.

To quantify the wound healing, weekly increments of the following measurements were calculated (figure 2):

B (bony defects). the sum of the distances between the opposite points on the wound margins of the denuded bony strips (1-2) + (3-4);
T (transverse width): the overall width of the palatal mucosa (1-4);
M (medial region). the distance between the opposite points near the wound margins in the medial region of the palate (5-6).

The distances (1-2) and (3-4) were added to avoid an error due to possible shifting of the mobilized mucoperiosteum during the early wound healing.

The experimental group 1, the sham group and the control group were compared using the Kruskal-Wallis test (non-parametric one-way analysis of variance) to test the hypothesis that the three means are equal. The wound healing of the three experimental groups 1, 2 and 3 was compared mutually.

Results

Accuracy of the method

The total error of the method is made up of an error of the photographic procedure and a measurement error, due to inexact defining of the tattoo points as well as inaccuracy of the measuring instrument. No systematic deviations were found with respect to age or distance. The total error of the method was found to be about 0.1 mm. The same held true for the measurement error. Therefore, it was concluded that errors were mainly due to inexact defining of the tattoo points and inaccuracy of the measuring instrument.

The increment error was calculated as the square root of the total error. Since the standard error of the mean of all increments was about 0.50 mm, the accuracy of the measurement method was considered acceptable.

Wound healing: clinical findings

The three experimental groups showed a similar pattern of wound healing but on different time scales.

In all three groups the denuded bony strips were largely filled with coagulum

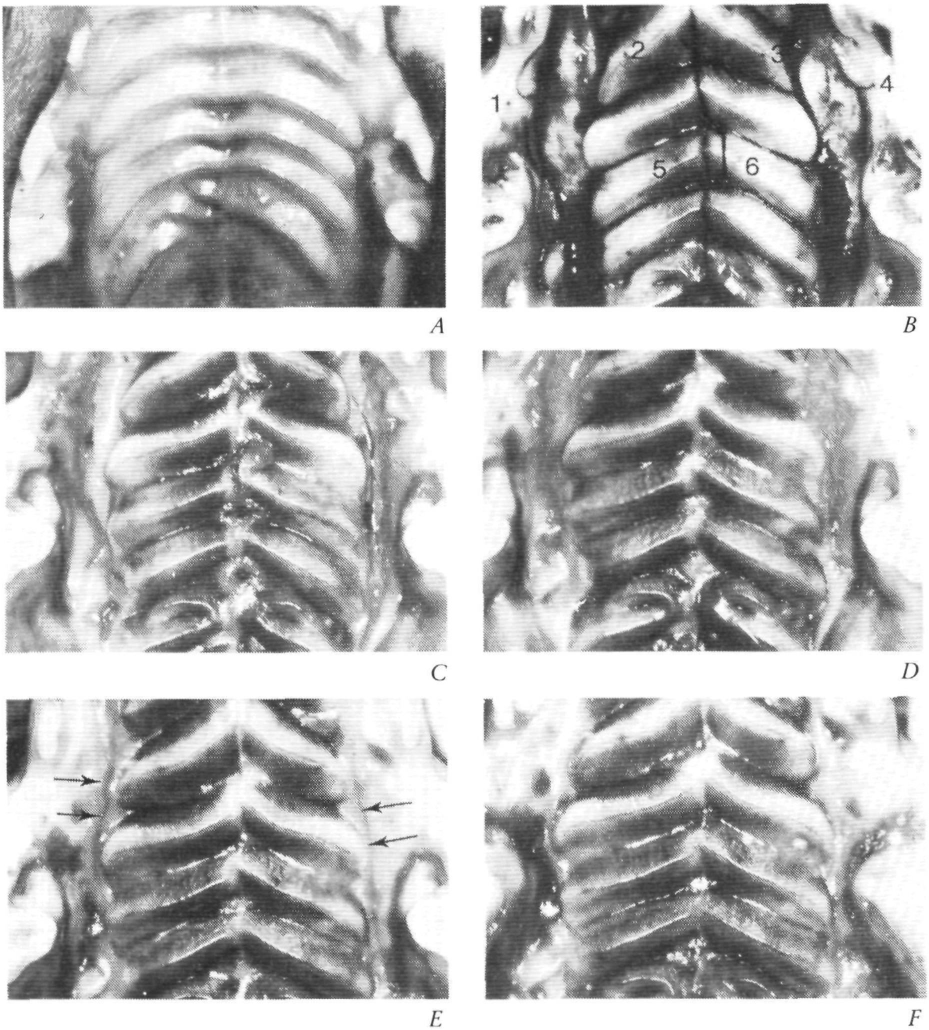

Figure 3: Wound healing after palatal surgery at the age of 6 weeks (group 1).

- A *Prior to the operation.*
- B *Immediately after the operation. The denuded bony areas were left open. The mucoperiosteum was sutured in the medial region of the palate. Tattoo points were placed (1-6).*
- C *1 week after the operation. The surface area of the denuded bone was reduced by about 75%. Remaining sutures in the medial region were removed now.*
- D *2 weeks after the operation. Fusion of the opposite wound margins of the denuded areas had occurred. In the medial region of the palate healing was complete and a narrow line of scar tissue was visible.*
- E *3 weeks after the operation. The fusion of the opposite wound margins of the denuded areas could be seen as a line (arrows), situated medially to the centre of the previously denuded area.*
- F *5 weeks after the operation. End of the experimental period. No palatal rugae pattern had developed in the healed area.*

(figure 3a, 3b). One week after the operation the wound margins were red-coloured, due to inflammatory reactions. In group 1 the surface area of the denuded bone was reduced by about 75% of its total area (figure 3c), while in groups 2 and 3 the reduction was only 40-50%. The surface area of the denuded bone decreased until fusion of the opposite wound margins occurred.
In group 1 the fusion was complete two weeks after the operation (figure 3d); in the groups 2 and 3 the secondary epithelialization took longer and fusion occurred during the fourth week after the operation. The bony areas were filled in by epithelial activity more from the lateral than from the medial side. Consequently, the fusion area, which showed up as a red-coloured line, was located medial to the centre of the denuded area (figure 3e).
Shortly after fusion the inflammation characteristics disappeared and a smooth strip of scar tissue remained. This point was defined as the end of the wound healing. In group 1 this stage was reached at 2 to 3 weeks after the operation and in groups 2 and 3 at 4 to 5 weeks after the operation. No palatal rugae pattern developed in the healed area. Normal pigmentation occurred except in the fusion line.
In all animals operated on, a more rapid healing was found in the medial region of the palate as compared with the excised areas on the lateral aspect of the palate. One week after the operation the remaining sutures in the medial region were removed and after two weeks no signs of inflammation could be found. A small line of scar tissue remained (figure 3f). In the sham group the relaxation incisions showed a wound healing similar to that of the incision in the medial region of the palate.

Wound healing: photographic measurements

To study the migration pattern of the palatal mucosa, weekly increments of measurements between tattoo points were calculated. The results are presented in tables 2, 3, and 4 and in figures 4, 5 and 6. Weekly increments of the distances B, T and M respectively were plotted against the age of the animals.
The distance B (table 2, figure 4) of the control group showed no significant weekly changes from 6 to 11 weeks of age. In the experimental group of the same age (group 1) the tattoo points on opposite wound margins of both denuded bony strips moved a total of 1.35 mm during the first week after the operation. The sham group showed the same effect for about half the amount. From the second week after the operation onwards the increments in experimental group 1 and the sham group were limited and did not differ from those in the control group. The two older experimental groups followed the pattern found in the youngest experimental group, although in the two older age groups initially the tattoo points moved considerably more towards each other (about 3 mm) than in the youngest group. This effect was not compensated for later on.

Table 2: Mean increments (mm/week) of distance B ((1-2) + (3-4)).

age	group 1	sham	control	significance
	mean SEM	mean SEM	mean SEM	
6- 7	−1.35 ± 0.10	−0.68 ± 0.14	−0.04 ± 0.09	
7- 8	0.00 ± 0.22	0.01 ± 0.30	0.24 ± 0.12	ns
8- 9	0.25 ± 0.08	0.45 ± 0.30	−0.01 ± 0.13	ns
9-10	0.25 ± 0.08	0.10 ± 0.06	0.14 ± 0.11	ns
10-11	0.27 ± 0.10	0.04 ± 0.14	0.12 ± 0.13	ns

age	group 2	age	group 3
	mean SEM		mean SEM
16-17	−3.23 ± 0.23	25-26	−3.07 ± 0.36
17-18	0.34 ± 0.12	26-27	0.08 ± 0.25
18-19	−0.21 ± 0.18	27-28	−0.15 ± 0.17
19-20	0.49 ± 0.20	28-29	0.18 ± 0.12
20-21	0.13 ± 0.04	29-30	0.20 ± 0.06

Increments in mm/week (mean and SEM) of distance B ((1-2) + (3-4)) Group 1, sham group and control group (6-11 weeks), group 2 (16-21 weeks) and group 3 (25-30 weeks). Ages are given in weeks. Age 6-7 means: the increment period from 6 to 7 weeks of age. The level of significance for inter-group differences of the 6 weeks old groups is given as follows:

ns	$P \geq 0.10$
( )	$0.05 \leq P < 0.10$
*	$0.01 \leq P < 0.05$
**	$P < 0.01$

The distance T (table 3, figure 5) of the control group increased by about 0.5 mm to 0.9 mm weekly. During the first three weeks after the operation in experimental group 1 smaller increments were found than in the control group. The experimental groups 2 and 3 followed the same pattern.

Table 3: Mean increments (mm/week) of distance T (1-4)

age	group 1	sham	control	significance
	mean SEM	mean SEM	mean SEM	
6-7	0.03 ± 0.14	0.49 ± 0.18	0.84 ± 0.15	(*)
7-8	0.22 ± 0.09	0.60 ± 0.29	0.86 ± 0.05	*
8-9	0.34 ± 0.11	0.84 ± 0.26	0.55 ± 0.11	*
9-10	0.61 ± 0.15	0.82 ± 0.08	0.80 ± 0.10	ns
10-11	0.64 ± 0.08	0.76 ± 0.12	0.68 ± 0.15	ns

age	group 2	age	group 3
	mean SEM		mean SEM
16-17	–0.36 ± 0.11	25-26	–0.57 ± 0.34
17-18	–0.10 ± 0.08	26-27	0.39 ± 0.24
18-19	–0.07 ± 0.13	27-28	–0.12 ± 0.17
19-20	0.48 ± 0.14	28-29	0.19 ± 0.08
20-21	0.18 ± 0.05	29-30	0.25 ± 0.06

Increments in mm/week (mean and SEM) of distance T (1-4) Group 1, sham group and control group (6-11 weeks), group 2 (16-21 weeks) and group 3 (25-30 weeks) Ages are given in weeks. Age 6-7 means: the increment period from 6 to 7 weeks of age The level of significance for inter-group differences of the 6 weeks old groups is given as follows.

ns	$P \geq 0.10$
(*)	$0.05 \leq P < 0.10$
	$0.01 \leq P < 0.05$
*	$P < 0.01$

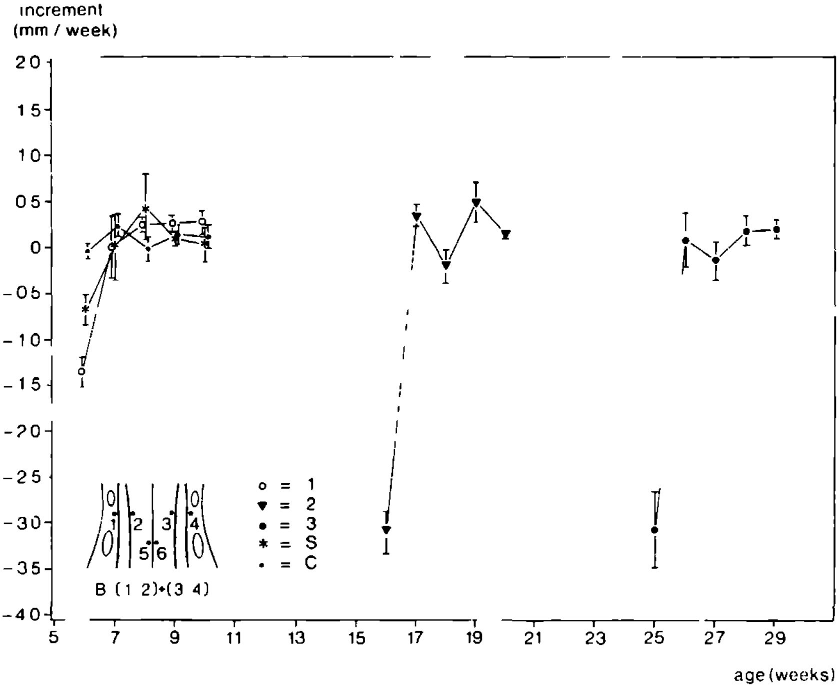

Figure 4 Distance B ((1-2) + (3-4)) Increments in mm/week plotted against the age of groups 1, 2, 3, sham group and control group Ages are given in weeks.

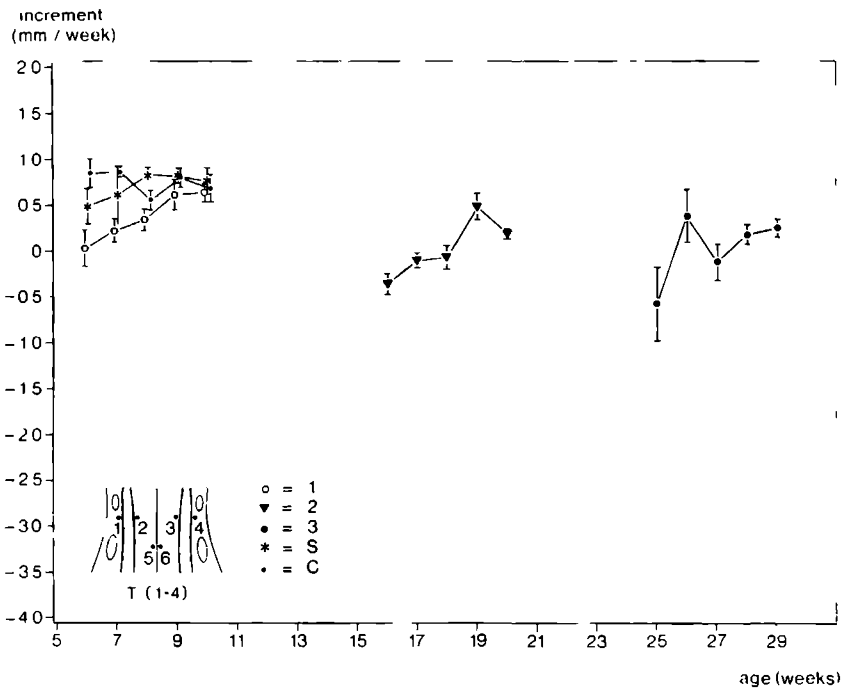

Figure 5 Distance T (1-4) Increments in mm/week plotted against the age of groups 1, 2, 3, sham group and control group Ages are given in weeks

Table 4: Mean increments (mm/week) of distance M (5-6).

age	group 1	sham	control	significance
	mean SEM	mean SEM	mean SEM	
6- 7	0.87 ± 0.10	0.58 ± 0.11	0.38 ± 0.02	(*)
7- 8	–0.11 ± 0.04	–0.18 ± 0.14	0.26 ± 0.09	*
8- 9	0.09 ± 0.03	0.34 ± 0.09	0.16 ± 0.05	ns
9-10	0.12 ± 0.03	0.33 ± 0.08	0.25 ± 0.07	ns
10-11	0.30 ± 0.04	0.33 ± 0.06	0.26 ± 0.07	ns
age	**group 2**	**age**	**group 3**	
	mean SEM		mean SEM	
16-17	1.14 ± 0.14	25-26	1.16 ± 0.25	
17-18	–0.44 ± 0.11	26-27	–0.29 ± 0.17	
18-19	0.00 ± 0.12	27-28	–0.01 ± 0.07	
19-20	0.15 ± 0.06	28-29	0.01 ± 0.05	
20-21	0.06 ± 0.09	29-30	0.02 ± 0.07	

Increments in mm/week (mean and SEM) of distance M (5-6) Group 1, sham group and control group (6-11 weeks), group 2 (16-21 weeks) and group 3 (25-30 weeks) Ages are given in weeks. Age 6-7 means: the increment period from 6 to 7 weeks of age. The level of significance for intergroup differences of the 6 weeks old groups is given as follows:

ns	$P \geq 0.10$
( )	$0.05 \leq P < 0.10$
	$0.01 \leq P < 0.05$
	$P < 0.01$

The distance M (table 4, figure 6) of the control group increased by about 0.3 mm weekly. During the first week after the operation in experimental group 1 larger increments were found than in the control group. During the second week after the operation in experimental group 1 and the sham group slight negative increments were found, while in the control group the increments were about the same as during the first week after the operation. During the third week the increments in these groups reached the level of those of the control group. The experimental groups 2 and 3 showed a similar pattern.

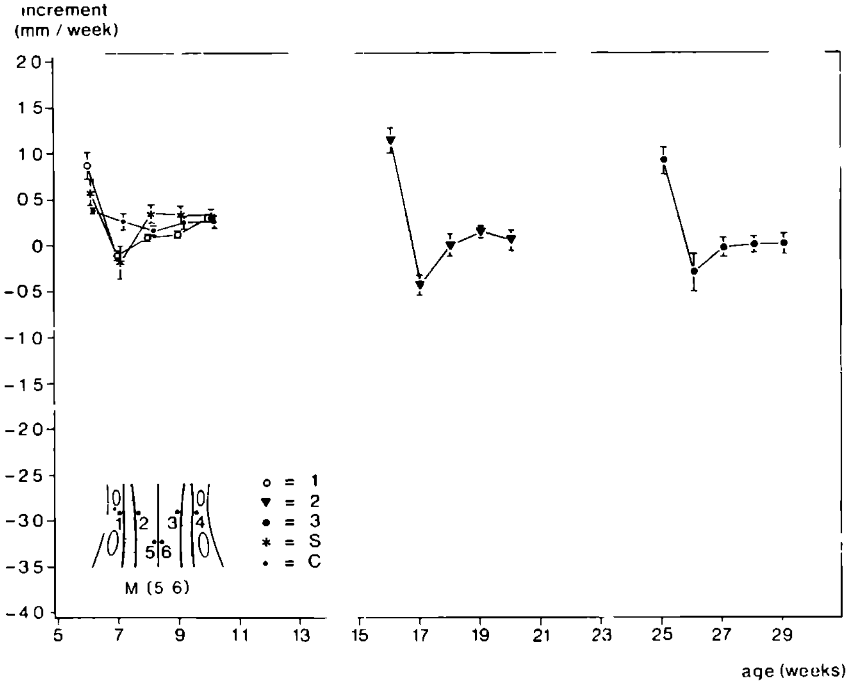

Figure 6 Distance M (5-6). Increments in mm/week plotted against the age of groups 1, 2, 3, sham group and control group Ages are given in weeks

Discussion

In the present study healing of excisional and incisional wounds of the palatal mucoperiosteum in relation to age-dependent surgery was investigated macroscopically and quantified with the aid of tattoo points. A non-cleft Beagle model was used since the presence of a bony palatal cleft was not essential for the aim of our study. In contrast to the 'canine one-sided strip model' of Kremenak et al. (1970) the operations were performed symmetrically, leaving two areas of denuded bone laterally. This was done to avoid possible asymmetrical effects on the growth of the maxilla and on the migration of the mucoperiosteal tattoo points. Therefore, it is difficult to compare the results of our study with those using the Kremenak (1984) model.

The experimental groups operated on at the age of 6, 16 and 25 weeks showed a similar pattern of migration of the tattoo points. The effect was mainly restricted to the first week after the operation. During this period wound contraction was found in the denuded areas, recorded as the approximation of the opposite tattoo points. As this effect was not compensated for later on, this led to a permanently diminished distance between the tattoo points. The decrease of the distance between tattoo points in the denuded areas corresponded to a lateral migration of the wound margins in the medial region of the palate. This dehiscence of the wound margins was compensated during the second week after the operation, when wound contraction was found in the medial region of the palate.

Clinically, the wound healing in the medial region was complete at the end of the second week after the operation, while in the denuded areas the wound healing continued for 2 to 3 weeks for the youngest experimental group and for 4 to 5 weeks for the two older age groups. According to Kahnberg and Thilander (1982) reduction of the denuded wound surface proceeds by epithelial cell proliferation as well as by wound contraction. Our results showed that during the first week after the operation wound contraction was mainly responsible for the reduction of the surface area of the denuded bone. Later on, epithelial cell proliferation was the predominant factor in the reduction of the wound surface, because no marked wound contraction was found after the first postoperative week. The slower wound healing in the older experimental groups seemed to be caused by a reduced epithelial cell proliferation as compared with the youngest experimental group. Moreover, it was observed clinically that the denuded bony areas were filled in by epithelial cell proliferation more from the lateral than from the medial side. Probably a more suitable environment for cell growth was present on the lateral aspect of the palate. All other parts of the mucoperiosteum were elevated and repositioned, which may have disturbed the vascularisation and the vitality of the bone cells and the subepithelial connective tissue. This assumption is investigated in a histological study which will be reported separately.

Elevation of the mucoperiosteum only, without excision of tissue (sham group), initially disturbed the migration pattern of the tattoo points also, but to a lesser extent as compared with experimental group 1. The study of Herfert (1958) and the replication and extension of this investigation by Kremenak et al. (1967), involving the elevation and immediate repositioning of the mucoperiosteum at one side of the palate, showed that subsequent growth of the operated side was disturbed. However, both studies cannot exclude asymmetrical effects on the growth of the maxilla due to the experimental set-up. Whether a symmetrical elevation of the mucoperiosteum has any influence on maxillary growth has to be investigated further.

In the present study a more extensive wound contraction and a delayed wound healing process were found in the older age groups. These results do not seem to support the hypothesis that late palatal surgery is more favourable for subsequent growth. However, it is uncertain whether the more extensive wound contraction and delayed wound healing, that takes place in a relatively short period following the operation, has to be considered an important growth-inhibiting factor for the maxilla in the long run. Therefore, the implications of these findings will be investigated further in a longitudinal radiographic study with the same experimental set-up.

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CHAPTER 3

Mucoperiosteal migration after palatal surgery on Beagle dogs

A LONGITUDINAL RADIOGRAPHIC STUDY

Wijdeveld, Maarten G.M.M.
Grupping, Ellen M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.

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Mucoperiosteal migration after palatal surgery on Beagle dogs

A LONGITUDINAL RADIOGRAPHIC STUDY

Abstract

In this study the effect of palatal surgery on the mucoperiosteum was investigated radiographically 33 Beagle dogs were used, divided into three experimental groups, a sham group and a control group.
At the age of 6, 16 or 25 weeks in the experimental groups a soft tissue defect was created in the medial region of the palate by excising a standardized elliptical mucoperiosteal flap This defect was closed according to the Von Langenbeck technique. Metallic implants were placed in the mucoperiosteum Dorso-ventral radiographs were taken until the age of 37 weeks. Increments of distances between these mucoperiosteum markers were calculated.
Wound contraction in the denuded areas, recorded as the approaching of the opposite metallic implants, followed the same pattern for all experimental groups and was restricted to the first two experimental weeks In all experimental groups the anterior and posterior overall palatal width diminished during the early wound healing as compared to the control group The largest initial effect was found in the anterior region of the palate The margins of the mucoperiosteal tissue in the medial region of the palate moved towards the denuded areas during the first week after the operation. Palatal surgery as performed did not influence antero-posterior distances on the palatal mucoperiosteum

Introduction

In primary cleft palate surgery the cleft in the hard palate is closed by means of incision, elevation and shifting of the mucoperiosteum, leaving two areas of denuded bone adjacent to the posterior teeth. Later growth disturbances have been attributed to this mucoperiosteal manipulation, which is followed by wound contraction in the healing areas (Kremenak, 1984, Kremenak et al., 1967, 1970; Kremenak and Searls, 1971) Studies with metallic markers placed in the periosteum of long bones and of craniofacial bones have shown that the periosteum has a distinct migration pattern along the bony surface (Koskinen-Moffett et al., 1981; Roskjaer, 1977; Theunissen, 1973). This migration pattern is thought to be related to the growth of the underlying bone. Other studies (Crilly, 1972; Kuijpers-Jagtman et al., 1988; McLain and Vig, 1983) have shown that periosteal manipulation influences the growth of long bones. From these studies it may be concluded that the periosteum plays a rôle in the regulation of bone growth.

Data concerning the behaviour of the palatal periosteum and its relation to normal palatal growth are not available. This periosteum differs from periosteum on other craniofacial bones because of the firm connection to the palatal mucosa. Both structures together are called mucoperiosteum. It is suggested that mucoperiosteal manipulation during cleft palate surgery changes the migration pattern of the periosteum and subsequent growth of the palate.

In our previous study (Wijdeveld et al., 1987) wound healing of the palatal mucoperiosteum after palatal surgery was investigated by means of tattoo points. In the denuded bony areas adjacent to the dentition wound contraction was found together with a lateral movement of the wound margins in the medial region of the palate. The effect was restricted to the first week after the operation and this effect was not compensated for later on. In another study with a comparable method (Olin et al., 1974) wound contraction was found to occur for about 20 days; thereafter, the tattoo points moved apart slowly. In both studies it was found that analogous tattoo points in non-wound (control) areas moved apart during growth.

In our previous study (Wijdeveld et al., 1987) the experimental period was restricted, because the tattoo points in the anterior and medial region of the palate began to fade six weeks after the operation. The tattoo points in the posterior region of the palate could not be incorporated in the data analysis, because many of them faded even earlier. It was felt that meaningful information could be provided by studying mucoperiosteal migration after palatal surgery until maturity. Since no data were present, an animal study on Beagle dogs was carried out, in which the migration of the mucoperiosteum was studied radiographically by means of metallic implants. Surgery was performed according to the Von Langenbeck technique, as used in primary cleft palate surgery on humans, at different stages related to the development of the dog's dentition.

Material and methods

A total of 33 Beagle dogs was used, divided at random into five groups. In the experimental groups palatal surgery was performed at the age of 6 weeks (group 1; n = 6), at the age of 16 weeks (group 2; n = 7) or at the age of 25 weeks

(group 3; n = 7). The animals of the sham group (n = 7) and the control group (n = 6) were 6 weeks old at the start of the study.
In the experimental groups a standardized elliptical soft tissue defect was created in the medial region of the palate by excising a mucoperiosteal flap. This flap extended from a line just behind the cuspids to the caudal margin of the hard palate. The maximum width of the flap was one third of the transverse distance between the deciduous second molars or the permanent fourth premolars. On both sides relaxation incisions were made adjacent to the teeth, the mucoperiosteum was elevated and the soft tissue defect was closed at the midline, leaving two areas of denuded bone adjacent to the dentition (figure 1 and figure 2). A detailed description of the surgical procedure was given previously (Wijdeveld et al., 1987).
In each dog 12 markers were placed in the mucoperiosteum as shown in figure 1. Small pieces of Ormco® (Sybron Zürich AG, Zürich, Switzerland) ligature wire (length 2-3 mm, diameter 0.08 mm) were placed in the mucoperiosteum, using an injection needle. The needle was placed in the deeper layers of the palatal mucoperiosteum and the marker was driven into the tissue with a wire pushed through the needle.
In the sham group a comparable procedure was followed with respect to the markers but no flap in the medial region of the palate was removed. In this group only an incision in the medial region and two lateral incisions were made, after which the mucoperiosteum was elevated from the underlying bone, replaced and sutured. This procedure was carried out to evaluate the influence of the soft tissue trauma applied without excision of a flap or displacement of tissue.

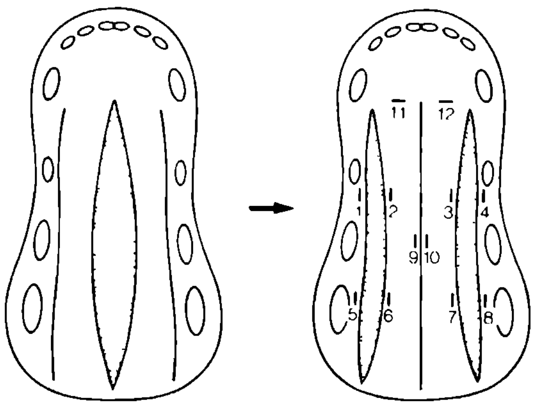

Figure 1: Schematic drawing of the palate and the surgical procedure in groups 1, 2 and 3. The position of the mucoperiosteum markers is given for all groups.

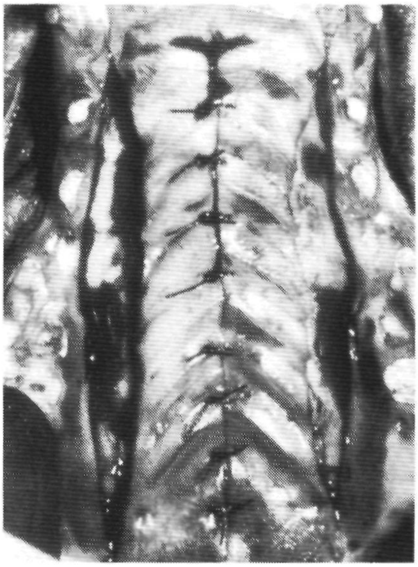

Figure 2: Palate of a Beagle dog immediately after operation.

In the control group no surgery was performed, only markers were placed in the mucoperiosteum following the procedure as described above.
After surgery dorso-ventral radiographs were taken under standardized conditions in a specially designed cephalostat (Maltha, 1982). The radiographs were taken under general anaesthesia which consisted of 30 mg/kg Sodium Pentobarbital (60 mg/ml) after premedication with Thalamonal® (Jansen Pharmaceutica, Beerse, Belgium). The animals were fixed in the cephalostat with two ear rods and with a pin in the mid-sagittal plane (figure 3). For the radiographs Kodak® dental X-ray speed photo (Kodak Nederland BV, Driebergen-Rijsenburg, The Netherlands) was used. They were taken with a Philips Practix® X-ray machine (Philips Nederland, The Hague, The Netherlands), set at 20 mA and 90 kV, the focus-film distance being 160 cm, the object-film distance 3 cm and the time of exposure 4 seconds. The radiographs were taken with the aid of a small support which was placed in the oral cavity in such a way that the film was parallel to the hard palate.
In group 1, the sham group and the control group the radiographic procedure was carried out at the age of 6, 7, 8, 9, 10, 11, 13, 15, 17, 19, 22, 26, 31 and 37 weeks. In group 2 the radiographic procedure was carried out at the age of 16, 17, 18, 19, 20, 21, 23, 25, 30 and 37 weeks; in group 3 this was done at the age of 25, 26, 27, 28, 29, 30 and 37 weeks. The error of the radiographic procedure was studied in three dogs aged 6, 16 and 25 weeks. Each dog was placed 5 times in the cephalostat and radiographed each time.

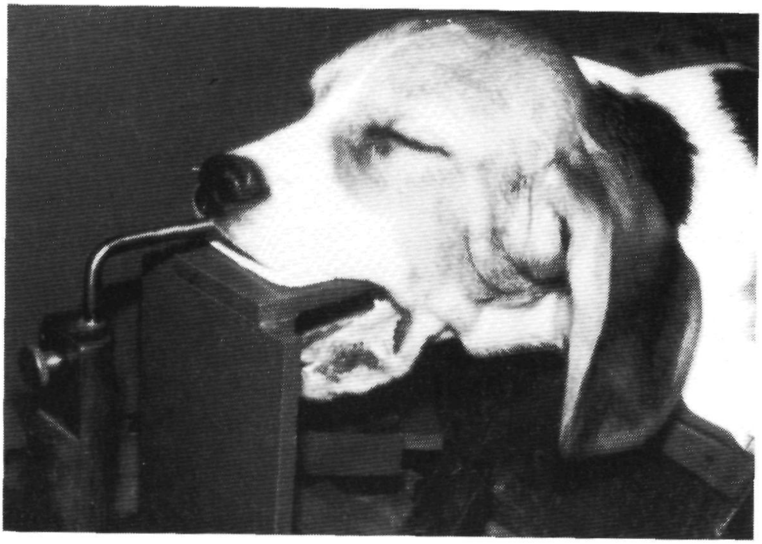

Figure 3: Beagle dog fixed in the cephalostat with the X-ray film in position.

On the dorso-ventral radiographs (figure 4) the co-ordinates of both ends of the mucoperiosteum markers were digitized with the aid of an electronic measuring table. The mean of these co-ordinates was defined as the position of the marker.

Figure 4: Dorso-ventral radiograph of the palate with mucoperiosteum markers. The six white spots are projections of bone markers which were not used in the present study.

To determine the error of the measuring method, all radiographs were measured twice.
To describe the migration of the mucoperiosteum, mean increments in mm/week of transverse and antero-posterior distances between mucoperiosteum markers were calculated (table 1 and figure 1) and plotted against the age of the animals.
The distances (1-2) and (3-4) as well as the distances (5-6) and (7-8) were added to compensate for invalid left-right differences due to possible asymmetrical displacement of the mobilized mucoperiosteal tissue during the early wound healing.
For each group of dogs the mean total migration was calculated by adding the mean weekly increments for the following periods: 6 to 16, 16 to 25 and 25 to 37 weeks. Differences in mean total migration between two groups of dogs were examined with the t-test. Experimental groups 1, 2, 3 and the sham group were compared with the control group.
At the end of the experimental period the animals were sacrificed. The position of the mucoperiosteum markers was checked. Markers which were embedded in the bone were excluded from the study.

Table 1: Transverse and antero-posterior distances between the mucoperiosteum markers.

transverse distances		antero-posterior distances	
B1	((1-2) + (3-4))	AP1	(1-5)
B2	((5-6) + (7-8))	AP2	(2-6)
T1	(1-4)	AP3	(3-7)
T2	(5-8)	AP4	(4-8)
M1	(11-12)		
M2	(2-3)		
M3	(9-10)		
M4	(6-7)		

The location of the distance is denoted by capitals. B = denuded bony area; T = transverse width; M = medial region; AP = antero-posterior. The numbers represent the mucoperiosteum markers according to figure 1.

Results

Error of the method

The total error of the method is made up of an error of the radiographic proce-

dure and a measurement error, due to inexact defining of the mucoperiosteum markers as well as inaccuracy of the measuring instrument.
For transverse distances both the total error and the measurement error were found to be about 0.1 mm. Therefore, it was concluded that the error of the radiographic procedure was of minor importance. For antero-posterior distances the total error was found to be about 0.6 mm and the measurement error about 0.2 mm. Therefore, it was concluded that errors in the antero-posterior distances were mainly due to inaccuracies of the radiographic procedure.

Migration of the mucoperiosteum

Transverse distances

The results of groups 1, 2, 3 and the control group are presented in the figures 5 to 7. The results of the sham group are not incorporated in the figures because this group showed a pattern comparable to the control group. Only during the first week after the operation some effect of surgery was seen.

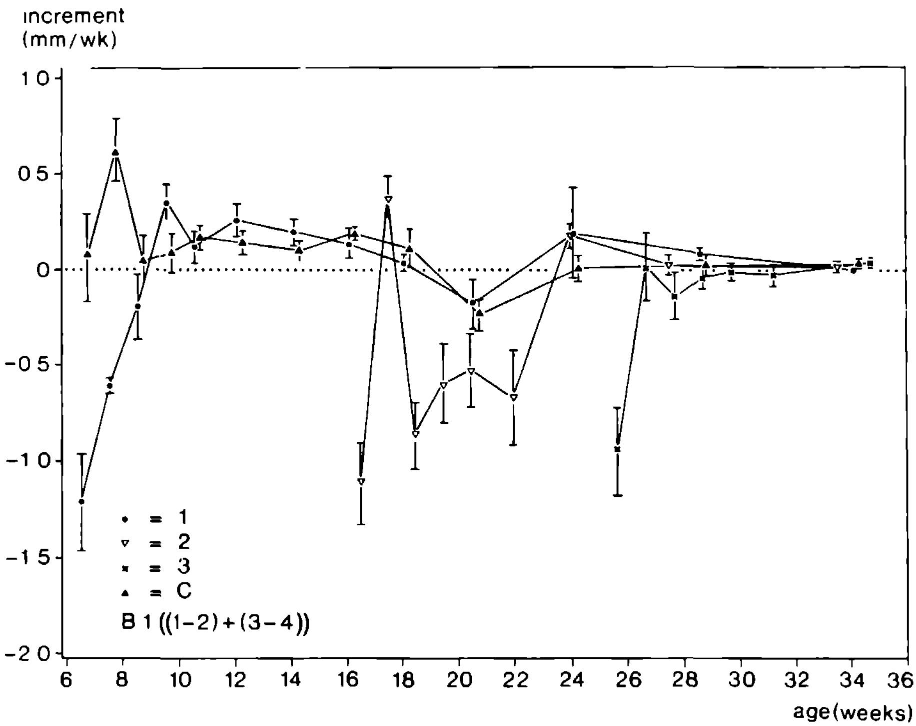

Figure 5: Distance B1 ((1-2) + 3-4)). Mean increments (mm/week) and SEM plotted against the age for groups 1, 2, 3 and the control group. Ages are given in weeks. The value of an increment is plotted at the midpoint of the increment period.

The distances B1 ((1-2) + (3-4)) (figure 5) and B2 ((5-6) + (7-8)) (not shown) represented the movement of the opposite wound margins adjacent to the denuded bony areas in the anterior and posterior regions of the palate respectively. The distance B1 of the control group showed a small increase until about 18 weeks of age; later on this distance remained approximately constant. The distance B2 of the control group showed minor changes from 6 to 37 weeks of age. In all experimental groups the distances B1 and B2 diminished during the early wound healing before reaching the control level. The largest initial effect was found in the anterior region of the palate. The distances T1 (1-4) (figure 6) and T2 (5-8) (not shown) represented the overall width of the palatal mucoperiosteum in the anterior and posterior regions of the palate respectively. The distance T1 of the control group increased with a diminishing rate (1 mm/week to zero at about 20 weeks of age). In group 1 during the first and second week after the operation no increase of this distance was found. In group 2 during four weeks after the operation smaller increments were found than in the control group. In group 3 the distance T2 increased less than in the control group. The largest effect, however, was found in the anterior region of the palate in groups 1 and 2.

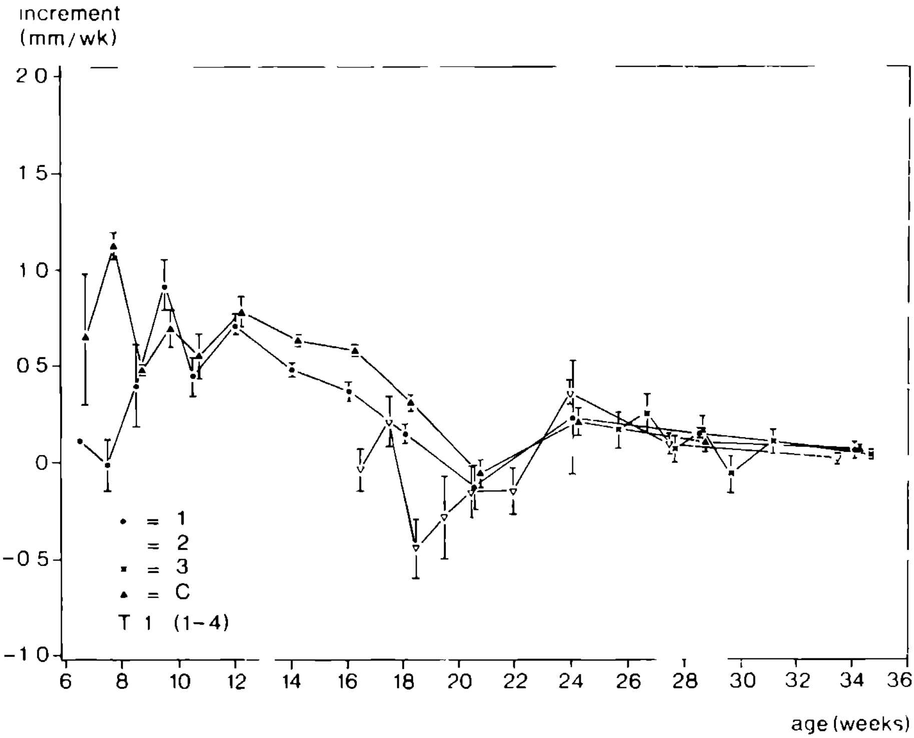

Figure 6 Distance T1 (1-4) Mean increments (mm/week) and SEM plotted against the age for groups 1, 2, 3 and the control group Ages are given in weeks The value of an increment is plotted at the midpoint of the increment period

The distance M1 (11-12) represented the growth of the medial region of the mucoperiosteum in the cuspid area. In the control group the distance increased with a diminishing rate from 6 to 37 weeks of age. In all experimental groups the mucoperiosteum markers moved more rapidly apart during the first week after the operation before reaching the control level. During this week the increase was about 0.5 to 0.7 mm.

The distance M3 (9-10) represented the movement of the opposite wound margins in the medial region of the palate. These mucoperiosteum markers moved according to a comparable pattern as described for distance M1, but groups 2 and 3 tended to show a reversed effect during the second week after the operation, i.e. a decreased rate of moving apart.

The distances M2 (2-3) (figure 7) and M4 (6-7) (not shown) represented the width of the mobilized mucoperiosteal tissue in the anterior and posterior regions of the palate respectively. In the control group these distances increased with a diminishing rate (0.6 mm/week to zero). In all experimental groups a larger increase of both distances M2 and M4 was found during the first week after the operation before reaching the control level.

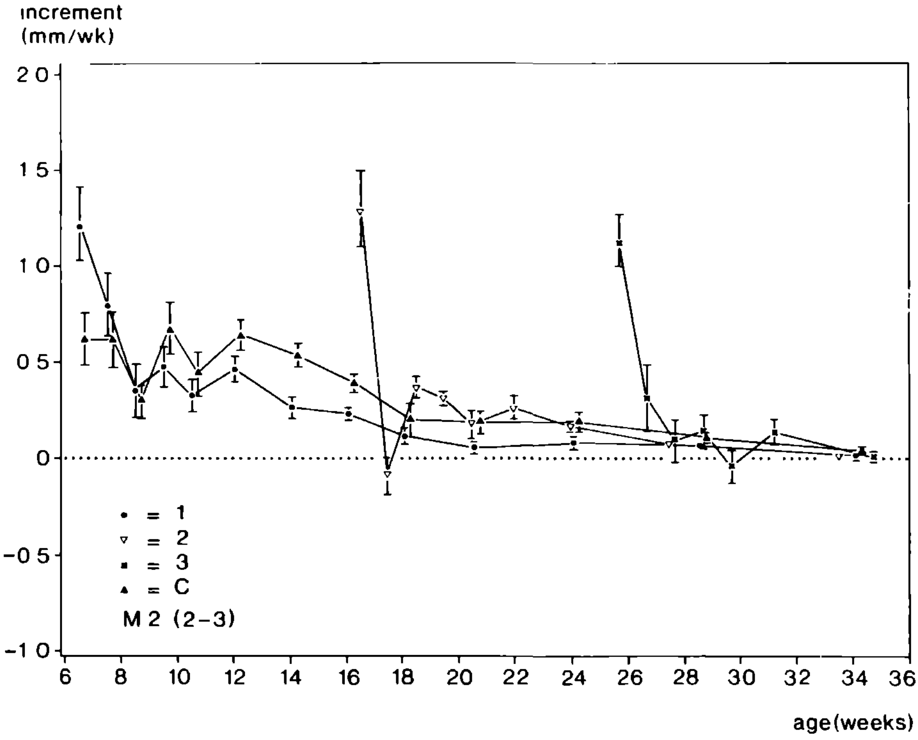

Figure 7: Distance M2 (2-3). Mean increments (mm/week) and SEM plotted against the age for groups 1, 2, 3 and the control group. Ages are given in weeks. The value of an increment is plotted at the midpoint of the increment period.

The mean total migration of the mucoperiosteum, calculated for all transverse distances and periods as mentioned above, is given in tables 2, 3 and 4 Groups 1 and 2 showed significantly less increase in the anterior region of the palate than the control group (tables 2 and 3). A comparable pattern was found in the sham group although to a lesser extent. Group 2 also showed significantly more increase in the medial region of the mucoperiosteum in-between the cuspids Group 3 showed significant differences in both the anterior and posterior regions of the palate (table 4).

Antero-posterior distances

The measurements of all antero-posterior distances did not show any differences between the experimental groups and the control group. All antero-posterior distances increased with a diminishing rate until maturity

Table 2 Total migration of all transverse distances in mm (mean and SEM) for group 1, the sham group and the control group Period 6-16 weeks.

distance	group 1	sham(S)	control(C)	1 vs C	S vs C
	mean SEM	mean SEM	mean SFM		
B1	–0 54 ± 0 43	0 21 ± 0 40	1.59 ± 0.38	*	**
B2	–0.15 ± 0 49	1 14 ± 0.49	0.05 ± 0 35	ns	ns
T1	4.62 ± 0 35	5 53 ± 0 37	6 88 ± 0.42	*	
T2	5 16 ± 0.38	6 45 ± 0.48	6.14 ± 0 37	ns	ns
M1	2 55 ± 0.30	2.14 ± 0.20	1 87 ± 0 18	ns	ns
M2	5.13 ± 0 43	5 91 ± 0 30	5.41 ± 0.36	ns	ns
M3	1 81 ± 0 28	1 23 ± 0.24	1.21 ± 0.28	ns	ns
M4	5 68 ± 0.38	5.62 ± 0 34	6 23 ± 0 31	ns	ns

Mean total migration in mm for transverse distances between mucoperiosteum markers for the period 6 to 16 weeks of age For each distance mean total migration and corresponding error (SEM) are given for group 1, the sham group and the control group Results of the t-test of group 1 and the sham group compared to the control group are given

ns P ≥ 0 05

* 0 01 ≤ P < 0 05

** P < 0 01

Table 3: Total migration of all transverse distances in mm (mean and SEM) for group 2 and the control group. Period 16-25 weeks.

distance	group 2	control(C)	2 vs C
	mean SEM	mean SEM	
B1	−4.13 ± 0.66	−0.32 ± 0.44	**
B2	−0.90 ± 0.86	0.16 ± 0.70	ns
T1	−1.00 ± 0.68	1.87 ± 0.38	**
T2	2.66 ± 0.53	3.19 ± 0.84	ns
M1	1.28 ± 0.17	0.67 ± 0.16	**
M2	2.92 ± 0.28	2.11 ± 0.34	ns
M3	0.80 ± 0.23	0.34 ± 0.12	ns
M4	3.86 ± 0.35	3.05 ± 0.26	ns

Mean total migration in mm for transverse distances between mucoperiosteum markers for the period 16 to 25 weeks of age. For each distance mean total migration and corresponding error (SEM) are given for group 2 and the control group. Results of the t-test of group 2 compared to the control group are given.

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
** $P < 0.01$

Table 4: Total migration of all transverse distances in mm (mean and SEM) for group 3 and the control group. Period 25-37 weeks.

distance	group 3	control(C)	3 vs C
	mean SEM	mean SEM	
B1	−1.03 ± 0.36	0.22 ± 0.27	**
B2	−1.41 ± 0.43	0.38 ± 0.20	**
T1	1.03 ± 0.25	0.97 ± 0.26	ns
T2	1.07 ± 0.27	1.76 ± 0.18	*
M1	1.12 ± 0.43	0.18 ± 0.07	*
M2	1.95 ± 0.33	0.77 ± 0.18	**
M3	0.49 ± 0.25	0.16 ± 0.11	ns
M4	2.33 ± 0.30	1.36 ± 0.15	**

Mean total migration in mm for transverse distances between mucoperiosteum markers for the period 25 to 37 weeks of age. For each distance mean total migration and corresponding error (SEM) are given for group 3 and the control group. Results of the t-test of group 3 compared to the control group are given.

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
** $P < 0.01$

Discussion

In the present study the effect of palatal surgery at different ages on the palatal mucoperiosteum was investigated radiographically with the aid of metallic mucoperiosteum implants. A non-cleft Beagle model was used since the presence of a bony palatal cleft was not essential for the aim of our study. In contrast to other studies (Olin et al., 1974; Wijdeveld et al., 1987) in which tattoo points were used, it was possible to investigate the behaviour of the palatal mucoperiosteum over a longer period by using metallic mucoperiosteum implants.
With regard to all antero-posterior distances, the control group and the experimental groups showed growth at a diminishing rate until maturity. The fact that no differences were found between the control group and the experimental groups might be due to the relatively large total error of the method for antero-posterior distances.
In the sham group some effect of surgery was seen during the first week after the operation. This might be related to post-surgical wound oedema. Furthermore, in all experimental groups rapid changes in measured distances were found during the first week after the operation. These changes far exceeded those found in the sham group.
The transverse distances B1 and B2 in the experimental groups operated on at the age of 6, 16 or 25 weeks showed a comparable mucoperiosteal migration. During the first two weeks after the operation wound contraction was found in the denuded bony areas. In experimental group 2 the effect in the anterior region of the palate lasted the longest, namely about 6 weeks after the operation. As this wound contraction was not compensated for until maturity, this led to a permanently smaller distance between the metallic implants. In our previous study (Wijdeveld et al., 1987) a comparable pattern of wound contraction was found in the anterior region of the palate, but only during the first week after the operation. In the older experimental groups the amount of wound contraction was about three times as much as in the present study. Wound contraction as measured on the surface of the mucoperiosteum (tattoo points) thereby differed from wound contraction as measured in the deeper layers of the mucoperiosteum (metallic implants). This finding suggested that the largest amount of wound contraction occurred in the mucosal region of the mucoperiosteum. This was in contrast with the findings of an electron microscopic study (Squier and Kremenak, 1980) which suggested that myofibroblasts, thought to be responsible for wound contraction, were mainly located in the periosteal region of the palatal mucoperiosteum. Possibly the amount of wound contraction was unevenly distributed over the palatal mucoperiosteum. It is difficult to draw conclusions, however, from these controversial findings, because the mechanism of wound contraction is still not fully explained.

With regard to distance T1, both younger experimental groups showed a diminished increase of the anterior overall palatal width during early wound healing. In contrast to these findings, the corresponding posterior overall palatal width (T2) did not show any differences with the control group. If the periosteum influences the growth of the alveolar process and the development of the dentition, then it is possible that the position of the posterior teeth will not be influenced to any extent by the kind of palatal surgery performed in this study.
With regard to the distances in the medial region of the palate, all experimental groups showed a lateral migration of the mucoperiosteum markers. This increase of distance corresponded with the wound contraction in the denuded bony areas. During the second week after the operation, in agreement with our previous study (Wijdeveld et al., 1987), the older experimental groups showed a reversed effect in the midline of the palate (M3), which compensated for the initial lateral migration. An unexpected finding was the similarity between the migration pattern in the cuspid area (M1) and that of other distances in the medial region of the palate, because the distance M1 was relatively distant from the surgical area. This emphasized the possible effect of mucoperiosteal manipulation on remote anatomical structures.
In the present study all experimental groups showed a similar pattern of mucoperiosteal migration after palatal surgery. These results do not answer the question as to which timing of palatal surgery is most favourable for subsequent growth. Both our studies showed that the reaction of the mucoperiosteum on palatal surgery occurred in a relatively short period of time after the operation; after this initial effect normal mucoperiosteal growth and development were found until maturity. Therefore, it is still uncertain as to whether these relatively early postsurgical phenomena have to be considered as an important growth inhibiting factor for the maxilla in the long run.

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CHAPTER 4

Growth of the maxilla after soft tissue palatal surgery at different ages on Beagle dogs

A LONGITUDINAL RADIOGRAPHIC STUDY

Wijdeveld, Maarten G.M.M.
Grupping, Ellen M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C

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Growth of the maxilla after soft tissue palatal surgery at different ages on Beagle dogs

A LONGITUDINAL RADIOGRAPHIC STUDY

Abstract

This study investigated maxillary growth after palatal surgery at different ages on Beagle dogs Soft tissue clefts were created in the medial region of the palate at the age of 6 (group 1), 16 (group 2) and 25 weeks (group 3). Relaxation incisions were made and the mucoperiosteum was elevated and closed in the midline, leaving two areas of denuded bone adjacent to the dentition Metallic implants were placed in the palate and dorso-ventral and lateral radiographs were made until the age of 37 weeks to study growth in palatal sutures and overall growth of the maxilla In groups 1 and 2 growth in the mid-palatal suture was less than in the control group during the periods from 16-25 weeks and from 16-37 weeks of age. In group 2 less increase was also found in the transverse palatal sutures. Group 3, the sham group and the control group did not show significant differences.
None of the dimensions measured on the lateral radiographs showed any significant differences for any group It was concluded that palatal surgery as performed in this study had no noticeable influence on vertical and antero-posterior maxillary growth; only transverse palatal growth was influenced to a minor extent, especially when surgery was performed before or during the eruption of the permanent posterior teeth.

Introduction

It is known that individuals with cleft lip and palate, whose clefts are not operated on, show a relatively normal maxillofacial growth (DeJesus, 1959, Ortiz-Monasterio et al , 1966, Bishara et al., 1976) Although the effects of primary surgery on cleft lip and palate patients are initially beneficial, later on they seem to be responsible for disturbances in maxillary growth Despite many studies with respect to this growth disturbance, there continues to be disagreement about the timing and the surgical techniques to be used in primary palatal closure (Blijdorp and Egyedi, 1984; Jorgenson et al., 1984; Witzel et al., 1984; Dingman and Argenta, 1985; Berkowitz, 1985). Various animal experiments have been performed to study facial growth after palatal surgery. However, when studying the effect of palatal surgery it has to be realized that closure of the palatal cleft is achieved by mucoperiosteal manipulation alone. Therefore, studies in which artificially created bony clefts are closed surgically (e.g. Sarnat, 1958; Freng, 1979, 1981; Bardach et al., 1982) can give conflicting results, because of the extensive surgical trauma of creating such a bony cleft.

Herfert (1958) studied maxillary growth in Beagle dogs after excision of a strip of mucoperiosteum adjacent to the posterior teeth without creating a bony cleft. His experiments were modified by Kremenak and his group (Kremenak et al., 1967, 1970; Kremenak and Searls, 1971; Kremenak, 1984), who concluded that later growth disturbances can be attributed to wound contraction in the healing areas which follows mucoperiosteal manipulation. However, the experimental design of their study had an important limitation: surgery was performed at one side of the hard palate only and the unoperated side was used as a control. As one-sided surgery could have an effect on palatal growth on the other side, it was concluded that more reliable results could be obtained from a study in which surgery is performed symmetrically on the palate. Symmetrical palatal surgery, as performed in our previous studies on wound healing (Wijdeveld et al., 1987b) and migration of the mucoperiosteum (Wijdeveld et al., 1987a), had an effect on the mucoperiosteum that was restricted to a relatively short period after the operation. Thereafter, normal growth of the mucoperiosteum was found until maturity. It was still uncertain whether these relatively early post-surgical changes can be an important growth inhibiting factor for the maxilla in the long run.

Only a few animal studies were found in which the effect of variation in timing of palatal surgery was investigated. Kremenak et al. (1985a, 1985b) performed unilateral palatal surgery on 4 groups of Beagle dogs at the age of 3, 5, 8 and 10 weeks respectively, prior to the eruption of the permanent teeth. They found significantly less transverse growth of the maxilla in all experimental groups as compared to the control group. The 10-week surgery group was the least affected; no significant differences were found between the younger age groups. However, these studies provide no information comparable to the human situation, in which hard palate closure is delayed until eruption of the permanent teeth starts or even until eruption of the permanent dentition is completed as proposed by Schweckendiek (1978).

The aim of this study was to investigate maxillary growth after palatal surgery performed on Beagle dogs at different stages of development of the dentition.

Material and methods

The experiments were performed on 37 Beagle dogs, divided at random into five groups. In the experimental groups 1, 2 and 3 palatal surgery was performed at three different stages of development: 1) during the eruption of the deciduous dentition (group 1; 10 dogs; age 6 weeks), 2) during the period of mixed dentition (group 2; 7 dogs; age 16 weeks) and 3) after the completion of the permanent dentition (group 3; 7 dogs; age 25 weeks). In the sham group (7 dogs) surgery was performed at the age of 6 weeks. The animals of the control group (6 dogs) were 6 weeks old at the start of the study.

In the experimental groups a standardized elliptical soft tissue defect was created in the medial region of the palate by excising a mucoperiosteal flap. On both sides relaxation incisions were made adjacent to the posterior teeth, the mucoperiosteum was elevated and the soft tissue defect was closed, leaving two areas of denuded bone adjacent to the dentition (figure 1). A detailed description of the surgical procedure was given previously (Wijdeveld et al., 1987b). All surgical procedures were carried out under general anaesthesia with 30 mg/kg Sodium Pentobarbital (60 mg/ml) after premedication with Thalamonal® (Fentanyl, 0.05 mg/ml + Droperidol 2.5 mg/ml; Jansen Pharmaceutica, Beerse, Belgium) and 0.5 ml Atropine (Atropine Sulphate 0.5 mg/ml).

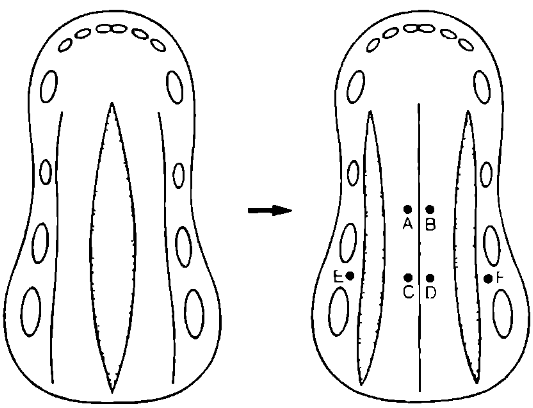

Figure 1: Schematic drawings of the palate and the surgical procedure in groups 1, 2 and 3. The position of the bone markers is also shown.

According to the method of Björk (Björk, 1968), six Tantalum bone markers (length 1.5 mm, diameter 0.5 mm) were placed in the hard palate just before the surgical closure of the soft tissue defect: two in the anterior region and four in the posterior region of the hard palate (figure 1 and figure 2). No bone markers were

placed anterior to the incisal suture because of the fragility of the bone in this area. Therefore, the growth of this suture was not incorporated in the study.
In the sham group an incision in the medial region and two lateral incisions were made, after which the mucoperiosteum was elevated from the bone, replaced and sutured. Bone markers were inserted as in the experimental groups. In the control group no surgery was performed; only small incisions (about 1 mm) were made to place the implant instrument on the palatal bone and to insert the bone markers.

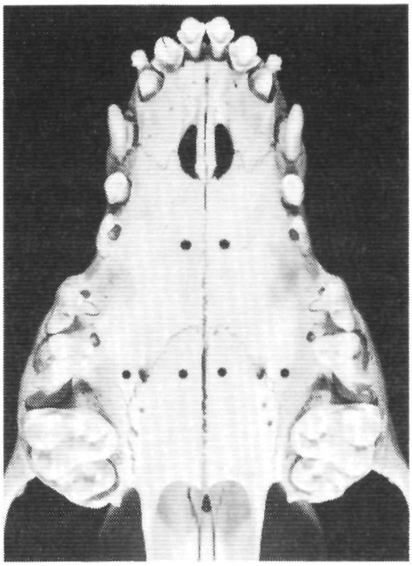

Figure 2: Skull of a Beagle dog with the position of the bone markers as they relate to the various sutures indicated on the palate.

Immediately after the operation a dorso-ventral and a lateral radiograph were taken under standardized conditions in a specially designed cephalostat (Maltha, 1982). The animals were fixed in the cephalostat with two ear rods and with a pin between the maxillary central incisors. The radiographs were taken with a Philips practix® X-ray machine (Philips Nederland, The Hague, The Netherlands), set at 20 mA and 90 kV. For the dorso-ventral radiographs the focus-film distance was 160 cm and the object-film distance was 3 cm. These radiographs were taken using a small stand that was placed in the oral cavity in such a way that the film was parallel to the hard palate. For the lateral radiographs the focus-film distance was 450 cm and the object-film distance was 9 cm. For both types of radiographs the time of exposure varied from 3 to 4 seconds and was related to the body weight of the animals.

In group 1, the sham group and the control group the radiographic procedure was carried out at the age of 6, 7, 8, 9, 10, 11, 13, 15, 17, 19, 22, 26, 31 and 37 weeks. In group 2 the radiographic procedure was carried out at the age of 16, 17, 18, 19, 20, 21, 23, 25, 30 and 37 weeks; in group 3 this was done at the age of 25, 26, 27, 28, 29, 30 and 37 weeks. The different measurement schedules for the three groups of dogs were compensated for by interpolation. For example, the values at age 21, 25 and 30 weeks were interpolated respectively to 22, 26 and 31 weeks, i.e. the schedule of group 1. To determine the error of the radiographic procedure, three dogs of 6, 16 and 25 weeks old, respectively, were placed five times in the cephalostat and radiographed.

The downward drift of the hard palate, caused by apposition on the oral side and resorption on the nasal side of the palatal bone, imposed restrictions on the time that the bone markers could be used; after about 6 to 12 weeks they were expelled into the nasal cavity. Therefore, a new series of markers was inserted in all animals every five weeks during the period of rapid growth. This was done while the animals were under general anaesthesia for the radiographic procedure. The measurements were continued by changing to the next bonemarkers; the radiograph was measured twice, once with the earlier and once with the later inserted bone markers. Continuity of the measurements was achieved by using the increment method. When no stable bone marker was available, the measurement was excluded from the study.

The co-ordinates of the bone markers were digitized on all radiographs with an electronic measuring table. To determine the error of the measuring method, all radiographs were measured twice. On the dorso-ventral radiographs, growth in the mid-palatal suture and in the transverse palatal sutures was studied by calculating the mean increments in millimetres per week of the transverse distances (A-B, C-D, E-C, D-F and E-F) and antero-posterior distances (A-C and B-D) between the bone markers (figure 1 and figure 2).

The increments were plotted against the age of the animals and the curves of the experimental groups were compared with the control group. The three experimental groups also were compared with each other. Furthermore, for each group of dogs the mean growth in the sutures was calculated by adding the mean weekly increments for the periods 6 to 16, 6 to 25, 6 to 37, 16 to 25, 16 to 37 and 25 to 37 weeks. The results of all groups were compared with each other, using a one-way analysis of variance. In case of a significant result, the t-test was used for further exploration of the differences between two groups.

On the lateral radiographs the overall growth of the maxilla was studied, using the following measuring points (figure 3):

1 the anterior limitation of the bony palate defined as the end of the fixation pin of the cephalostat between the central incisors;
2 the most posterior point of the bony palate;

3 the most posterior point of the supraorbital ridge;
4 the point of intersection of the frontonasal suture with the superior bony limitation of the nasal cavity;
5 the most anterior point of the nasal bone.

The measuring points 3', 4' and 5' represented the projections of points 3, 4 and 5 on the line 1-2. The following distances and angles between these points were calculated (figure 3):

antero-posterior distances: 1-2, 1-3', 1-4', 1-5';
vertical distances : 3-3', 4-4', 5-5';
angles : ∠ 3-1-2, ∠ 4-1-2, ∠ 5-1-2.

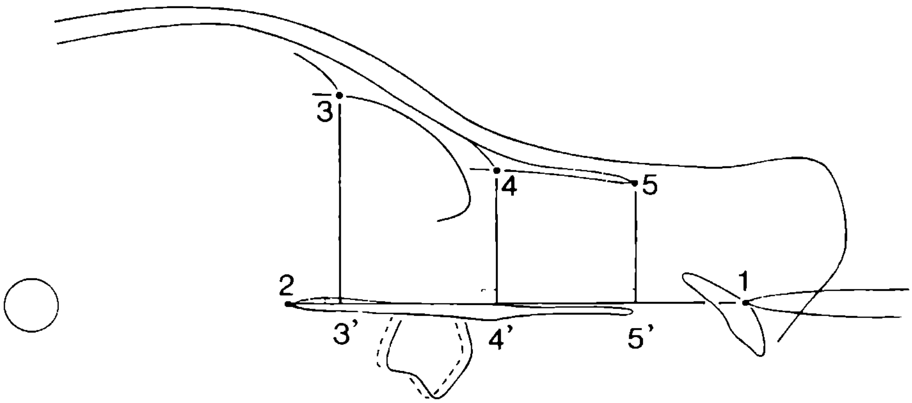

Figure 3: Schematic drawing of a lateral radiograph. The measuring points used in this study are shown.

The measurements were plotted against the age of the animals. The control group showed several technical radiographic failures at age 37 weeks. Therefore, the measurements at this age were not included in the study. The curves of the experimental groups 1, 2 and 3 were compared with the control group. The three experimental groups also were compared with each other.

Results

Error of the method

The total error of the method is made up of an error of the radiographic procedure and a measurement error, due tot inexact definition of the measuring points as well as inaccuracy of the measuring instrument. Since the total error of the method for both types of radiographs was about the same as the measurement error, it was concluded that the error of radiographic procedure could be neglected. For the dorso-ventral radiographs the measurement error was found to be about 0.1 mm for the transverse distances and 0.4 mm for the antero-posterior distances. For the lateral radiographs the measurement error was found to be about 0.25 mm for both antero-posterior and vertical distances; the angular measurements showed an error of about 0.25 degrees.

Dorso-ventral radiographs

The distances A-B and C-D represented the transverse growth in the mid-palatal suture (figure 1 and figure 2). The distances E-C and D-F represented the transverse growth in the transverse palatal sutures. The distance E-F represented the total transverse growth of the palate. The distances A-C and B-D represented the antero-posterior growth in the transverse palatal sutures.
The mean growth of the control animals from 6 to 37 weeks of age is presented in figure 4. The left and right sides showed comparable amounts of growth. In the posterior region of the palate the total amount of transverse growth in the mid-palatal and in the transverse palatal sutures was about the same as the amount of transverse growth in the anterior part of the mid-palatal suture alone. Antero-posterior growth was about 16 mm while the added transverse growth was about 8 mm.

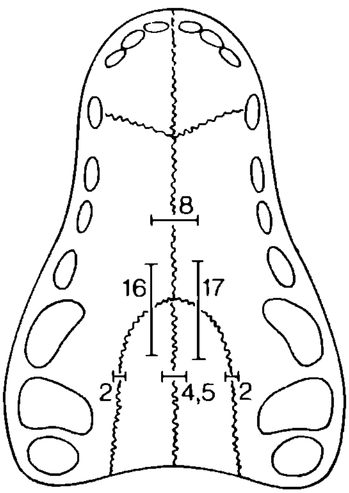

Figure 4: Schematic drawing of the palate showing the mean total growth in the mid-palatal and the transverse palatal sutures in the control group from 6 to 37 weeks of age. Growth is given in millimetres.

The results in groups 1, 2, 3 and the control group for the distance A-B are presented in figure 5. The results of the sham group were not incorporated, because this group showed essentially the same pattern as the control group. In the control group all distances increased steadily until about 16 weeks of age; after that the growth rate diminished with the age of the animals. The sham group and group 3 did not show any differences compared to the control group. Group 1 showed no differences except for distances A-B (figure 5) and C-D (not shown). From about 16 to 22 weeks of age this group seemed to show less increase than the control group. During the same period, group 2 also showed less increase than the control group with respect to the distances A-B, C-D, E-F and B-D; this effect was not compensated for later on.

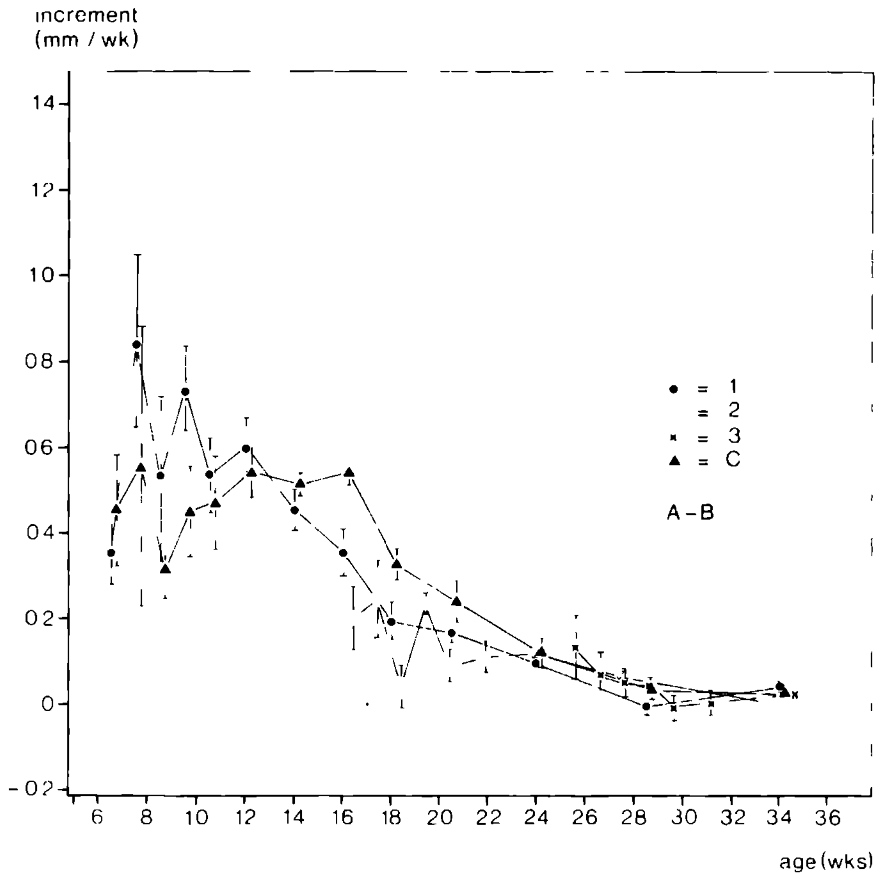

Figure 5 Increments in millimetres per week (mean and SEM) for distance A-B plotted against the age of the animals of groups 1, 2, 3 and the control group. The value of an increment is plotted at the midpoint of the increment period

The mean growth in the mid-palatal and in the transverse palatal sutures, calculated for all distances and periods as previously mentioned, did not show any significant differed between group 3, the sham group and the control group. The results of groups 1 and 2 differed from the control group and are presented in tables 1 and 2.

Table 1: Growth of all distances in mm (mean and SEM) for groups 1, 2 and the control group in the period of 16-25 weeks.

distance	group 1	group 2	control(C)	1 vs C	2 vs C
	mean SEM	mean SEM	mean SEM		
A-B	1.41 ± 0.29	1.27 ± 0.15	2.39 ± 0.22	**	**
C-D	0.79 ± 0.19	0.40 ± 0.21	1.28 ± 0.19	ns	**
E-C	0.69 ± 0.36	0.55 ± 0.34	0.34 ± 0.58	ns	ns
D-F	0.41 ± 0.40	0.26 ± 0.20	0.49 ± 0.49	ns	ns
E-F	1.83 ± 0.29	1.30 ± 0.15	2.58 ± 0.27	ns	**
A-C	6.06 ± 0.39	4.76 ± 0.43	5.70 ± 0.38	ns	ns
B-D	6.00 ± 0.40	4.11 ± 0.45	5.96 ± 0.27	ns	**

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
** $P < 0.01$

Table 2: Growth of all distances in mm (mean and SEM) for groups 1, 2 and the control group in the period of 16-37 weeks.

distance	group 1	group 2	control(C)	1 vs C	2 vs C
	mean SEM	mean SEM	mean SEM		
A-B	1.63 ± 0.32	1.67 ± 0.17	2.75 ± 0.28	**	**
C-D	0.79 ± 0.20	0.49 ± 0.22	1.53 ± 0.23	*	**
E-C	0.88 ± 0.44	0.82 ± 0.42	0.80 ± 0.61	ns	ns
D-F	0.68 ± 0.47	0.51 ± 0.28	0.16 ± 0.57	ns	ns
E-F	2.28 ± 0.31	1.97 ± 0.20	2.98 ± 0.32	ns	**
A-C	7.75 ± 0.45	7.34 ± 0.50	7.31 ± 0.51	ns	ns
B-D	8.09 ± 0.46	6.76 ± 0.52	7.97 ± 0.43	ns	ns

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
** $P < 0.01$

Group 2 showed significantly less transverse suture growth than the control group. Group 1 showed the same pattern, although to a lesser extent. During the early postoperative period (16 to 25 weeks) group 2 also showed less antero-posterior growth than the control group.

Lateral radiographs

Comparison of the antero-posterior and vertical distances in the experimental groups, the sham group and the control group showed a similar growth pattern for all dogs: the distances increased with a diminishing rate until maturity. Total antero-posterior growth (distance 1-2) was about 30 to 40 mm. The angles showed also a similar pattern for all groups of dogs; they decreased with a diminishing rate until maturity. None of the dimensions of the maxilla as calculated from the lateral radiographs showed any significant differences between the groups.

Discussion

In this study a non-cleft Beagle model was used, since the presence of a bony palatal cleft was not essential for the purpose of the study. The results of experiments of Freng (1979, 1981) supported the use of a non-cleft Beagle model, because a 50% reduction of transverse growth appeared after making a medial bony palatal cleft, whereas the palatal dimensions of sham-operated and unoperated controls did not differ.

In contrast to the unilateral surgical method used by Herfert (1958) and Kremenak and his group (e.g. Kremenak et al., 1967, 1970; Kremenak and Searls, 1971; Kremenak, 1984), the operations in this study were performed symmetrically. This was done to avoid possible asymmetrical effects on the growth of the maxilla. Therefore, it was difficult to compare the results of our study with those using the Herfert/Kremenak model.

Antero-posterior growth, as measured on the lateral radiographs, did not appear to be influenced by the surgical procedure in any of the experimental groups. Comparison of the overall antero-posterior growth of the maxilla, as measured on the lateral radiographs, and the antero-posterior growth in the posterior transverse palatal sutures, as measured on the dorso-ventral radiographs, indicates that these sutures can be held responsible for about 50% of the overall antero-posterior growth. In group 1 transverse growth in the mid-palatal suture seemed to decrease from about 16 to 22 weeks of age, that is from 10 to 16 weeks after the operation. In group 2 a decreased transverse growth was also found from about 16 to 22 weeks of age, which in this case was immediately after the operation. In

group 3, operated on at 25 weeks of age, no influence on transverse growth was observed. The fact that the influence of the operation on transverse growth was found in the same age period, even after different postoperative times, suggested that this influence is restricted to a distinct phase in the growth and development of the animals, irrespective of the postoperative period. The period from 16 to 22 weeks of age corresponds roughly with the transition of the teeth in the premolar-molar region (Maltha, 1982; Kremenak, 1967). It has been suggested that transverse growth of the maxilla is correlated with mandibular growth by the interdigitation of the teeth in the posterior segments (Van der Linden, 1986). In Beagles a scissors bite exists between the posterior deciduous molars of the maxilla and the mandible. It is theorized that, due to the loss of occlusion/ interdigitation of the teeth during the period of mixed dentition, this mechanism cannot compensate for unfavourable environmental factors such as palatal cleft closure, leading to a decreased transvere palatal growth.
Other investigators (Herfert, 1958; Kremenak et al., 1967, 1970; Kremenak, 1984) have also concluded that palatal surgery may disturb maxillary growth. However, the results of their studies were based on measurements of the dental arch, while conclusions were drawn about maxillary growth. It might also be possible that palatal surgery mainly disturbs growth of the dentoalveolar structures. This assumption needs to be further investigated.

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CHAPTER 5

The influence of palatal surgery on the migration pattern of the mucoperiosteum along the palatal bone in growing Beagle dogs

Wijdeveld, Maarten G.M.M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.
Van 't Hof, Martin A.
Grupping, Ellen M.

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The influence of palatal surgery on the migration pattern of the mucoperiosteum along the palatal bone in growing Beagle dogs

Abstract

This study investigated migration of the mucoperiosteum along the palate after palatal surgery at different ages on Beagles.
Soft tissue clefts were created in the medial region of the palate at the age of 6 (group 1), 16 (group 2) and 25 weeks (group 3). All 33 animals involved were followed until 37 weeks of age. Closure was performed according to the Von Langenbeck technique, leaving two areas of denuded bone adjacent to the dentition. Metallic bone and mucoperiosteum implants were placed and dorso-ventral radiographs were taken until maturity.
In the control group and in group 3 the mucoperiosteum adjacent to the dentition migrated laterally until maturity; medial migration was found in groups 1 and 2 during the first month after the operation. In the control group the medial mucoperiosteum remained stable Lateral migration of the medial mucoperiosteum was found in the experimental groups during the first week after the operation.
The migration pattern of the mucoperiosteum along the palate in growing Beagles was unevenly distributed over the palate and was influenced by surgery, especially in the younger operated experimental groups.

Introduction

Studies on the behaviour of the periosteum of long bones and craniofacial bones, using metallic periosteum markers, have shown that the periosteum has a distinct migration along the bony surface, which is supposed to be related to the growth of the underlying bones (Theunissen, 1973; Roskjaer, 1977; Koskinen-Moffett et al.,1981) Investigations of long bones (McLain and Vig, 1983, Kuijpers-Jagtman et al., 1988) and craniofacial bones (Moss, 1960, Hellquist, 1972) have shown that periosteal manipulation influences the growth of bony structures. In rat calvaria accelerated fusion of sutures was found after resection of the periosteum (Moss, 1960). Hellquist (1972) reported increased bone deposition after periosteal resection. From these studies it was concluded that the periosteum plays a rôle in the regulation of bone growth, probably by a biomechanical influence on related bony structures.

Previous publications (Wijdeveld et al., 1987a, b) reported upon the effect of palatal soft tissue surgery on tissue migration of the mucoperiosteum in Beagle dogs. These studies revealed that wound contraction in the mucoperiosteum, recorded as an approaching of the opposite wound margins at both sides of the denuded areas, occurred during the first two weeks after the operation. In these areas the effect was not compensated for later on. This contraction might increase tension in the mucoperiosteum, unless compensatory growth occurs elsewhere.

The aim of the present investigation was to study the mucoperiosteal migration pattern along the surface of the palatal bone after Von Langenbeck palatal surgery, based on the hypothesis that the migration pattern of the mucoperiosteum will be influenced by wound healing with subsequent changes of the palatal growth pattern. Therefore, the following questions were raised: does palatal surgery influence the transverse migration of the lateral parts of the mucoperiosteum and does this surgery influence the anterior migration of the mucoperiosteum anterior to the operation area. Because the influence of surgery on the tissues might be dependent on age and stage of development of the dentition, dogs of different ages were used. The timing of surgery corresponded with different stages of development of the dentition.

Material and methods

This study involved 33 Beagle dogs, divided at random into five groups. In the experimental groups, palatal surgery was performed at three stages of development, i.e. during the eruption of the deciduous dentition (group 1; n = 6; age 6 weeks), during the transition of the teeth (group 2; n = 7; age 16 weeks) and after the completion of the permanent dentition (group 3; n = 7; age 25 weeks). The animals of the sham group (n = 7) and the control group (n = 6) were 6 weeks old at the start of the study. All animals were followed until 37 weeks of age.

Surgical procedures

All surgical procedures were performed under general anaesthesia with 30 mg/kg Sodium Pentobarbital (60 mg/ml) after premedication with Thalamonal® (Fentanyl, 0.05 mg/ml + Droperidol 2.5 mg/ml) and 0.5 ml Atropine (Atropine Sulphate 0.5 mg/ml). The oral mucosa and the dentition were cleaned with Chlorhexidine Digluconate 1% in water. In addition 1.8 ml Xylocaine® (Lidocaine Hydrochloride 0.4 mg/ml + Adrenaline 0.0125 mg/ml) was injected into the palatal mucoperiosteum to avoid excessive bleeding during surgery.

In the experimental groups 1, 2 and 3 a soft tissue defect was created in the medial region of the palate by incising, elevating and removing an elliptical-shaped mucoperiosteal flap which had been drawn on the mucosa with Boney's Blue ink. This flap extended from a line just behind the cuspids to the dorsal margin of the hard palate (figure 1). In groups 1 and 2 the maximum width of the flap was one third of the transverse distance between the second deciduous molars; in group 3 this was one third of the transverse distance between the fourth premolars. On both sides relaxation incisions adjacent to the posterior teeth were made and the remaining palatal mucoperiosteum was elevated from the underlying bone with a small raspatory. The major palatine neurovascular bundle was not damaged during the operation. The soft tissue defect was closed in the medial region of the palate and sutured in one layer with 4-0 Vicryl® . The denuded bony surfaces adjacent to the posterior teeth were left open to heal by secondary epithelialization.

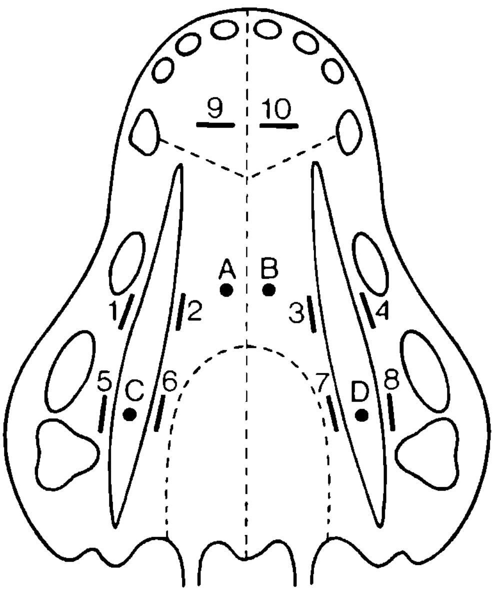

Figure 1: Schematic drawing of the palate and the dentition of a 6 weeks old Beagle dog. The denuded areas after the operation are shown. The positions of the bone markers (A-D) and the mucoperiosteum markers (1-10) are also shown

According to the method of Björk (1968), Tantalum bone markers (length 1.5 mm, diameter 0.5 mm) were inserted in the hard palate; two in the anterior region and two in the posterior region (figure 1). Then the soft tissue defect was closed and mucoperiosteum markers (pieces of Ormco® ligature wire, length 2-3 mm, diameter 0.08 mm) were placed (figure 1). The markers were placed in the deeper layers of the mucoperiosteum through an injected hypodermic needle.
In the sham group only an incision in the medial region and two lateral incisions were made after which the mucoperiosteum was elevated from the bone, replaced and sutured. In the control group no surgery was performed. Both the sham group and the control group were provided with bone markers and mucoperiosteum markers as in the experimental groups.
During the period of rapid growth the hard palate showed a downward drift by apposition at the oral side and resorption at the nasal side of the palatal bone. This imposed restrictions on the time the bone markers could be used; after about 6 to 12 weeks they were expelled into the nasal cavity. Therefore, subsequent series of bone markers were inserted in all animals every five weeks during the period of rapid growth, while the old bone markers were still in position. This was done while the animals were under general anaesthesia for the radiographic procedure described below. The measurements were continued by changing to subsequent bone markers; the radiograph was measured twice, once with earlier and once with later inserted bone markers. Continuity of the measurements was achieved by using the increment method. When no stable bone marker was available, the measurement was excluded from the study.
At the end of the experimental period the animals were sacrificed. The position of the mucoperiosteum markers was checked; markers which were embedded in the palatal bone were excluded from the study.

Radiographic procedure

After surgery dorso-ventral radiographs were taken under standardized conditions in a specially designed cephalostat (Maltha, 1982). The animals were fixed in the cephalostat with two ear rods and with a pin between the maxillary central incisors. The radiographs were taken with a Philips Practix® X-ray machine (Philips Nederland, The Hague, The Netherlands), set at 20 mA and 90 kV with focus-film distance 160 cm and object-film distance 3 cm. The radiographs were taken, using a small stand which was placed in the oral cavity in such a way that the film was parallel to the hard palate. The time of exposure varied from 3 to 4 seconds and was related to the body weight of the animals.
In group 1, the sham group and the control group the radiographic procedure was carried out at the age of 6, 7, 8, 9, 10, 11, 13, 15, 17, 19, 22, 26, 31 and 37

weeks, in group 2 at the age of 16, 17, 18, 19, 20, 21, 23, 25, 30 and 37 weeks and in group 3 at the age of 25, 26, 27, 28, 29, 30 and 37 weeks The differences between the measurement schedules of the youngest groups (1, sham and control) and the older groups of dogs (2 and 3) were compensated for by interpolation The values at the age of 21, 25 and 30 weeks were linearly interpolated to 22, 26 and 31 weeks respectively, i e the schedule of the youngest groups
To determine the error of the radiographic procedure, three dogs of 6, 16 and 25 weeks old respectively were placed five times in the cephalostat and radiographed

Parameters calculated

On the dorso-ventral radiographs the co-ordinates of the markers were digitized with an electronic measuring table. To determine the error of the measuring method, all radiographs were measured twice
To study the migration of the lateral wound margins along the bony surface, the increments of the transverse distances A-1, B-4, C-5 and D-8 were calculated To study the migration of the medial wound margins, the increments of the transverse distances A-2, B-3, C-6 and D-7 were calculated Transverse distances were defined as the distance between the projections of the markers on a line perpendicular to the midline of the palate. To study the antero-posterior migration of the mucoperiosteum in the area between the cuspids, the increments of the distances A-9 and B-10 parallel to the midline of the palate were calculated

Statistical analysis

To describe the migration of the mucoperiosteum relative to the bony palate, mean increments in mm/week of distances between bone markers and mucoperiosteum markers were calculated and plotted against the age of the animals
For each group of dogs the amount of migration of the mucoperiosteum along the bony palate during the early postoperative period (4 weeks) and during the entire period of the experiments was calculated by adding the increments concerned from first to last observation of the period under consideration For all transverse distances, migration towards the midline of the palate was recorded with negative numbers and migration away from the midline of the palate was recorded with positive numbers For both antero-posterior distances, anterior migration was recorded with positive numbers while posterior migration was recorded with negative numbers.

The results of all groups were compared with each other, using a one-way analysis of variance. In case of a significant result the t-test was used for further exploration of the differences between groups. The Bonferroni's correction was applied when several contrasts were tested on the same variable during the same period.

Results

Error of the method

The total error of the method is made up of an error of the radiographic procedure, due to inaccurate positioning of the dogs in the cephalostat, and a measurement error, due to inexact definition of the markers as well as inaccuracy of the measuring instrument.
For the transverse distances both the total error and the measurement error were found to be about 0.1 mm (standard deviation of the error). For the antero-posterior distances the total error was found to be about 0.5 mm, including the measurement error which was about 0.3 mm.
Therefore, it was concluded that errors in the transverse distances depended largely upon measurement errors, while errors in the antero-posterior distances were partly due to inaccuracy of the radiographic procedure.

Migration pattern of the mucoperiosteum

For all distances the sham group showed generally the same pattern as the control group except for a small initial effect during the first week after the operation.
The transverse distances A-1, B-4 and C-5, D-8 represented the migration of the mucoperiosteum laterally from the denuded bony surfaces (lateral wound margins) in the anterior and posterior region of the palate respectively. In the control group and in group 3 (25 weeks surgery) the mucoperiosteum in these areas showed some lateral migration until maturity. Group 1 (6 weeks surgery) and group 2 (16 weeks surgery) showed a migration pattern which was comparable to that of the control group except for the first month after the operation. During this period the lateral wound margins showed minor migration towards the midline of the palate. As an example the increments of distance A-1 plotted against the age of the animals are given in figure 2.

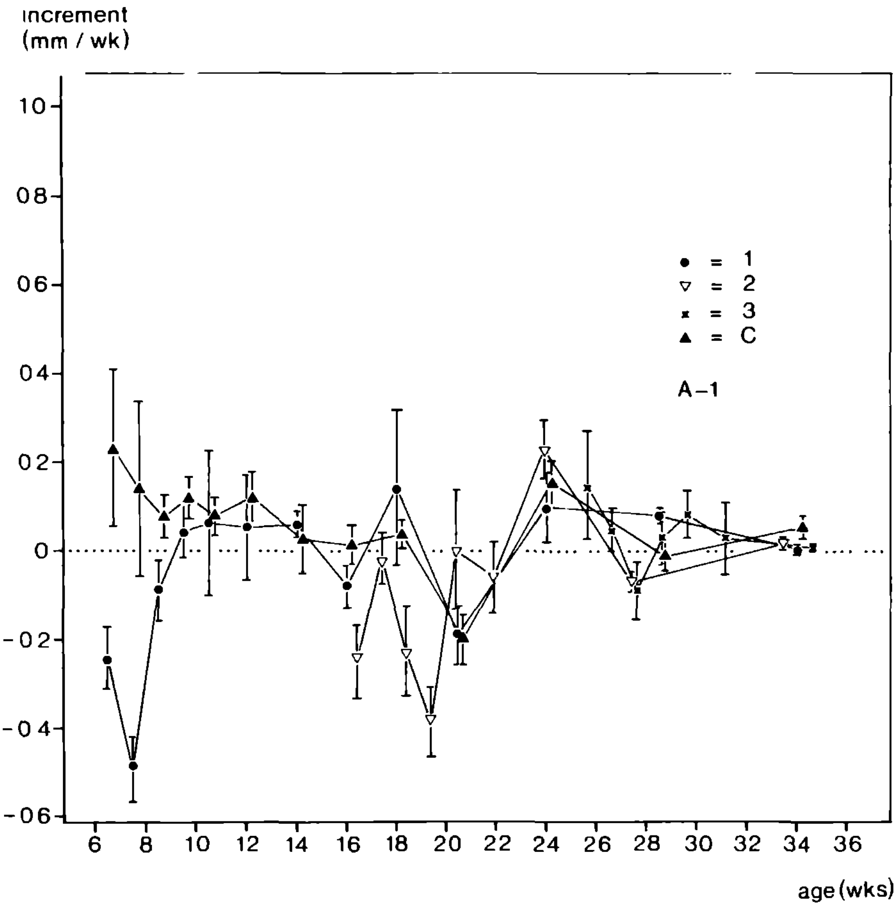

Figure 2: Distance A-1. Increments in mm/week (mean and SEM) plotted against the age of the animals of groups 1, 2, 3 and the control group. Ages are given in weeks. The value of an increment is plotted at the midpoint of the increment period.

The transverse distances A-2, B-3 and C-6, D-7 represented the migration of the mucoperiosteum medially from the denuded bony surfaces (medial wound margins) in the anterior and posterior regions of the palate respectively. In the control group the distances in the anterior region showed only minor changes while in the posterior region minor lateral migration of the mucoperiosteum was found until maturity. All experimental groups showed a migration pattern comparable to the control group except for the period soon after the operation. A lateral migration towards the denuded areas was found during the first week after the operation. As an example the increments of distance B-3 plotted against the age of the animals are given in figure 3.

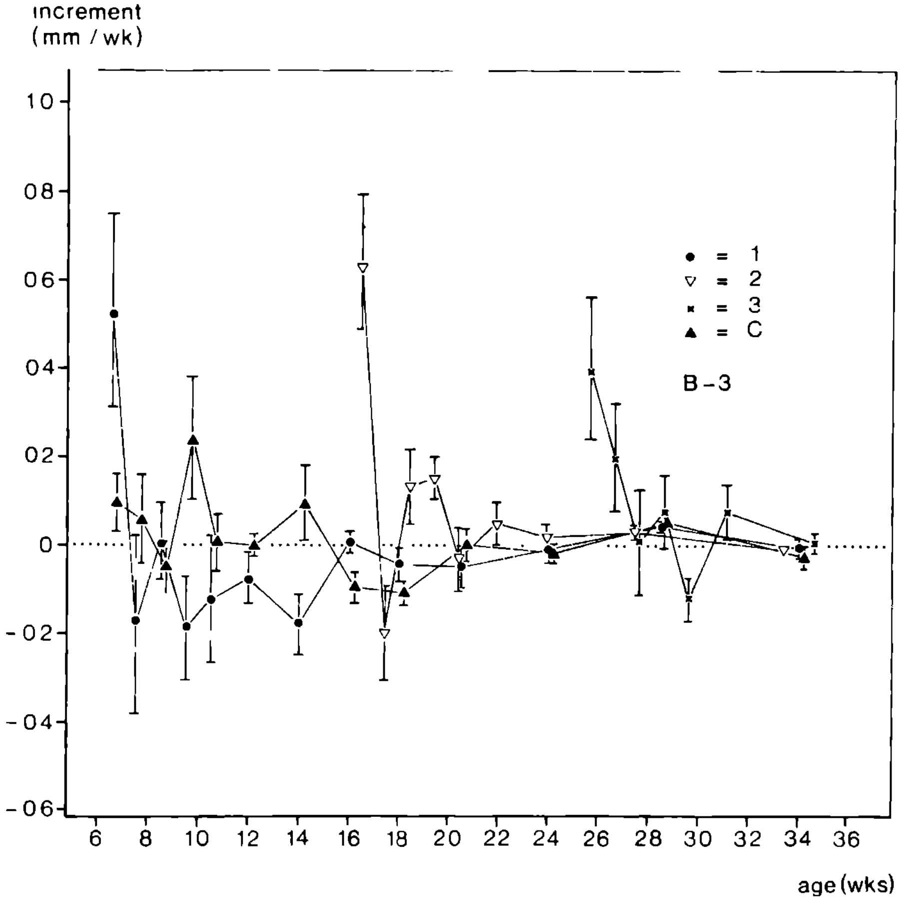

Figure 3: Distance B-3. Increments in mm/week (mean and SEM) plotted against the age of the animals of groups 1, 2, 3 and the control group. Ages are given in weeks. The value of an increment is plotted at the midpoint of the increment period.

The distances A-9 and B-10 represented the antero-posterior migration of the palatal mucoperiosteum in the cuspid area. In the control group this mucoperiosteum showed a relatively large anterior migration which diminished with the age of the animals. Group 1 (6 weeks surgery) and group 3 (25 weeks surgery) showed a migration pattern comparable to the control group. Group 2 (16 weeks surgery) showed a decreased anterior migration during the early period after the operation. This effect was not compensated for later on and persisted until maturity.

Amount of migration of the mucoperiosteum

The amount of migration during the early postoperative period and during the entire experimental period is presented in tables 1 to 4.

Table 1: Changes in distances between bone markers and mucoperiosteum markers in mm (mean and SEM) for group 1, the sham group and the control group. Results of the t-test are given. Period 6-10 weeks.

distance	group 1	sham(S)	control(C)	1 vs C	S vs C
	mean SEM	mean SEM	mean SEM		
A-1	–0.78 ± 0.14	0.09 ± 0.48	0.57 ± 0.28	**	ns
B-4	–0.18 ± 0.23	0.00 ± 0.19	0.54 ± 0.25	ns	ns
C-5	–0.12 ± 0.12	0.14 ± 0.11	0.05 ± 0.20	ns	ns
D-8	–0.27 ± 0.12	0.30 ± 0.14	0.54 ± 0.11	**	ns
A-2	0.21 ± 0.19	–0.40 ± 0.19	0.09 ± 0.25	ns	ns
B-3	0.47 ± 0.33	0.16 ± 0.28	0.35 ± 0.19	ns	ns
C-6	–0.16 ± 0.15	–0.53 ± 0.23	0.06 ± 0.12	ns	ns
D-7	0.22 ± 0.15	0.36 ± 0.21	0.10 ± 0.10	ns	ns
A-9	2.94 ± 0.39	3.50 ± 0.51	2.93 ± 0.42	ns	ns
B-10	2.88 ± 0.36	2.49 ± 1.13	2.91 ± 0.33	ns	ns

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
$P < 0.01$

The sham group did not show any significant difference with the control group during these periods. Therefore, comparisons between the experimental groups and the sham group were not included.
The results of group 1 (6 weeks surgery), the sham group and the control group from 6 to 10 weeks of age are given in table 1 and those from 6 to 37 weeks in table 2. The transverse distances A-1 and D-8 showed significant differences between group 1 and the control group during the early period after the operation. In group 1 the lateral wound margins migrated somewhat towards the midline of the palate whereas the control group showed a minor lateral migration. This migration pattern persisted during the entire period of the experiments.
The results of group 2 (16 weeks surgery) from 16 to 20 weeks of age are given in table 3. In this group the medial wound margins migrated away from the midline of the palate towards the denuded areas, whereas in this area in the control group hardly any migration was observed (distances B-3, C-6 and D-7). Furthermore, a significantly reduced anterior migration of the mucoperiosteum in the cuspid

Table 2: Changes in distances between bone markers and mucoperiosteum markers in mm (mean and SEM) for group 1, the sham group and the control group. Results of the t-test are given. Period 6-37 weeks.

distance	group 1	sham(S)	control(C)	1 vs C	S vs C
	mean SEM	mean SEM	mean SEM		
A-1	–0.12 ± 0.63	0.26 ± 0.74	1.34 ± 0.49	ns	ns
B-4	0.60 ± 0.70	0.60 ± 0.79	0.80 ± 0.43	ns	ns
C-5	–0.27 ± 0.43	1.53 ± 0.39	1.49 ± 0.65	ns	ns
D-8	–0.90 ± 0.42	2.03 ± 0.37	1.28 ± 0.48	**	ns
A-2	–0.57 ± 0.47	–0.12 ± 0.53	0.31 ± 0.43	ns	ns
B-3	–0.17 ± 0.48	0.41 ± 0.51	0.25 ± 0.37	ns	ns
C-6	–0.79 ± 0.36	0.14 ± 0.41	1.19 ± 0.36	**	ns
D-7	–0.35 ± 0.46	1.00 ± 0.36	0.72 ± 0.33	ns	ns
A-9	11.86 ± 0.78	11.07 ± 0.75	13.42 ± 0.73	ns	ns
B-10	12.53 ± 0.62	10.95 ± 1.29	13.42 ± 0.63	ns	ns

ns P ≥ 0.05
0.01 ≤ P < 0.05
P < 0.01

Table 3: Changes in distances between bone markers and mucoperiosteum markers in mm (mean and SEM) for group 2 and the control group. Results of the t-test are given. Period 16-20 weeks.

distance	group 2	control(C)	2 vs C
	mean SEM	mean SEM	
A-1	–1.02 ± 0.18	–0.11 ± 0.10	**
B-4	–0.29 ± 0.22	–0.18 ± 0.10	ns
C-5	–0.42 ± 0.40	–0.42 ± 0.30	ns
D-8	0.20 ± 0.26	–0.12 ± 0.14	ns
A-2	0.21 ± 0.23	–0.14 ± 0.13	ns
B-3	0.91 ± 0.22	–0.30 ± 0.07	**
C-6	0.75 ± 0.19	–0.06 ± 0.10	**
D-7	1.21 ± 0.29	0.03 ± 0.07	**
A-9	0.93 ± 0.33	2.21 ± 0.22	**
B-10	0.92 ± 0.24	2.21 ± 0.23	**

ns P ≥ 0.05
0.01 ≤ P < 0.05
P < 0.01

Table 4: Changes in distances between bone markers and mucoperiosteum markers in mm (mean and SEM) for group 3 and the control group. Results of the t-test are given. Period 25-29 weeks.

distance	group 3	control(C)	3 vs C
	mean SEM	mean SEM	
A-1	0.14 ± 0.16	-0.05 ± 0.13	ns
B-4	0.09 ± 0.14	0.38 ± 0.05	ns
C-5	-0.47 ± 0.25	0.38 ± 0.13	**
D-8	0.17 ± 0.14	0.29 ± 0.09	ns
A-2	0.39 ± 0.20	0.05 ± 0.06	ns
B-3	0.91 ± 0.26	0.22 ± 0.09	*
C-6	0.22 ± 0.24	0.24 ± 0.08	ns
D-7	0.98 ± 0.24	0.35 ± 0.08	*
A-9	0.25 ± 0.64	0.85 ± 0.13	ns
B-10	0.52 ± 0.35	0.73 ± 0.10	ns

ns $P \geq 0.05$
* $0.01 \leq P < 0.05$
** $P < 0.01$

area was found (distances A-9 and B-10). During the entire period of the experiments of group 2 (16 to 37 weeks) the described migration pattern persisted (table not shown).

The results of group 3 (25 weeks surgery) from 25 to 29 weeks of age are given in table 4. In the control group the mucoperiosteum, corresponding with the areas of both medial and lateral wound margins, migrated somewhat away from the midline of the palate. In group 3 this migration increased for the medial wound margins (distances B-3 and D-7). During the entire period of the experiments of group 3 (25 to 37 weeks) this migration pattern persisted (table not shown).

Discussion

In the present study the migration of the mucoperiosteum along the palatal bone, after surgery at different stages of development, was investigated radiographically with the aid of metallic bone implants and mucoperiosteum implants. The reliability of this method was studied by Theunissen (1973). His study showed that the periosteum of the rat tibia moved along the bony surface during growth. Metallic periosteum markers and tattoo points in the periosteum next to these markers maintained their position to each other, but migrated with respect to stable metallic bone markers.

It is difficult to compare the results of the present study with implant studies on other craniofacial bones or long bones, because the palatal periosteum differs from periosteum at other sites by the firm connection to the palatal mucosa. Therefore, in the present paper the term mucoperiosteum was used for the palate while periosteum was used for other bones.

In the control animals the migration of the palatal mucoperiosteum showed a symmetrical pattern. The migration was, however, not the same in all areas, e.g. the antero-posterior migration in the cuspid area was much larger than the lateral migration in any other area. These observations are in agreement with those of Kuijpers-Jagtman et al. (1988) and Theunissen (1973), who reported upon periosteal migration along long bones and with those of Koskinen-Moffett et al. (1981) and Roskjaer (1977), who studied this migration on other craniofacial bones. They all concluded that the rate and direction of periosteal migration is dependent on the growth rates at the growth sites of a bony structure and the relative position of the periosteum marker with respect to those growth sites. Because bone growth in the antero-posterior direction of the palate was faster than in the lateral direction (Wijdeveld et al., 1988), substantial anterior migration of the mucoperiosteum in the cuspid area was to be expected.

Lateral growth of the palatal bones partly takes place in the mid-palatal suture, but also bone remodelling in the alveolar structures, causing buccal drift, might be involved. Thus, the transverse migration pattern is expected to be unevenly distributed over the palatal bones. Mucoperiosteum close to the dentoalveolar structures will tend to move laterally, while in the medial region the migration will be in a medial direction. Somewhere in-between a so-called neutral area (Theunissen, 1973) is expected, where no migration with respect to the bony surface will be found.

The mucoperiosteum markers 1 to 8 were placed in the more lateral parts of the palatal mucoperiosteum. In the control group they tended to move in a lateral direction or they remained stationary, indicating that they were positioned laterally from the neutral area.

In the experimental groups wound contraction was superimposed on the normal mucoperiosteal movement. In group 1 (6 weeks surgery) the migration of the medial mucoperiosteum markers (2, 3, 6 and 7) did not differ significantly from the controls, migrating somewhat laterally. The lateral markers (1, 4, 5 and 8) in group 1, however, moved medially, while the markers of the control group moved laterally. This difference was significant for two of the distances (table 1), indicating that wound contraction was mostly located adjacent to the dento-alveolar structures and not in the medial region of the palate. This was in agreement with findings, reported by us previously (Wijdeveld et al., 1988), that surgery at 6 weeks of age did not influence suture growth during the first weeks after the operation. The reaction in the dentoalveolar region can be of two kinds: first an additional tissue augmentation or stretching of the mucoperiosteum and second a tipping or medial displacement of the teeth; both will lead to the same result. Studies of dental casts and histological evaluation of palatal tissues after this kind of palatal surgery might provide more insight into the reaction in this region.

In group 2 (16 weeks surgery) the medial wound margins in most cases migrated significantly more laterally than in the controls, where they were more or less stable (table 3). This lateral migration might be compensated by tissue augmentation or stretching of the mucoperiosteum in the medial region. Stretching would change the biomechanical circumstances around the suture. This might provide an explanation for the decreased suture growth during the first weeks after palatal surgery on dogs at the age of 16 weeks, reported upon previously (Wijdeveld et al., 1988). As the operation site was also adjacent to the dentoalveolar structures, an influence on these structures was expected as well. The different migration pattern in the antero-posterior direction as measured in group 2 from 16 to 20 weeks of age could not be explained.

In group 3 (25 weeks surgery) the migration pattern of the medial wound margins was systematically different from the control group; two of the distances indicated that these margins moved more laterally in the experimental group (table 4). The growth of the mid-palatal suture had decreased considerably at that age and was not influenced by the palatal surgery (Wijdeveld et al., 1988). The lateral wound margins remained stable in most cases, while in the control group some lateral displacement was still found. At that age the permanent dentition was complete and the dentoalveolar structures were stable.

The results of the present study showed that the palatal mucoperiosteum has a distinct migration pattern along the bone, which is unevenly distributed and seems to be related to the growth of the palatal bone and the dentoalveolar structures. The palatal surgery changed this migration pattern. These changes were most pronounced in the groups which were operated on at the age of 6 or 16 weeks, i.e. before or during the transition of teeth and before the growth in the mid-palatal suture had ceased.

If the mucoperiosteum plays a comparable rôle in the regulation of the growth of the palatal bone and the dentoalveolar structures, as shown for the periosteum of long bones (e.g. McLain and Vig, 1983; Kuijpers-Jagtman et al., 1988), then manipulation of the mucoperiosteum during growth can disturb this regulation.

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CHAPTER 6

Maxillary arch dimensions after palatal surgery at different ages on Beagle dogs

Wijdeveld, Maarten G.M.M.
Grupping, Ellen M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.

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Maxillary arch dimensions after palatal surgery at different ages on Beagle dogs

Abstract

Changes of maxillary arch dimensions were studied longitudinally until maturity after palatal surgery at different ages. 37 Beagle dogs were used, divided into three experimental groups, a sham group and a control group. At the age of 6, 16 or 25 weeks in the experimental groups a soft tissue cleft was created in the medial region of the palate, relaxation incisions were made and the mucoperiosteum was elevated and closed in the midline, leaving two areas of denuded bone adjacent to the dentition. Dental casts were made regularly until the age of 37 weeks and maxillary arch dimensions were studied.
Surgery performed before or during the transition of teeth did not change maxillary arch dimensions in the deciduous dentition, but after the transition the arch width in the premolar region was decreased. Surgery performed after completion of the permanent dentition did not change maxillary arch dimensions.
Delay of palatal surgery, until the transition of teeth was completed, favoured normal development of the maxillary dental arch.

Introduction

Surgical procedures, as used in human cleft palate surgery, can disturb palatal growth and maxillary arch dimensions (for a review see Berkowitz, 1978), whereas unoperated cleft palate cases have a growth pattern close to that of non-cleft individuals, except for the clefted area itself (Van Limborgh, 1964; Ortiz-Monasterio et al., 1966; Bishara et al., 1985). From studies by Dahl (1970) and Bishara (1973) it was concluded that palatal surgery does not influence the antero-posterior skeletal relationships, but does influence the transverse skeletal relationships. Furthermore, the effects were more pronounced on the dentition than on the bony structures (Bishara et al., 1985).
Other authors have suggested a correlation between the age at which surgery is performed and the effect on palatal and dentoalveolar growth (Longacre et al., 1968; Jorgenson et al., 1984). After early closure of unilateral clefts a decreased maxillary arch width was found (Ranta et al., 1974; Robertson and Fish, 1975),

while arch width was nearly normal when closure of the palatal cleft was postponed until the age of 4 years (Jorgenson et al., 1984), or even until maturity (Schweckendiek, 1978).

The results of clinical studies vary widely with respect to the ultimate effect of palatal surgery on the dentoalveolar structures. This may be due to the number of variables in these studies, such as type and extension of the cleft, type and timing of surgery, the skill of the surgeon and other treatment procedures. In animal experiments it is possible to control these variables to a certain extent. The presence of a bony palatal cleft is not essential in such studies, since closure of palatal clefts in the clinical setting is achieved by mucoperiosteal manipulation alone and not by osseous surgery. Kremenak et al. (1967, 1970) and Kremenak (1984) concluded in a series of studies, based on the work of Herfert (1958), that unilateral excision of a strip of mucoperiosteum adjacent to the posterior deciduous teeth resulted in inhibition of maxillary growth. These conclusions were based on measurements on the dental arch and on the medial raphe. Both maxillary growth and the dentition could, however, be affected by the surgery. It is therefore necessary to investigate these phenomena separately. In a previous bone marker study in dogs (Wijdeveld et al., 1988a) it was shown that soft tissue palatal closure had a minor influence on growth in palatal sutures, especially when surgery was performed before or during the eruption of the permanent posterior teeth. It was assumed that surgery mainly affects the dentition; this assumption will be investigated in the present study.

Because the influence of surgery on the dentition might be dependent on age and stage of development of the dentition, the surgery was performed at different ages.

Material and methods

The study involved 37 Beagle dogs, divided at random into five groups. In the experimental groups palatal surgery was performed at three stages of development, i.e. during eruption of the deciduous dentition (group 1; n = 10; age 6 weeks), during transition of the teeth (group 2; n = 7; age 16 weeks) and after completion of the permanent dentition (group 3; n = 7; age 25 weeks). The animals of the sham group (n = 7) and the control group (n = 6) were six weeks old at the start of the study. All animals were followed until 37 weeks of age.

Surgical procedures

All surgical procedures were performed under general anaesthesia of 30 mg/kg

Sodium Pentobarbital after premedication with 0.5 ml Thalamonal® (Fentanyl 0.05 mg/ml + Droperidol 2.5 mg/ml; Jansen Pharmaceutica, Beerse, Belgium).
In the experimental groups a standardized elliptical soft tissue cleft was created in the medial region of the palate by excising a mucoperiosteal flap. On both sides relaxation incisions were made adjacent to the posterior teeth, the mucoperiosteum was elevated from the bone and the soft tissue cleft was closed, leaving two areas of denuded bone adjacent to the dentition (figure 1). A more detailed description of the surgical procedure was given previously (Wijdeveld et al., 1987).
In the sham group a comparable procedure was followed, but no flap in the medial region of the palate was removed. In this group only an incision in the medial region and two lateral incisions were made, after which the mucoperiosteum was elevated, replaced and sutured.
In the control group no surgery was performed.

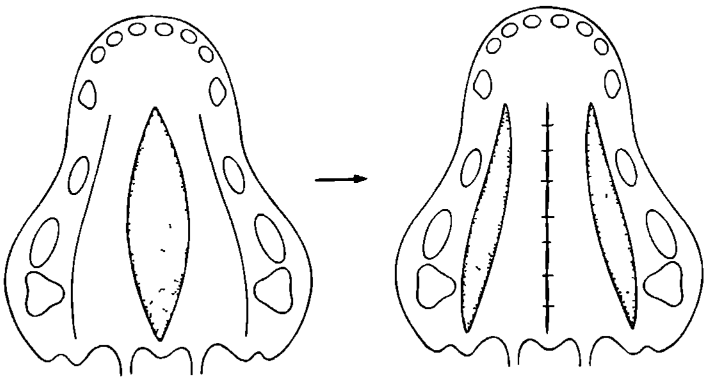


Figure 1 Schematic drawing of the palate and the surgical procedure in a 6-week-old Beagle. A mucoperiosteal flap was removed in the medial region of the palate and two lateral incisions were made The remaining mucoperiosteum was elevated, repositioned and sutured in the midline, leaving two areas of denuded bone at the lateral aspect of the palate

Dental casts

At the start of the study and prior to surgery the first series of alginate impressions of the upper arch was made and poured out within a few hours. In group 1, the sham group and the control group impressions were made at the age of 6, 11, 17, 22, 26, 31 and 37 weeks. In group 2 and group 3 this was done at the age of 16, 21, 25, 30 and 37 weeks, and 25, 30 and 37 weeks respectively. The impressions were made under general anaesthesia as described for the surgical procedure. On the dental casts measuring points were placed with a pencil; the crista measuring points were placed at the junction of the mesial crista with the cervical crown contour.

For the deciduous dentition (6 to 17 weeks) the following measuring points were defined (figure 2):

m3 top	:	tops of the right and left third deciduous molars;
m2 top	:	tops of the right and left second deciduous molars;
m1 top	:	tops of the right and left first deciduous molars;
c crown	:	most medial limitation of the clinical crowns of the right and left deciduous cuspids;
i midpoint	:	midpoint between the deciduous central incisors.

For the permanent dentition (21 to 37 weeks) the following measuring points were defined (figure 3):

M1 top	:	tops of the right and left first permanent molars;
P4 top	:	tops of the right and left fourth premolars;
P3 top	:	tops of the right and left third premolars;
P3 crista	:	mesial cristae of the right and left third premolars;
P2 top	:	tops of the right and left second premolars;
P2 crista	:	mesial cristae of the right and left second premolars;
P1 top	:	tops of the right and left first premolars;
P1 crista	:	mesial cristae of the right and left first premolars;
C top	:	tops of the right and left permanent cuspids;
C crista	:	mesial cristae of the right and left permanent cuspids;
I midpoint	:	midpoint between the permanent central incisors.

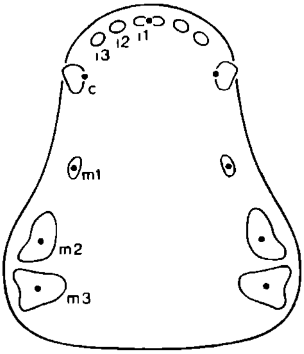


Figure 2: Schematic drawing of the deciduous dentition with measuring points indicated.

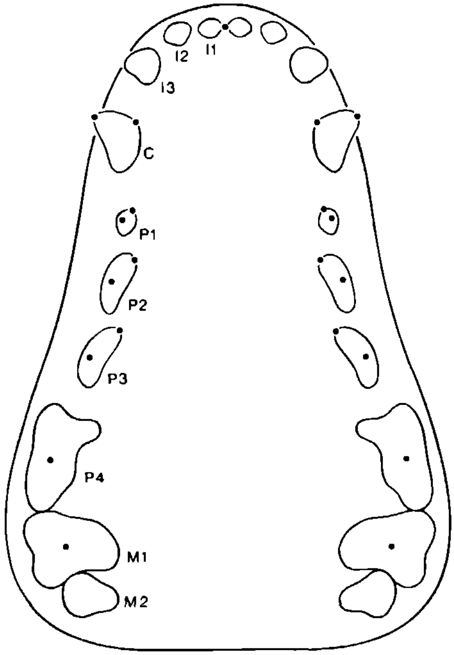


Figure 3: Schematic drawing of the permanent dentition with measuring points indicated.

Error of the method

To determine the error of the impression procedure, in two dogs with a deciduous dentition (6 and 16 weeks) and in two dogs with a permanent dentition (25 and 37 weeks) series of five impressions were taken at one session and poured out. To determine the error of placement of the measuring points, these series of casts were provided with measuring points with intervals of one week. To determine the measurement error, five longitudinal series of dental casts of control animals were measured twice with an interval of one week.

Measurements

The measurements were carried out on fully emerged teeth only; therefore, it was inevitable that during the transition some data were missing. The co-ordinates of the measuring points were digitized by means of the Optocom (Van der Linden et al., 1972).

For the deciduous dentition the following distances were calculated:

Transverse :	m3 top width (right m3 top - left m3 top);
	m2 top width (right m2 top - left m2 top);
	m1 top width (right m1 top - left m1 top);
	c crown width (right c crown - left c crown).
Antero-posterior :	right deciduous arch depth (right m3 top - i midpoint);
	left deciduous arch depth (left m3 top - i midpoint).

For the permanent dentition the following distances were calculated:

Transverse :	M1 top width (right M1 top - left M1 top);
	P4 top width (right P4 top - left P4 top);
	P3 top width (right P3 top - left P3 top);
	P3 crista width (right P3 crista - left P3 crista);
	P2 top width (right P2 top - left P2 top);
	P2 crista width (right P2 crista - left P2 crista);
	P1 top width (right P1 top - left P1 top);
	P1 crista width (right P1 crista - left P1 crista);
	C top width (right C top - left C top);
	C crista width (right C crista - left C crista).
Antero-posterior :	right permanent arch depth (right M1 top - I midpoint);
	left permanent arch depth (left M1 top - I midpoint).

Statistical procedures

Aiming at a compensation for size and shape differences between different dogs, the maxillary dimensions of all individual dogs were standardized at the start of the study. Therefore, in the control group the mean values of four transverse and two antero-posterior distances were calculated as standards at the age of 6, 16 and 25 weeks. For the dogs of group 1 and the sham group the 6 weeks standards were used to determine their standardization factor. For the dogs of groups 2 and 3 respectively the 16 and 25 weeks standards determined their individual factor. The individual standardization factor was defined as the quotient of the mean value of the control group and the individual initial value. The standardization was used during the entire period of the experiments. The differences in the measurement schedule of the youngest groups and the older groups of dogs were compensated for by interpolation. The values at the age of 16, 21, 25 and 30 weeks respectively were linearly interpolated to 17, 22, 26 and 31 weeks, i.e. the schedule of the youngest groups.

The standardized and sometimes interpolated distances were plotted against the age of the animals. The curves of all groups were compared mutually, using a one-way analysis of variance. In case of significant results, Tukey's multiple comparisons test was used for further exploration of the differences between the groups.

Results

Error of the method

The total error of the method is made up of an error of the impression procedure, an error of the placement of the measuring points and a measurement error, due to inexact digitizing of the measuring points as well as inaccuracy of the measuring instrument. No systematic deviations were found with respect to age or distance. The total error was found to be about 0.15 mm; the measurement error was found to be about 0.07 mm.

The accuracy of the method was considered acceptable.

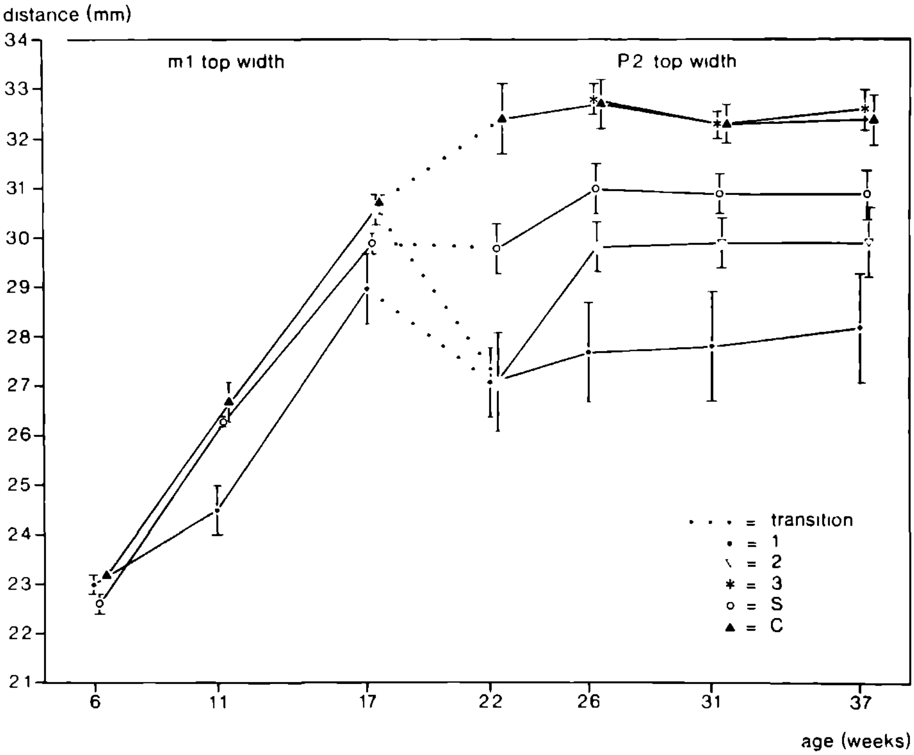


Figure 4: Growth curve for all groups of the distance m1 top width from 6 to 17 weeks of age and the distance P2 top width from 22 to 37 weeks of age. Distances (mean and SEM) are given in mm, ages are given in weeks.

Deciduous dentition

From 6 to 17 weeks of age all transverse and antero-posterior distances increased in group 1, the sham group and the control group. Between these groups no significant differences were found except for the transverse distance m1 top width at 11 weeks of age. This distance was significantly smaller in group 1 than in the control group. The growth curve of this distance is shown in figure 4 (page 83).

Permanent dentition

From 22 to 37 weeks of age the control group showed a minor increase (0-1 mm) for most transverse distances, except for the P4 top width which increased about 5 mm; the antero-posterior distances increased about 3 mm.
The results of the statistical procedures for the period from 22 to 37 weeks of age are given in table 1; the sham group is not mentioned in this table because the statistical analysis showed that no significant differences with the control group existed. During this period group 3 showed no significant differences with either the sham group or the control group.

Table 1: Results of Tukey's multiple comparisons test for comparison of groups 1, 2, 3, and the control group in the permanent dentition. Differences are given at the $P < 0.05$ level. Ages are given in weeks.

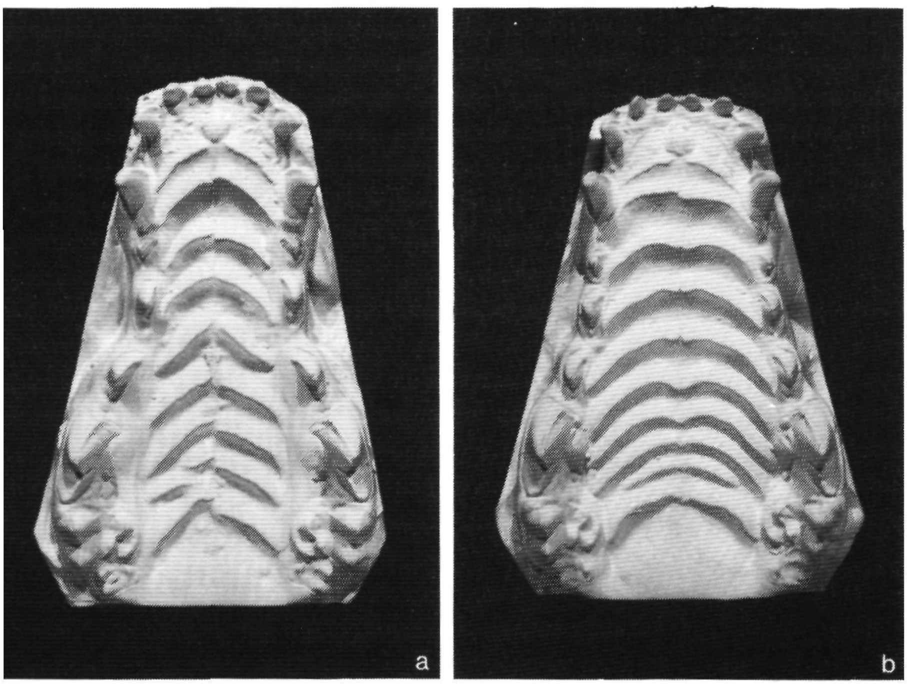
distance	age 22	age 26	age 31	age 37
M1 top width	ns	2 < C,1	2 < 1	2 < 1
P4 top width	ns	ns	ns	ns
P3 top width	1,2 < C	1,2 < C,3	1,2 < C,3	1,2 < C,3
P3 crista width	–	1,2 < C,3	1,2 < C,3	1,2 < C,3
P2 top width	1,2 < C	1 < C,3	1 < C,3	1 < C,3
P2 top width		2 < 3		
P2 crista width	–	1,2 < C,3	1,2 < C,3	1,2 < C,3
P1 top width	1 < C,2	1 < C,2,3	1 < 2	ns
P1 crista width	ns	ns	ns	ns
C top width	–	ns	ns	ns
C crista width	–	ns	ns	ns
right arch depth	2 < 1	2 < 1	2 < 1	2 < 1
left arch depth	ns	ns	2 < 1	2 < 1

Groups: 1,2,3,C
– : missing due to transition
ns : not significant

ıfter the transition of teeth (from 22 weeks on) in groups 1 and 2 the transverse istances between the premolars, as measured on first, second and third premolar ɔps and cristae, were in general significantly reduced as compared to the control roup and group 3. As an example, the growth curves of the P2 top width and its redecessor m1 top width are shown in figure 4. The growth curve of the sham roup also showed a decreased arch width from 22 weeks on, but the effect was maller than in groups 1 and 2. From 22 to 37 weeks of age no significant diffe- ences between groups were observed, neither for the fourth premolar width nor ɔr the permanent cuspid width. During this period the first permanent molar ʼidth in group 2 was significantly reduced as compared to group 1.

n the permanent dentition the antero-posterior distances did not show any sig- ificant differences between the experimental groups on the one hand and the ham group or the control group on the other hand. From 22 to 37 weeks of age ı group 2 the right arch depth was significantly smaller than in group 1. That pplied for the left side only from 31 to 37 weeks of age.

'he above-mentioned findings in the permanent dentition are demonstrated in ıgure 5, which shows maxillary dental casts at 37 weeks of age of a dog of roup 1 (figure 5a) and one of the control group (figure 5b).



ïgure 5: Photographs of the palatal aspect of dental casts of a dog of group 1 (figure 5a) and one f the control group (figure 5b) at 37 weeks of age.

Discussion

In the present study, changes in maxillary arch dimensions in relation to age-dependent surgery were investigated longitudinally on dental casts. A non-cleft Beagle model was used, since the presence of a bony palatal cleft was not essential for the aim of the study.

Palatal surgery performed at 6 or 16 weeks of age (groups 1 and 2) did not change the maxillary arch dimensions in the deciduous dentition, but from the transition on, the maxillary arch width appeared to be disturbed. These disturbances persisted until maturity. This is in agreement with clinical conclusions about a severe occlusal impairment which occurred during the transition (Bergland and Sidhu, 1974). Palatal surgery performed after the transition of posterior teeth (group 3) did not change any maxillary arch dimension in the permanent dentition. It was therefore concluded that delay of palatal surgery, until the transition was completed, was more favourable for the dentition than surgery performed before or during the transition.

Elevation of the mucoperiosteum without excision of tissue (sham group) did not result in changes of maxillary arch dimensions that differed significantly from the control group. Nevertheless, the growth curve of the transverse distance between the second premolars of the sham group as shown in figure 4 suggested that such manipulation of the mucoperiosteum also might affect the maxillary dental arch during the transition.

In groups 1 and 2 the transverse distances between the first, second and third premolars were reduced, while distances between the fourth premolars and first permanent molars in most cases did not differ significantly from the control group. In Beagle dogs an open bite exists in the first, second and third premolar region, while more posterior permanent teeth erupt in a firm scissors bite. It was theorized that, due to this overlap, the fourth premolars and first permanent molars of the maxilla could maintain their normal position, while in the open bite premolar region this co-ordination mechanism could not compensate for unfavourable environmental factors introduced by the palatal surgery.

The transverse measurements between tops or cristae of corresponding teeth showed comparable results. Theoretically, measuring points on the top of teeth are further away from the centre of resistance of the tooth than measuring points at the junction of the mesial crista and the cervical crown contour. Therefore, comparable results of both types of measurements implicated that, in case of reduction of width, corresponding teeth migrated bodily or migrated by means of tipping with mesio-medial rotation or by a combination of these possibilities. Observation on the dental casts of the position of the premolars in experimental groups 1 and 2 suggested medial tipping of the teeth. The mechanism of this tooth migration will be studied in a histological study with a comparable experimental design.

In group 2 the right permanent arch depth, as shown in table 1, seemed to be reduced as compared to all other groups, although significant differences were found only between groups 1 and 2 The difference between the left and right arch depths at ages 22 and 26 weeks could, however, not be explained. The reduced arch width in group 2 is in agreement with the reduced anterior migration of the mucoperiosteum in the cuspid area from 16 to 20 weeks of age, reported previously (Wijdeveld et al., 1988b). These findings suggest that palatal surgery as performed in this study also might influence antero-posterior maxillary arch dimensions

It was concluded that palatal surgery mainly disturbed the transverse development of the maxillary dental arch, especially when the surgery was performed before or during transition of the posterior teeth.

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CHAPTER 7

Tissue response to palatal surgery at different ages on Beagle dogs

A HISTOLOGICAL STUDY

Wijdeveld, Maarten G.M.M.
Maltha, Jaap C.
Grupping, Ellen M.
De Jonge, Jaap
Kuijpers-Jagtman, Anne M.

Submitted for publication to Archives of Oral Biology

Tissue response to palatal surgery at different ages on Beagle dogs

A HISTOLOGICAL STUDY

Abstract

The tissue response of maxillary structures to mucoperiosteal manipulation at different ages was studied microscopically during the early period after the operation and at maturity. 32 Beagle dogs were used, divided into three experimental groups, a sham group and a control group. At the age of 6, 16 or 25 weeks in the experimental groups a soft tissue cleft was created in the medial region of the palate, relaxation incisions were made and the mucoperiosteum was elevated and closed in the midline, leaving two areas of denuded bone adjacent to the dentition. The animals were sacrificed 1, 2 or 3 weeks after the operation or at the age of 37 weeks. Serial sections of maxillary tissues were prepared, stained according to different techniques and histologically studied.
Two weeks after the operation the epithelium and connective tissue at the denuded bony areas were continuous. The scar tissue lacked elastic fibres, indicating a more rigid type of tissue. The palatal bone showed rapid trabecular bone deposition and the suture growth was normal. The periodontal ligament was connected to the mucoperiosteum. Cervicopalatal and apicobuccal bone resorption in the alveolar socket indicated medial tipping of the teeth. The different soft tissue composition persisted until maturity. In the areas where scar tissue had developed, a firm attachment by means of Sharpey's fibres from the mucoperiosteum to the palatal bone was found at the age of 37 weeks.
Palatal surgery performed at different ages resulted in highly comparable tissue reactions in the different groups. It is theorized that the different mechanical properties of scar tissue adjacent to the dentition and its attachment to the palatal bone might influence growth and development of dentoalveolar structures.

Introduction

A controversial side effect of surgical closure of cleft lip and palate is the apparent restriction of normal growth of midfacial and especially maxillary structures. The

primary closure of a cleft in the hard palate is achieved by manipulation of the mucoperiosteum, such as incising, elevating and shifting of the mucoperiosteum towards the cleft, leaving two areas of denuded bone adjacent to the posterior teeth. It had been shown that early wound healing of elevated and replaced mucoperiosteum showed evidence of a prolific cellular response of the mucoperiosteum and renewed osteogenic activity on the third day after the operation (Barro and Latham, 1981). Early wound healing of excisional wounds on the palatal mucoperiosteum showed a defect filled by coagulum, a pronounced inflammatory reaction and epithelial and connective tissue outgrowth from the wound margins, which re-established the continuity by forming an epithelial bridge (Dabelsteen and Kremenak, 1978; Fejerskov, 1972; Kahnberg and Thilander, 1982; Searls et al., 1979). All these studies dealt with the first few weeks of wound healing; no data were found of histological studies over a longer period. Since growth inhibition appeared to be a long term effect, it was felt that the tissue response to palatal surgery had to be studied over a longer period. Furthermore, all studies mentioned were restricted to the palatal mucoperiosteum and the underlying bony surface. No data were available about the tissue response of other maxillary growth sites, i.e. sutures and dentoalveolar structures. The questions as to which growth sites are concerned and which mechanisms are responsible for this growth inhibition are still unanswered, indicating the need for further investigation. In the present study the tissue response to palatal surgery was therefore investigated for different maxillary growth sites.
Studies in which bony clefts were created artificially are not mentioned because of possibly conflicting results due to the extensive trauma of creating such clefts. In our experimental design primary closure of a palatal cleft according to the Von Langenbeck technique was simulated on a non-cleft Beagle model by mucoperiosteal manipulation alone. The variation in timing of surgery was adjusted to the human situation by performing surgery at three stages of development, i.e. during the eruption of the deciduous dentition, during the transition of the teeth and after completion of the permanent dentition.

Material and methods

The experiments were performed on 32 Beagle dogs, divided at random into five groups. In the experimental groups 1, 2, and 3 palatal surgery was performed at three different stages of development, i.e. during the eruption of the deciduous dentition (group 1; 6 dogs; age 6 weeks), during the period of mixed dentition (group 2; 6 dogs; age 16 weeks) and after completion of the permanent dentition (group 3; 6 dogs; age 25 weeks). In the sham group (6 dogs) surgery was performed at the age of 6 weeks. The animals of the control group (8 dogs) were 6 weeks old at the start of the study.

The animals of the experimental groups and the sham group were premedicated with 0.5 ml Thalamonal® (Fentanyl 0.05 mg/ml + Droperidol 2.5 mg/ml; Jansen Pharmaceutica, Beerse, Belgium) and Atropine (Atropine Sulphate 0.5 mg/ml). General anaesthesia was achieved by an intravenous injection of 30 mg/kg Narcovet® (Sodium Pentobarbital 60 mg/ml; Apharmo, Arnhem, The Netherlands). The oral mucosa and the dentition were cleaned with Chlorhexidine digluconate 1% in water. In addition 1.8 ml Xylocaine® (Lidocaine hydrochloride 0.4 mg/ml + Adrenalin 0.0125 mg/ml; Astra Chemicals Benelux BV, Rijswijk, The Netherlands) was injected into the palatal mucoperiosteum to avoid excessive bleeding during surgery. In the experimental groups a standardized elliptical soft tissue defect was created in the medial region of the palate by excising a mucoperiosteal flap. On both sides relaxation incisions were made adjacent to the posterior teeth. The mucoperiosteum was then elevated from the underlying bone and the soft tissue cleft was closed in the midline, leaving two areas of denuded bone adjacent to the dentition (figure 1). A detailed description of the surgical procedures was given previously (Wijdeveld et al., 1987).
In the animals of the sham group a sagittal incision in the medial region and two sagittal incisions adjacent to the posterior teeth were made. The mucoperiosteum was then elevated from the underlying bone, replaced and sutured. In the control group no surgery was performed.
For the histological study the animals were sacrificed in pairs relatively soon after the operation or at maturity. For the different groups this was done at the following ages: group 1 and the sham group at 7, 8 or 37 weeks, group 2 at 18, 19 or 37 weeks and group 3 at 27, 28 or 37 weeks. The control animals were sacrificed in pairs at 8, 18, 27 or 37 weeks of age, the 8, 18 and 27 weeks old animals serving as controls for the 7 and 8, 18 and 19, 27 and 28 weeks old animals in the experimental groups respectively.

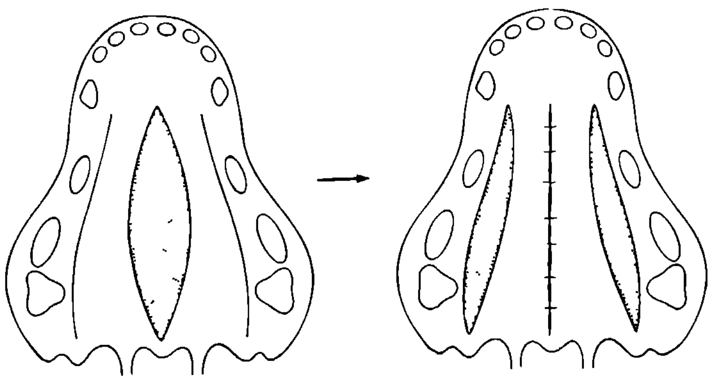


Figure 1: Schematic drawing of the palate and the surgical procedure in the experimental groups.

The animals were brought under general anaesthesia using 30 mg/kg Narcovet®, after which 0.5 mg/kg Heparin (Thromboliquine®; Organon Teknika, Boxtel, The Netherlands) was administered. After some minutes an overdose of Narcovet® was injected intravenously. The thorax of the animals was opened and the vascular system was perfused via the arch of the aorta with physiologic saline, followed by 4% neutral formaldehyde as a fixative.
After perfusion the maxillae were dissected and immersed in 4% neutral formaldehyde for another two weeks. They were then sawed into smaller blocks, decalcified in 20% Formic acid and 5% Sodium Citrate, dehydrated and embedded in Paraplast® (Sherwood Medical, St. Louis, U.S.A.). Serial sections of 7 μm were prepared. For general tissue survey, sections were stained with Haematoxylin and Eosin. Selected sections were stained according to Goldner's variation of Masson's trichrome stain (Burck, 1973) for the study of osteoid formation and collagenous fibres, Herovici's polychrome staining (Herovici, 1963) for the study of young and old collagen or the Weigert-Van Gieson staining to study elastic fibres (Lillie, 1965).

Results

Control group

The palatal bone was covered with stratified squamous epithelium which was parakeratotic. Many villi were protruding into the underlying connective tissue. Just underneath the epithelium the fibrous connective tissue, containing many coarse collagenous fibres, formed a three-dimensional network (figure 2). In deeper layers of the connective tissue, sagittally oriented collagenous fibres became more predominant and elastic fibres were randomly distributed (figure 3). In this zone an expansion tissue was formed by sagittally oriented large blood sinuses along the whole width of the palate (figure 2). At the lateral aspect the major palatine artery and branches of the palatine nerve were found close to the bone in-between those sinuses. In the youngest animals the periosteal layer was thick and cell-rich. The palatal bone showed rapid trabecular deposition and a broad osteoid zone. The mid-palatal suture had a normal appearance for a fast growing end-to-end suture; many osteoblasts were covering the surface and trabecular deposition was found. In the older animals the attachment of the mucoperiosteum to the palatal bone was created by a thin periosteum in which the cellular layer was largely restricted to some resting osteoblasts. Only few thin collagenous fibres were connecting the fibrous layer of the periosteum to the palatal bone. No bone deposition was found at the palatal bone, which was of the lamellar type. The growth in the mid-palatal suture had ceased.

Figure 2: Low power photomicrograph of a transverse section of the medial region of the muco-periosteum. M: mid-palatal suture, S: sinus, C: connective tissue, E: epithelium.
H and E staining, x 25.

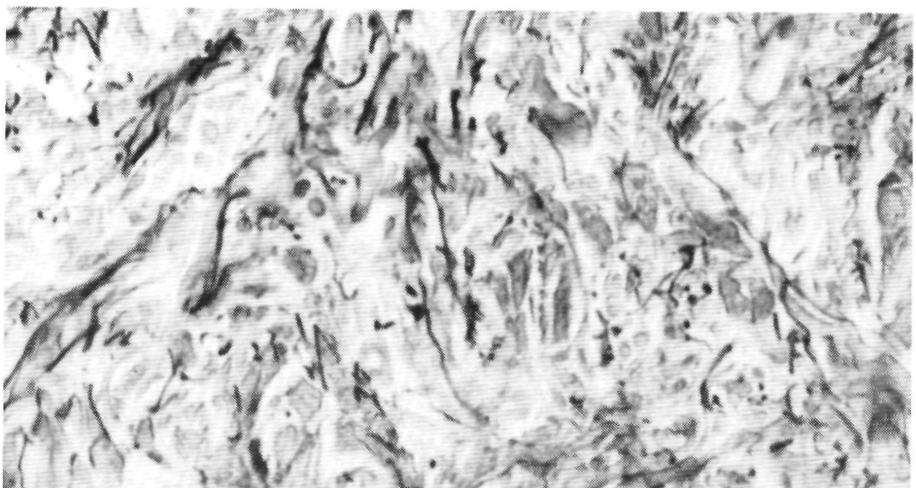
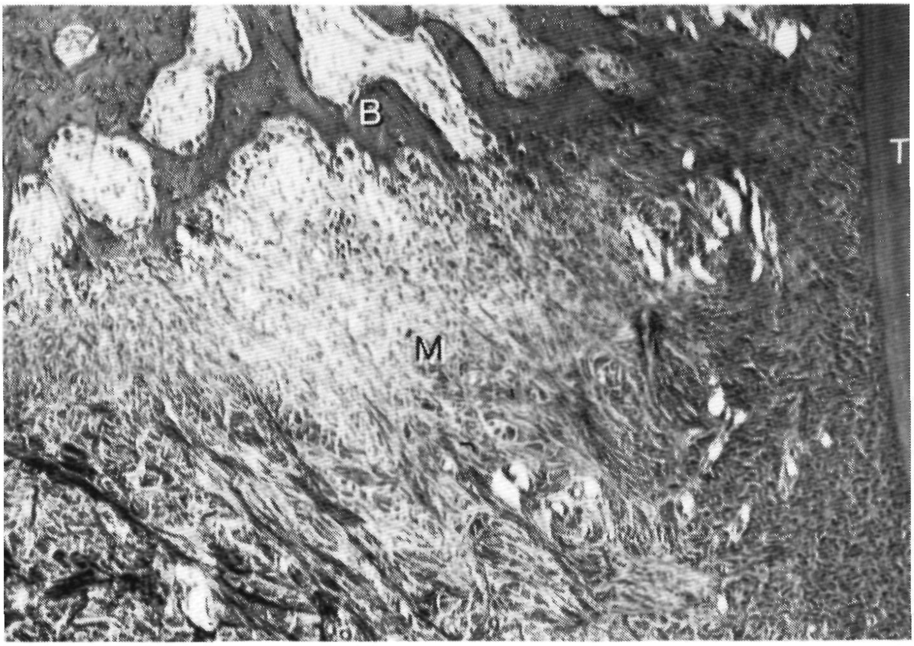


Figure 3: Photomicrograph showing coarse collagenous fibres and randomly oriented elastic fibres in the deeper layers of the connective tissue.
Weigert-Van Gieson staining, x 270.

In all control animals the palatal mucoperiosteum was continuous with the perio dontal ligament; cervical periodontal fibres were fanning out into the gingiva anc the deeper layers of the palatal connective tissue (figure 4). In the apical region o the socket these fibres connected the tooth to the alveolar bone. In the younges animals bone deposition was found on both the palatal and buccal aspects of th alveolar socket. At 18 weeks of age osteoclasts were found in the apical part of th alveolar socket; later on these cells disappeared. In the oldest animals neithe deposition nor resorption of alveolar bone was found.



igure 4: Photomicrograph showing the cervical region of a tooth and its fibrous connection to th alveolar bone and the deeper layers of the mucoperiosteum. T: tooth, B: bone, M: mucoperiosteum.
Herovici staining, x 65.

Experimental groups

5 weeks surgery

One week after the operation the palatal bone at the denuded bony areas was covered with young connective tissue; a capillary plexus and many inflammatory cells were present. The epithelium, which was proliferating from both sides, did not completely cover the wound and was not yet keratinizing (figure 5). The connective tissue was re-attached to the palatal bone by a thick periosteum in which few inflammatory cells were present. The system of blood sinuses and the major palatine arteries and nerves were displaced medially. Trabecular bone deposition was found along the palatal bone except for some osteoclastic resorption in the most lateral parts. The mid-palatal suture was normal. The capillary plexus was extending to the gingiva and no periodontal fibres were fanning out into the wound area.

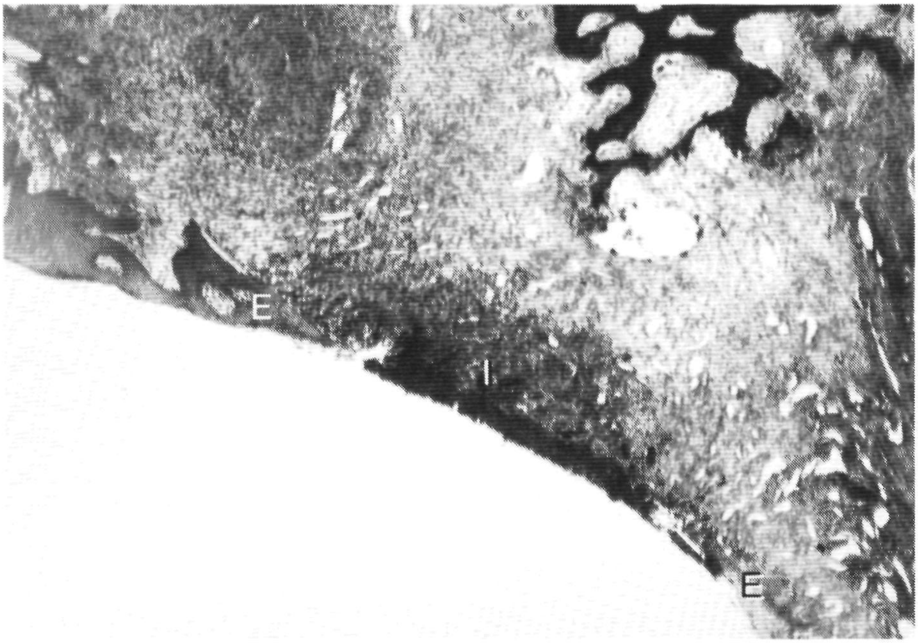
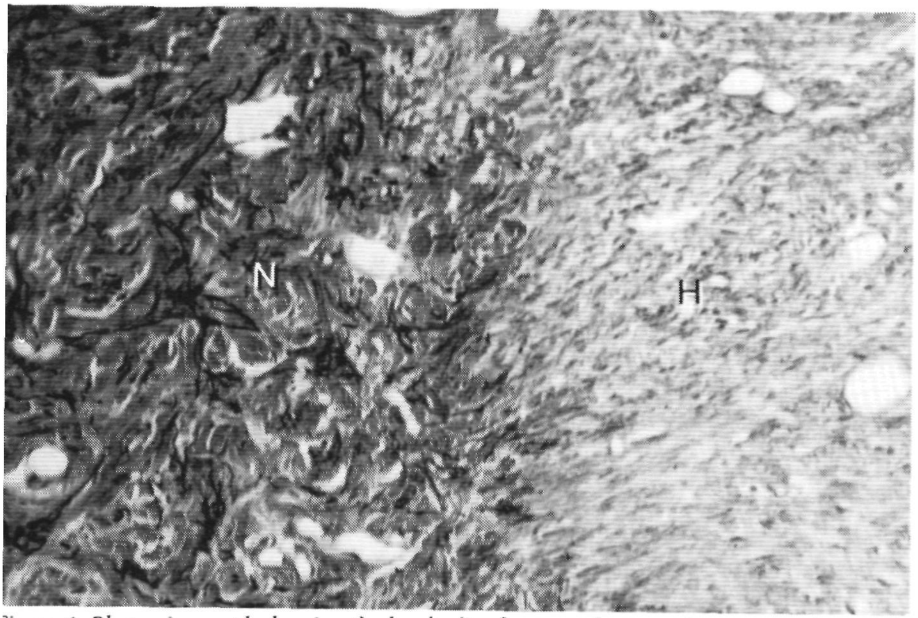


Figure 5: Low power photomicrograph showing the lateral operation area one week after surgery at 6 weeks of age. The epithelium is not yet closed and a cellular infiltrate is present.
E: epithelium, I: infiltrate.
Goldner's trichrome staining, x 25.

Two weeks after the operation the denuded bony areas were completely covered with stratified squamous epithelium, which was still thin, non keratinized and only few villi were present. In the connective tissue underneath, a capillary plexus and few inflammatory cells were found. Collagenous fibre formation had occurred, but no elastic fibres were present in the healing tissue (figure 6). The collagenous fibres were oriented medio-laterally and traversed the denuded bony areas. In the medial region of the palate the coarse fibres of the three-dimensional network, the blood sinuses and the major palatine arteries and nerves were found (figure 7). The palatal bone was covered with a thick cell-rich periosteum and rapid trabecular bone deposition was evident. A resting line, where growth was interrupted, demarcated the surface of the palatal bone at the moment of surgery



igure 6: Photomicrograph showing the border line between the normal connective tissue (left) nd the healing tissue in the wound area (right), lacking elastic fibres. N: normal, H: healing. Veigert-Van Gieson staining, x 110.

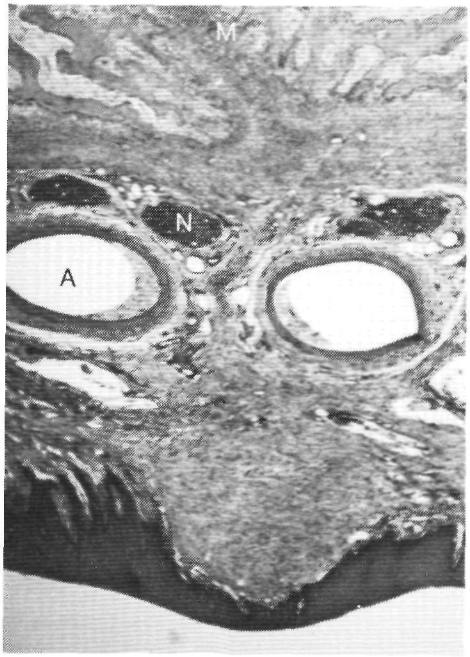


Figure 7: Photomicrograph showing the medial region of the mucoperiosteum two weeks after the operation. The major palatine arteries and nerves are found in the vicinity of the mid-palatal suture. A: artery, N: nerve, M: mid-palatal suture. H and E staining, x 25.

from the subsequent deposition of bone. The mid-palatal suture was normal. In the cervical part of the periodontal ligament collagenous fibres emerged from the cementum and were fanning out into the gingiva and palatal connective tissue. Bone resorption was found at the cervicopalatal and the apicobuccal regions of the alveolar socket; in the other regions of the socket bone deposition was found (figure 8 and figure 9).

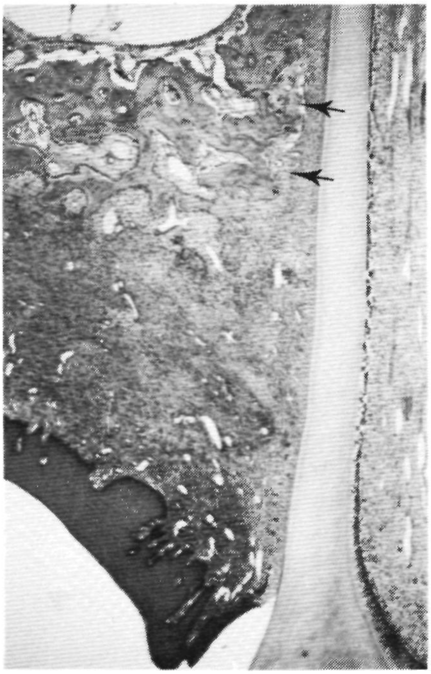


Figure 8: Low power photomicrograph of the lateral aspect of the palate two weeks after the operation. Osteoclasts are present at the cervicopalatal aspect of the alveolar socket (arrows).
H and E staining, x 25.

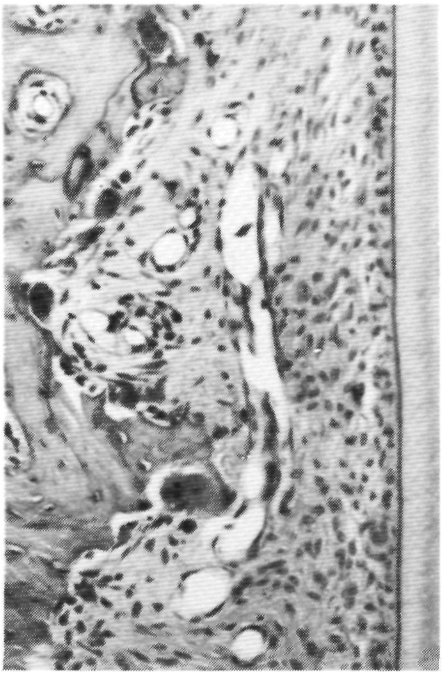


Figure 9: Detail of figure 8 showing osteoclasts at the cervicopalatal aspect of the alveolar socket.
H and E staining, x 170.

At the site of the medial incision the epithelium was restored and in the underlying connective tissue a scar was formed in which elastic fibres were lacking. A capillary plexus was still present in that area and few inflammatory cells could be observed.

16 weeks surgery

Two weeks after the operation in most cases the epithelium in the denuded bony areas was closed. The growth of connective tissue into the denuded area originated mainly from the deeper layers of the mucoperiosteum. The bony areas were completely covered with this young cell-rich connective tissue, which did not contain any elastic fibres. At the oral aspect of the palatal bone only little bone deposition was found. The mid-palatal suture was normal. Collagenous fibres from the cervical region of the periodontal ligament of the deciduous molars were fanning out into the mucoperiosteum or they were penetrating into the alveolar bone. At the occlusal side of the erupting premolars osteoclasts were present, but none were found in the apical region of the deciduous molars. In the periodontal space of the premolars collagenous fibres were found, which were mainly oriented parallel to the tooth surfaces.

Three weeks after the operation the wound healing had proceeded; scar tissue was found in the lateral operation areas and the medial incision area. The structure of the mucoperiosteum in other areas was similar to that in the control animals. The same held true for the bony palate except for the resting line. In cases where a deciduous molar was not yet exfoliated, its cervical periodontal fibres were still fanning out into the deeper layers of the mucoperiosteum. The connection to the alveolar bone was severed by the erupting premolar, of which the top had already emerged from the alveolar bone. In cases where a deciduous molar was exfoliated, some osteoclasts were present on the alveolar bone at the medial aspect of the premolar. In none of the cases, however, cervical fibres from the erupting premolar had established a connection to the alveolar bone or the mucoperiosteum. This connection occurred not before the later stages of the eruption.

25 weeks surgery

Two weeks after the operation the epithelium already covered the denuded areas completely; only few inflammatory cells were found. The stage of wound healing was highly comparable to the stage three weeks after the operation of the 16 weeks group. The palatal bone was of the lamellar type; no resting line was found since the bone deposition had ceased at this age. Cervical periodontal fibres were connecting the premolars to the alveolar bone and the deeper layers of the mucoperiosteum. Some osteoclasts were found in the cervicopalatal and the apicobuccal regions of the alveolar socket.

Mature tissue conditions

All experimental animals, although operated on at different ages, showed comparable mature tissue conditions. A schematic drawing is given in figure 10.

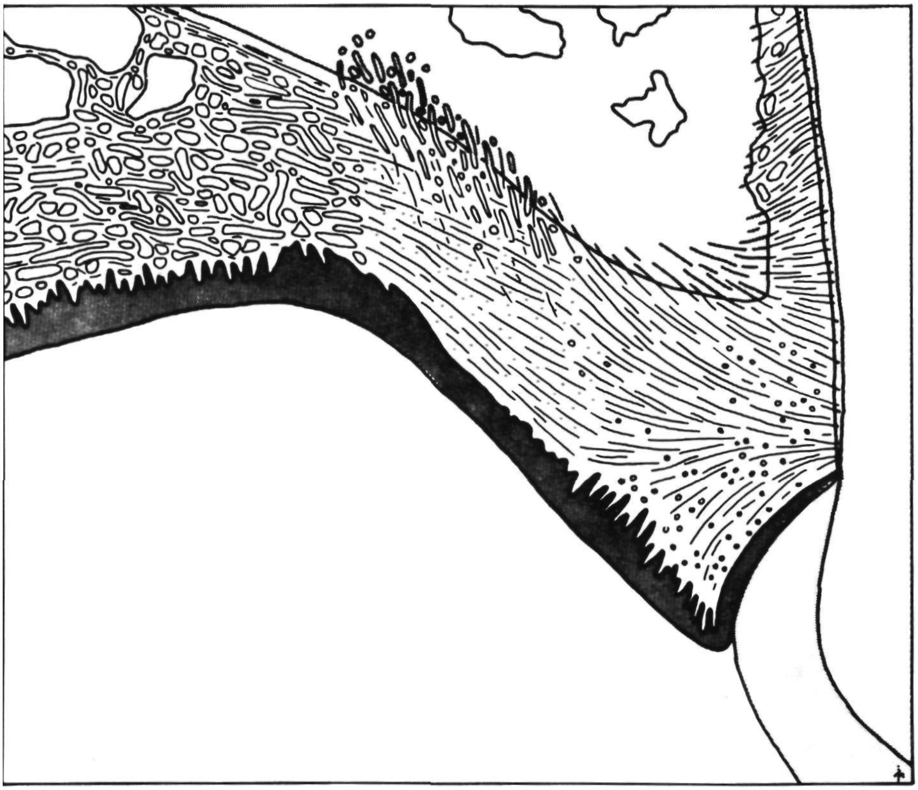


Figure 10: Schematic drawing of the mature tissue conditions after the palatal surgery.

The epithelium in the operation areas seemed to be somewhat thinner, the connective tissue showed thinner collagenous fibres and the absence of elastic fibres was evident. The system of blood sinuses as well as the major palatine arteries and nerves were still located in the medial region of the palate; no lateral migration towards the denuded areas had taken place (figure 11). A very thin periosteum covered the palatal bone in most places. The cellular layer consisted of few inactive osteoblasts and the fibrous layer was connected to the palatal bone by few thin collagenous fibres. The periosteum in the scar tissue area was, however, different. In that area thick collagenous fibres were penetrating into the palatal bone as Sharpey's fibres, thus creating a firm attachment of the scar tissue to the bone (figure 12 and figure 13). No bone deposition or resorption was found at any place at the surfaces of the palatal bone, in the mid-palatal sutures or in the alveolar sockets. The periodontal ligament showed a firm attachment between the teeth, and the gingiva, the mucoperiosteal connective tissue and the alveolar bone respectively (figure 14 and figure 15).

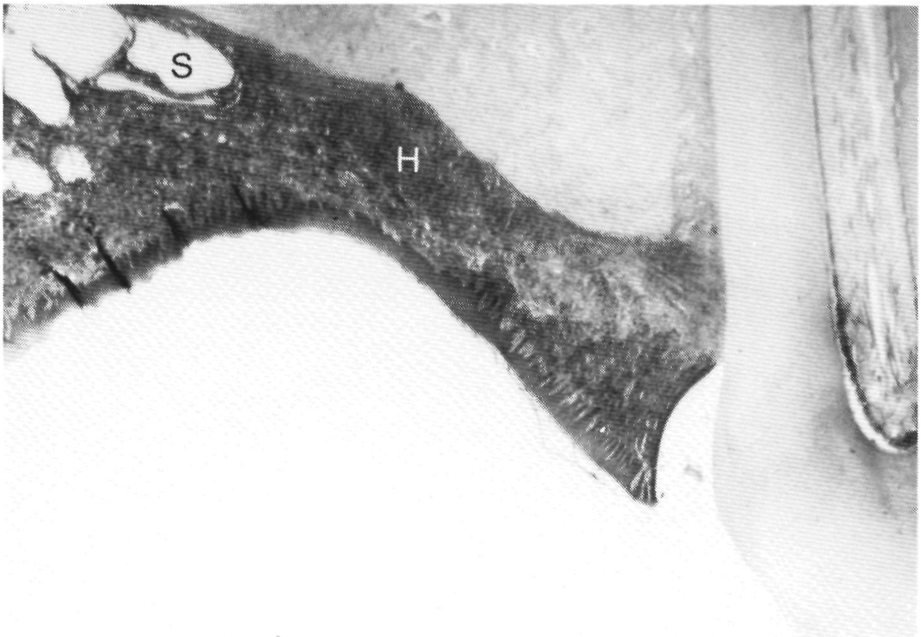
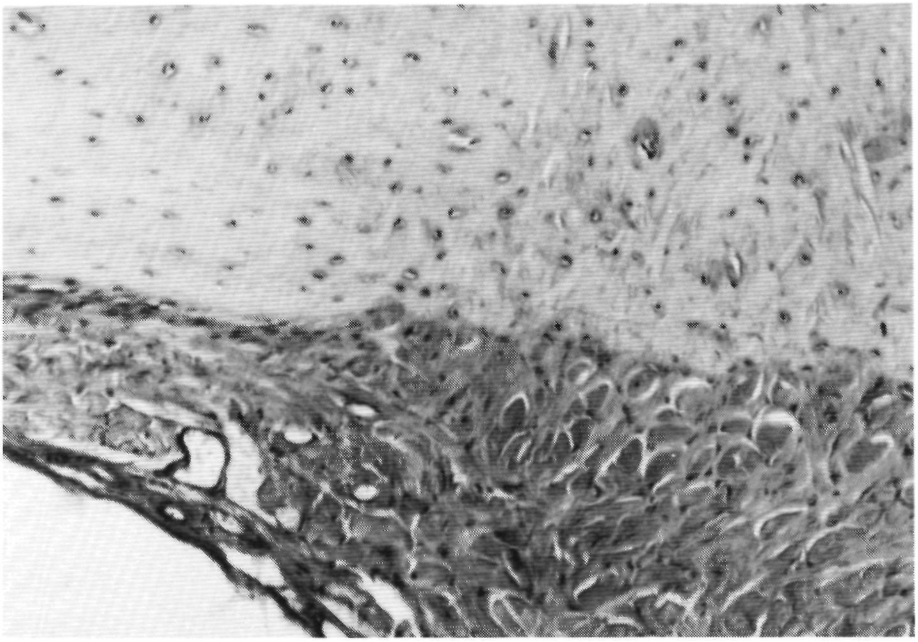


Figure 11: Low power photomicrograph showing the absence of blood sinuses in the healed tissue.
H: healed tissue, S: sinus.
H and E staining, x 10.

Sham group

One week after the operation the attachment of the mucoperiosteum to the palatal bone was re-established. The soft tissue response at the lateral aspects of the palate was comparable to that at the medial incision in the experimental groups. Later on the operation areas were almost unrecognizable except for the absence of elastic fibres in the scar tissue. At the oral aspect of the palatal bone a rapid trabecular bone growth was found two weeks after the operation, i.e. at the age of 8 weeks. Later on the palatal bone and the dentoalveolar structures were very much like those of the control group.



'igure 12: Detail of figure 11 showing the margin of the previous wound area. An abrupt change n orientation is found in the deeper layers of the mucoperiosteum. H and E staining, x 110.

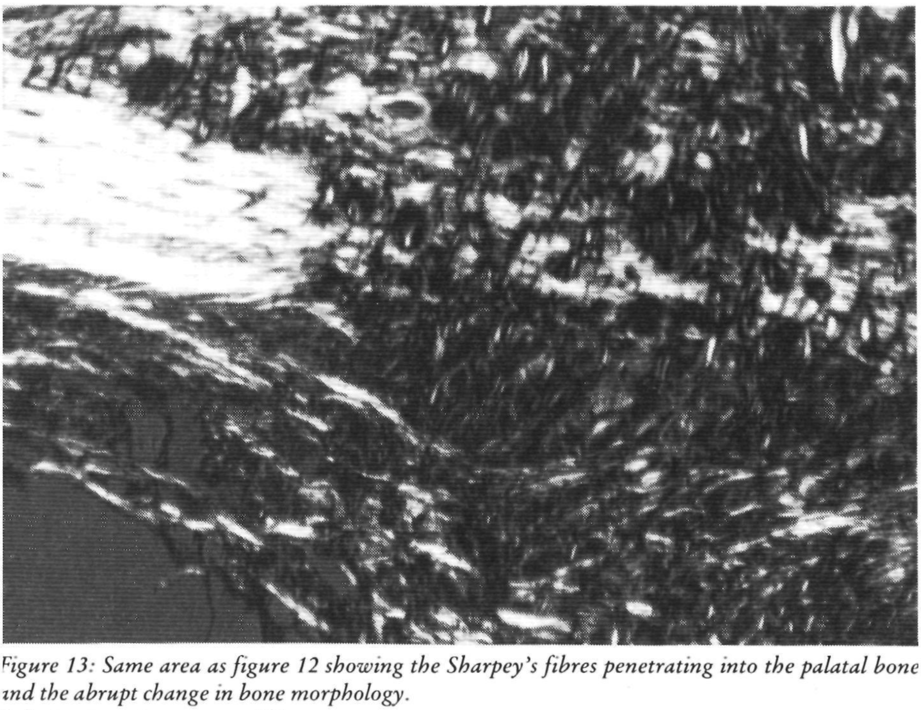


Figure 13: Same area as figure 12 showing the Sharpey's fibres penetrating into the palatal bone and the abrupt change in bone morphology. Polarization microscopy, x 110.

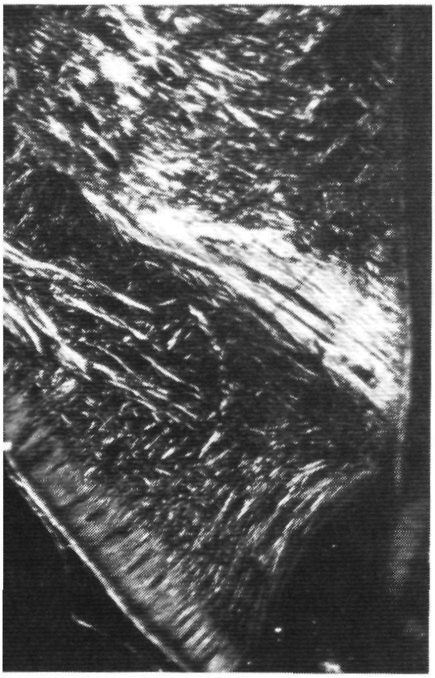


Figure 15: Same area as figure 14 showing the main orientation of the cervical collagenous fibres.
Polarization microscopy, x 25.

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from those of the rest of the mucoperiosteum. The absence of elastic fibres indicated a more rigid type of tissue. Especially the relatively large zone of this type of tissue at the denuded areas might alter the force distribution in the lateral areas of the palate. The firm attachment of the scar tissue to the palatal bone by means of Sharpey's fibres in the older animals might strengthen this effect by preventing an even distribution of tensile forces along the whole mucoperiosteum. Because the mucoperiosteum was continuous with the periodontal ligament, a tensile force might act in a medial direction on the teeth which in the normal animal tend to displace laterally during growth. This theory was supported by the observation that bone resorption was found in the cervicopalatal and apicobuccal regions of the alveolar socket, while bone deposition was found in other areas. This suggested a medial tipping of the teeth, which might be caused by the scar tissue in the lateral areas of the mucoperiosteum. This is in agreement with the results of a previous study on dental casts (Wijdeveld et al., 1988b), showing such a tooth displacement. The absence of blood sinuses in the regenerating tissue indicated, moreover, that this tissue possessed different properties from the original tissue.

Although bone growth in the mid-palatal suture was not quantified in the present study, histological evaluation showed no large differences between groups in bone deposition patterns in this suture. This is in agreement with a previous study (Wijdeveld et al., 1988a), in which serial radiographs were used to determine changes in growth of the mid-palatal suture caused by this type of surgery. In that study it was found that suture growth was influenced only to a minor extent.

In both the youngest experimental groups and the sham group a more rapid trabecular growth at the oral aspect of the palatal bone was found during the first two weeks after the operation as compared to the control group. This might be caused by the detachment of the periosteal part of the mucoperiosteum from the underlying bone. This is in agreement with the results of Barro and Latham (1981).

The transition of some premolars was studied on the animals sacrificed at 18 or 19 weeks of age. The premolars, of which the tops had already emerged from the alveolar bone, showed collagenous fibres which were mainly oriented parallel to the tooth surfaces. Even after the exfoliation of the deciduous molars none of these fibres connected the tooth to the alveolar bone or the mucoperiosteum. Such a connection developed during the later stages of the eruption and formed into the periodontal ligament. This observation is in agreement with the study of Maltha (1982) concerning the process of tooth eruption in Beagle dogs.

In the present study surgery was carried out at different stages of development in growing Beagle dogs. Apart from the normal age differences all animals showed highly comparable initial and long-term tissue reactions. It is theorized that, although the tissue response to palatal surgery seems to be relatively independent of the timing of surgery, the overall effect of this tissue response on growth and development of maxillary structures might be strongly dependent on this timing of surgery.

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J Dent Res, 1988b Submitted

CHAPTER 8

Skull dimensions after palatal surgery at different ages on Beagle dogs

Wijdeveld, Maarten G.M.M.
Grupping, Ellen M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.
Van 't Hof, Martin A.

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Skull dimensions after palatal surgery at different ages on Beagle dogs

Abstract

Craniofacial and dentoalveolar dimensions were studied on adult dry skulls of Beagle dogs after palatal surgery at different stages of development of the dentition. 37 dogs were used, divided into three experimental groups, a sham group and a control group. In the experimental groups at the age of 6, 16 or 25 weeks a soft tissue cleft was created in the medial region of the palate, relaxation incisions were made and the mucoperiosteum was elevated and closed in the midline, leaving two areas of denuded bone adjacent to the dentition. At the age of 37 weeks all animals were sacrificed and decapitated, then the skulls were cleaned and measured.

Surgery did not influence antero-posterior or vertical skull dimensions. Transverse maxillary dimensions, i.e. snout and teeth top widths in the premolar region, were reduced if surgery was performed before or during the transition of teeth. Surgery performed after completion of the permanent dentition did not change any skull dimension.

Delay of palatal surgery, until the transition of teeth had been completed, was more favourable for normal maxillary growth than earlier surgery.

Introduction

The effects of primary surgical treatment on children with cleft lip and palate are initially beneficial. Later on this surgery seems, however, to be responsible for disturbances in facial growth. The mechanism of this growth disturbance has been the subject of many experimental studies. In some studies bony clefts were surgically created and then closed (Urbanus, 1974; Bardach et al., 1979, 1982). These studies can give conflicting results because of the extensive surgical trauma of creating such a bony cleft. Freng (1979, 1981) reported a 50% reduction of transverse growth after creating an isolated bony palatal cleft which was left open. Other investigators studied the effect of palatal soft tissue manipulation alone. Kremenak et al. (1967, 1970) and Kremenak (1984) concluded in a series of studies, based on the work of Herfert (1958), that unilateral excision of a strip of mucoperiosteum adjacent to the posterior deciduous teeth disturbed maxillary growth. In the clinical setting the closure of a palatal cleft is achieved by medial displacement of palatal mucoperiosteal flaps, leaving two areas of denuded bone adjacent to the dentition. Since this surgery consists of soft tissue manipulation alone, it was felt that the presence of a bony palatal cleft is not essential in such studies. Therefore, in our experimental design the closure of a palatal cleft according to the Von Langenbeck technique was simulated on a normal bony palate.

Using this experimental design, soft, bony and dental tissues were previously investigated in a series of longitudinal and histological studies (Wijdeveld et al., 1987a,b, 1988 a-c). From a radiographic study (Wijdeveld et al., 1987a) it was concluded that the surgery had no influence on antero-posterior and vertical maxillary growth; transverse growth in palatal sutures was influenced only to a minor extent. From a dental cast study (Wijdeveld et al., 1988a) it was concluded that surgery, performed before or during the transition of teeth, disturbed the dental arch width in the premolar region. Consequently, in a histological study a medial tipping of posterior teeth was suggested by resorptive areas in the alveolar tooth socket (Wijdeveld et al., 1988c). To complete these investigations, the present study evaluated the ultimate skull dimensions of Beagle dogs after soft tissue palatal surgery. Because the influence of surgery on facial growth might be dependent on age and stage of development of the dentition, surgery was carried out at different ages.

Material and methods

The experiments were performed on 37 Beagle dogs, divided at random into five groups. In the experimental groups 1, 2 and 3 palatal surgery was performed at three different stages of development, i.e. during the eruption of the deciduous dentition (group 1; 10 dogs; age 6 weeks), during the period of mixed dentition (group 2; 7 dogs; age 16 weeks) and after completion of the permanent dentition (group 3; 7 dogs; age 25 weeks). In the sham group (7 dogs) surgery was performed at the age of 6 weeks. The animals of the control group (6 dogs) were 6 weeks old at the start of the study. All animals were sacrificed at 37 weeks of age and the skulls were analyzed.

Surgical procedures

In the experimental groups a standardized elliptical soft tissue defect was created in the medial region of the palate by excising a mucoperiosteal flap. On both sides relaxation incisions were made adjacent to the posterior teeth, the mucoperiosteum was elevated and the soft tissue defect was closed, leaving two areas of denuded bone adjacent to the dentition (figure 1). A detailed description of the surgical procedure was given previously (Wijdeveld et al., 1987b). All surgical procedures were carried out under general anaesthesia with 30 mg/kg Sodium Pentobarbital after premedication with Thalamonal® (Fentanyl, 0.5 mg/ml + Droperidol 2.5 mg/ml; Jansen Pharmaceutica, Beerse, Belgium) and 0.5 ml Atropine (Atropine Sulphate 0.5 mg/ml).

In the sham group an incision in the medial region and two lateral incisions were made after which the mucoperiosteum was elevated from the bone, replaced and sutured. In the control group no surgery was performed.

At the age of 37 weeks all animals were sacrificed with an intracardial overdose of Sodium Pentobarbital. The dogs were decapitated, the heads were flayed and the skulls were cleaned by small carnivorous beetles.

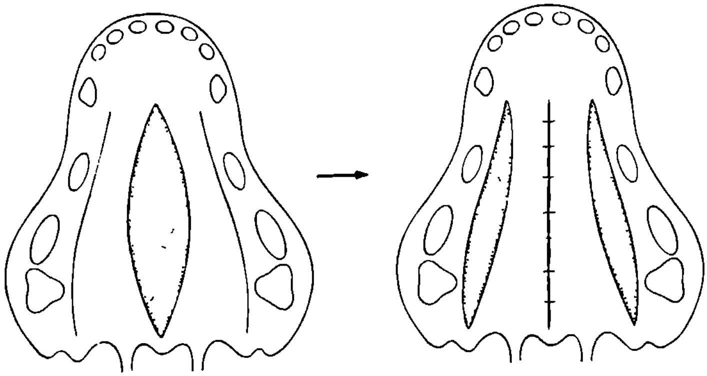


Figure 1: Schematic drawing of the palate and the operation in groups 1, 2 and 3. A mucoperiosteal flap was removed in the medial region of the palate and two lateral incisions were made. The remaining mucoperiosteum was elevated, repositioned and sutured in the midline, leaving two areas of denuded bone adjacent to the posterior teeth

Skull dimensions

The dry skulls were inspected from different sides and the qualitative appearance was described. The dimensions of the skulls were then quantified by means of measurements which were carried out with a sliding gauge or caliper (read in tenths of millimetres). To determine the error of the method, all skulls were measured twice with an interval of one week.

The measurements were defined as follows:

Maxillary complex length: spheno-occipital synchondrosis to the anterior aspect of the interincisal alveolar crest;
Palate length: posterior nasal spine to the anterior aspect of the interincisal alveolar crest;
Posterior head length: anterior aspect of the foramen magnum to the posterior nasal spine;
Snout length: posterior limitation of the frontonasal suture to the anterior aspect of the interincisal alveolar crest;
Snout height: alveolar crest between the right second and third premolars to the junction of the maxillonasal suture and the caudocranial end of the premaxillary suture;
Snout widths: distances between the buccal alveolar walls at the bifurcations of the corresponding maxillary premolars for the first, second, third and fourth premolars respectively;
Premolar top widths: distances between the corresponding maxillary premolar tops for the first, second, third, and fourth premolars respectively;
Spacing: spatial conditions in the maxilla and the mandible respectively, as measured by caliper. Therefore, the distance from the medial side of the right first molar to the distal side of the right cuspid minus the sum of the mesial-distal widths of the premolars was calculated.

Statistical procedures

With the aim of compensating for size- and shape-differences between adult animals, the skull dimensions of all individual dogs were standardized. Therefore, some distances, away from the surgical area were assumed to be representative variables for the size and shape of each individual dog's skull. For the antero-posterior measurements the mandible length served as standardization factor, for the transverse distances the zygoma width and for the vertical distances the posterior head height.
These parameters were defined as follows:

Mandible lenght: posterior limitation of the right condyle to the anterior aspect of the interincisal alveolar crest;
Zygoma width: largest width between the lateral limitations of both zygomatic arches;
Posterior head heigth: cranial limitation of the external accustic meatus to the junction of the coronal and sagittal sutures.

The correlation coefficients between these factors varied from 0.68 to 0.86. The quotient of each individual measurement and its standardization factor was used for the comparisons between the groups. The mean values of all groups were compared mutually using a one-way analysis of variance. In cases of significant results, Tukey's multiple comparisons test was used for further exploration of the differences between groups.

Results

Error of the method

The total error of the method is made up of an error of definition of the measuring points and a measurement error, due to inaccuracy and inexact read-out of the measuring instrument. No systematical deviations were found with respect to the distances. The total error of the sliding gauge measurements was found to be about 0.13 mm. The total error of the spacing measurements was found to be about 0.47 mm.

The accuracy of the method was considered acceptable.

Skull description

The dry skulls of the animals of all groups showed a comparable overall shape; no asymmetries were found. Between the experimental groups on the one hand and the sham group and the control group on the other hand some systematic local shape differences were found, however. If the skull was inspected from the cranial side, in groups 1 and 2 the snout width in the premolar region was smaller. If the maxillary structures were inspected from the oral side, in the control group the mid-palatal suture was seen as a straight ridge. In the experimental groups, however, this ridge was flattened and a more irregular outline was observed; the transverse palatal sutures also showed this irregularity. The foramina of the major palatine arteries and nerves were located more medially and the direction of these bundles could be studied, using the depressions in the palatal bony surface. In the sham group and the control group these arteries and nerves were located more or less parallel to the mid-palatal suture, but in the experimental groups they approached this suture. On the lateral aspect of the palate a relatively smooth bony surface was seen in the sham group and the control group. In the experimental groups, however, this area showed a strip of bone with a relatively rough and porous surface. Lateral from these strips in the experimental groups the medial alveolar ridges of the premolars seemed to be vertically less developed as compared to the control group. In the younger experimental groups the transverse size of the palate and maxillary dental arch appeared to be smaller and the premolars concerned showed medial tipping and mesial-medial rotation.

Skull dimensions

The results of Tukey's multiple comparisons test for comparison of groups 1, 2, 3 and the control group are given in table 1. The results of the sham group are not mentioned in this table because no significant differences were found between the sham group and any other group. With regard to the antero-posterior measurements, no significant differences between the groups were found for maxillary complex length, palate length and snout length. In groups 1 and 2 the posterior head length was smaller than in the control group.
In group 1 the snout height was significantly smaller than in groups 2 and 3.
With regard to the transverse measurements, no significant differences between

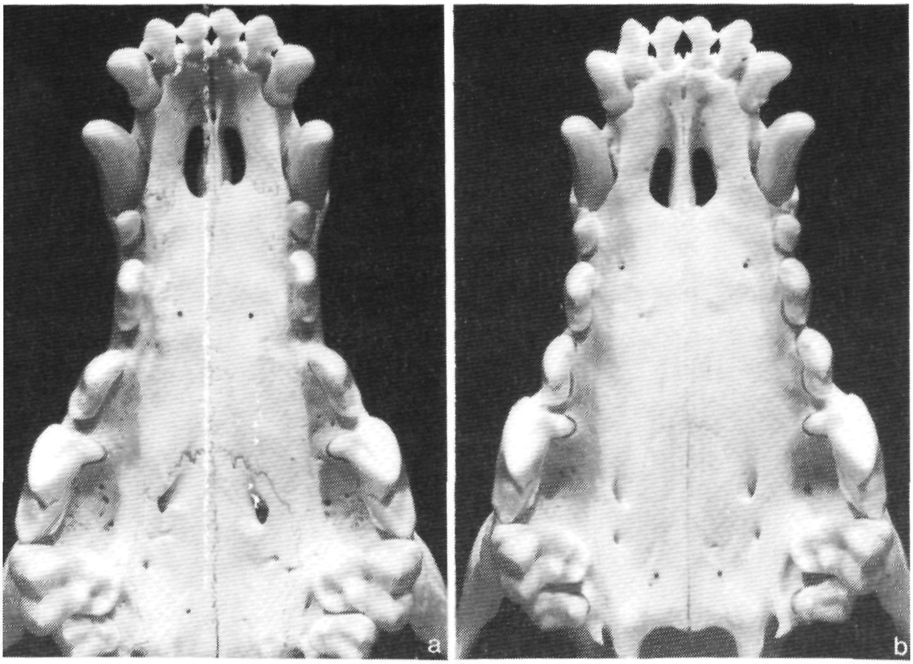
Table 1: Results of Tukey's multiple comparisons test for comparison of groups 1, 2, 3 and the control group at age 37 weeks. Differences are given at the $P < 0.05$ level.

distance	difference between groups
maxillary complex length	ns
palate length	ns
posterior head length	1,2 < C
snout length	ns
snout height	1 < 2,3
p1 snout width	ns
p2 snout width	1 < 3,C
p3 snout width	1,2 < 3,C
p4 snout width	ns
p1 top width	ns
p2 top width	1 < 3,C
p3 top width	1,2 < 3,C
p4 top width	ns
spacing maxilla	1 > 2
spacing mandible	ns

groups: 1,2,3,C
ns : not significant

he groups were found for the first and fourth premolar snout and top widths. In ;roup 1 the second and third premolar snout and top widths were significantly maller than in group 3 and the control group. As an example photographs of the kull of a dog of group 1 and one of the control group are given in figure 2. In ;roup 2 the second premolar snout and top widths were also smaller than in ;roup 3 and the control group.

[he results of the spacing measurements are given in table 2. In group 2 less naxillary spacing was found than in other groups; the level of significance was)nly reached between groups 1 and 2.



'igure 2: Photographs of the palatal aspect of the skull of an adult dog of group 1 (figure 2a) and)ne of the control group (figure 2b).

Table 2 Spacing in mm (mean and SEM) of the maxillary and mandibular arch segments for groups 1, 2, 3, the sham group and the control group

	spacing maxilla	spacing mandible
	mean SEM	mean SEM
group 1	6.2 ± 0.4	5.2 ± 0.5
group 2	2.8 ± 1.0	4 7 ± 1.5
group 3	5.8 ± 1.0	7.4 ± 0.8
sham group	3.4 ± 0.6	5.5 ± 0 6
control group	5.3 ± 1.2	4.8 ± 0.9

Discussion

In the present study the dimensions of the skulls of adult animals after surgery at different ages were investigated. The skulls of the animals of all groups showed comparable overall dimensions. This is in agreement with the results of a previous longitudinal radiographic study (Wijdeveld et al., 1987a). Nevertheless, in the younger experimental groups some systematic deformities in and around the area of surgery were found as compared to group 3, the sham group and the control group. In group 1, and to a lesser extent in group 2, the widths of the dental arch and the snout in the premolar region were found to be smaller. The present measurements on the teeth are obviously in agreement with a previous study on dental casts (Wijdeveld et al., 1988a) The results indicate that the transverse dimensions of both the dental arch and the maxillary bones can become reduced by palatal surgery. It was concluded that the surgery, if performed before or during the transition of teeth, inhibited transverse growth and development of maxillary structures.

The sham group did not show any significant difference with the control group. This is in agreement with the results of previous studies (Wijdeveld et al , 1987 a, 1988a). It was concluded that elevation of the mucoperiosteum alone, without excision of tissue, did not change the adult skull dimensions. This is, however, in contrast with the studies of Herfert (1958), Kremenak et al. (1967, 1970) and Kremenak (1984), who reported that growth was disturbed after such mucoperiosteal manipulation.

Group 3 did not show any significant difference with the control group either. This is in agreement with the results of previous longitudinal studies on radiographs and dental casts (Wijdeveld et al., 1987a, 1988a). It was concluded that delay of palatal surgery, until the transition of teeth had been completed, was more favourable for normal maxillary growth than earlier surgery.

In the experimental groups the palatal sutures showed a different appearance as compared to the control group. The more irregular outline and the flattened ridge might be related to the disturbance of suture growth, as shown in a previous radiographic study (Wijdeveld et al , 1987a).

On the lateral aspect of the palate a strip of bone with a relatively rough and porous surface was seen in the experimental groups. This strip corresponded with the denuded bony areas adjacent to the posterior teeth. In a previous histological study (Wijdeveld et al , 1988c) these areas showed a firm attachment of the healed mucoperiosteum to the palatal bone by numerous Sharpey's fibres. It was concluded that the porosities on the surface of the palatal bone corresponded with the intrusions of these fibres.

The smallest snout height was found in group 1, but the level of sinificance was only reached between group 1 on the one hand and groups 2 and 3 on the other hand. This might suggest that also vertical dimensions near the surgical area can become influenced by early surgery

In group 2 the smallest maxillary spacing was found; the level of significance was only reached between groups 1 and 2. This is in agreement with the results of a previous study, showing a reduced arch depth in the permanent dentition in group 2 (Wijdeveld et al., 1988a). These findings might suggest that palatal surgery which is performed during the transition of the dentition also can affect some antero-posterior dimensions of dentoalveolar structures.

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CHAPTER 9

Growth and development of maxillary structures after palatal surgery at different ages on Beagle dogs

Wijdeveld, Maarten G.M.M.
Kuijpers-Jagtman, Anne M.
Maltha, Jaap C.
Grupping, Ellen M.

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Abstract

This paper summarizes and discusses the results of a series of animal studies (Wijdeveld et al., 1987a,b, 1988a-e). The aim of these studies was to investigate growth and development of the mucoperiosteum, maxillary bones and dento-alveolar structures after palatal surgery at different ages. 69 Beagle dogs were used, divided into three experimental groups, a sham group and a control group. Each group was divided into two sub-groups for macroscopic or microscopic studies.

At the age of 6, 16 or 25 weeks in the experimental groups a soft tissue cleft was created in the medial region of the palate, relaxation incisions were made and the mucoperiosteum was elevated and closed in the midline, leaving two areas of denuded bone adjacent to the dentition. In the animals used for the macroscopic studies, tattoo points, metallic bone implants and mucoperiosteum markers were placed. Photographs, radiographs and dental impressions were longitudinally taken and finally the adult dry skulls were measured. The animals used for the microscopic study were sacrificed relatively soon after the operation or at maturity.

Palatal surgery, performed before or during the transition of teeth, disturbed mucoperiosteum, maxillary bones and dentoalveolar structures. Surgery which was delayed until completion of the permanent dentition, did disturb the mucoperiosteum, but was more favourable for normal growth and development of maxillary bones and dentoalveolar structures.

Introduction

Individuals with untreated facial clefts show a relatively normal maxillofacial growth (Dejesus, 1959; Ortiz-Monasterio et al., 1966; Bishara et al., 1976). In spite of the beneficial effects, the surgical treatment seems to be responsible for later disturbances of maxillofacial growth. Although these growth disturbances have been the subject of many studies, there continues to be disagreement about the timing and the technique of surgery (Blijdorp and Egyedi, 1984; Jorgenson et al., 1984; Witzel et al., 1984; Berkowitz, 1985). This might be due to an important limitation of clinical studies, caused by the large number of variables, e.g. patient, type and extension of the cleft, number, timing and technique of surgery, presurgical orthopedics and orthodontics.

In animal experiments the number of variables can be limited to some extent. Since the breeding of mammals with identical clefts appeared to be impossible, many investigators created their clefts surgically (Sarnat, 1958; Freng, 1979, 1981; Bardach et al., 1982). These studies can, however, give conflicting results because of the extensive trauma of creating such a cleft. Freng (1979, 1981) reported a 50% reduction of transverse maxillary growth after creating a medial bony palatal cleft.

Other investigators restricted their surgery to soft tissue manipulation. Kremenak et al. (1967, 1970), Kremenak and Searls (1971) and Kremenak (1984) concluded from a series of studies, based on the classic work of Herfert (1958), that unilateral excision of a strip of mucoperiosteum adjacent to the posterior teeth resulted in inhibition of maxillary growth. Although their results were a stimulus for further investigations, their experimental design had important limitations. The surgery was performed at one side of the palate only, which might affect the unoperated control side. Furthermore, their conclusions about maxillary growth were based on measurements between posterior teeth on the one hand and the medial palatal raphe or suture on the other hand. These measurements reflect, however, reactions at different growth sites.

This paper summarizes and discusses the results of a series of studies which consisted of separate investigations of different growth sites, i.e. mucoperiosteum, maxillary bones and dentoalveolar structures, after bilateral palatal soft tissue surgery at different ages. The surgery was performed during the eruption of the deciduous dentition, during the transition or after completion of the permanent dentition; this corresponded with the different timing used in the clinical setting (Wijdeveld et al., 1987a,b, 1988a-e).

Material and methods

This series of studies involved 69 Beagle dogs, divided at random into five groups. Each group consisted of two sub-groups: one for macroscopic (macro) and one for microscopic (micro) studies. In the experimental groups palatal surgery was performed at three stages of development, i.e. during the eruption of the deciduous dentition (group 1; macro n = 10, micro n = 6; age 6 weeks), during the transition of teeth (group 2; macro n = 7, micro n = 6; age 16 weeks) and after completion of the permanent dentition (group 3; macro n = 7, micro n = 6;

age 25 weeks). The animals of the sham group (macro n = 7, micro n = 6) and the control group (macro n = 6, micro n = 8) were six weeks old at the start of the study.
In the experimental groups a soft tissue cleft was created in the medial region of the palate under general anaesthesia, relaxation incisions were made and the mucoperiosteum was elevated and closed, leaving two areas of denuded bone adjacent to the dentition (Wijdeveld et al., 1987b). In the sham group only an incision in the medial region and two lateral incisions were made, then the mucoperiosteum was elevated, replaced and sutured. In the control group no surgery was performed.
In the animals used for the macroscopic studies tattoo points, metallic bone implants and metallic mucoperiosteum markers were placed. From the surgery on, intraoral photographs (Wijdeveld et al., 1987b), dorso-ventral and lateral radiographs (Wijdeveld et al., 1987a, 1988a, d) and dental casts (Wijdeveld et al., 1988b) were taken longitudinally. At the age of 37 weeks all animals were sacrificed after which the adult dry skulls were inspected and measured (Wijdeveld et al., 1988c).
The animals used for the microscopic studies were sacrificed relatively soon after the operation or at 37 weeks of age. Serial sections were prepared, stained according to different techniques and studied with a light microscope (Wijdeveld et al., 1988e).
In each study the experimental groups and the sham group were compared with the control group and with each other.

Results of the macroscopic studies

Mucoperiosteum

The palatal mucoperiosteum was studied clinically, and experimentally on longitudinal series of intraoral photographs and dorso-ventral radiographs. In all dogs operated on, the wound healing in the medial region of the palate was completed after two weeks. In the denuded areas adjacent to the posterior teeth the healing continued for two to three weeks after the operation in group 1 and for four to five weeks in groups 2 and 3. The healed area was clinically different from unoperated mucoperiosteum, e.g. no rugae developed.
The surgery did not influence antero-posterior distances between the tattoo points on the mucoperiosteum, but transverse distances showed significant differences between the experimental groups and the control group. Wound contraction in the denuded areas, recorded as the approaching of opposite tattoo points, was restricted to the first week after the operation and was larger in groups 2 and

3 than in group 1. When this wound contraction was recorded as the approaching of opposite metallic mucoperiosteum markers, it occurred during the first two weeks after the operation in all experimental groups. The measurements at the surface of the mucoperiosteum using tattoo points showed more wound contraction than those in the deeper layers using metallic implants. For both methods the largest contraction was observed in the anterior region of the palate.
The migration pattern of the mucoperiosteum along the growing palatal bone was studied on longitudinal series of dorso-ventral radiographs using metallic bone implants and mucoperiosteum markers. In the unoperated control animals the mucoperiosteum at the lateral aspect of the palate migrated laterally until maturity; the migration pattern was unevenly distributed over the palate. From 6 to 10 weeks of age the control group showed lateral migration of the lateral wound margin area and a stable position of the medial wound margin area. In group 1 during this period the lateral wound margins migrated medially. From 16 to 20 weeks of age in the control group both areas remained stable while in group 2 the medial wound margins migrated laterally. In group 3 the migration pattern also showed significant differences with the control group, but to a lesser extent than in the younger groups.
In all mucoperiosteum studies the sham group showed generally the same pattern as the control group except for a small initial effect during the first week after the operation.

Maxillary bones

The overall growth of craniofacial structures was studied on longitudinal series of lateral radiographs and on adult dry skulls. From both studies it was concluded that the surgery did not influence the antero-posterior and vertical overall dimensions of the skull. In group 1 and to a lesser extent in group 2 the transverse maxillary width, as measured between corresponding buccal limitations of the snout in the premolar region, was significantly smaller than in group 3, the sham group and the control group.
The growth of the transverse and mid-palatal sutures was studied in detail on longitudinal series of dorso-ventral radiographs, using metallic bone implants. In groups 1 and 2 growth in the mid-palatal suture was significantly reduced in the period from 16 to 22 weeks of age as compared to the control group. In group 2 less increase of antero-posterior growth was also found in the posterior transverse palatal sutures.

Dentoalveolar structures

The growth and development of dentoalveolar structures of the maxilla were studied on longitudinal series of dental casts and on adult dry skulls. In groups 1 and 2 the surgery, performed before or during the transitional period, did not change maxillary arch dimensions in the deciduous dentition, except for the arch width between the first deciduous molars at 11 weeks of age. From the transition on, however, the arch width between the second and third premolars became significantly reduced.
Sham-surgery or delayed experimental surgery (group 3) did not change the growth and development of either maxillary bones or dentoalveolar structures.

Results of the microscopic study

Two weeks after the operation in the experimental groups the denuded bony areas were covered with thin stratified squamous epithelium and young cell-rich connective tissue. Collagenous fibre formation had occurred but no elastic fibres were present in the healing tissue. The expansion tissue, formed by large blood sinuses, and the major palatine arteries and nerves were displaced medially. In groups 1 and 2 the palatal bone was covered by a thick cell-rich periosteum; rapid trabecular bone deposition was evident. A clear resting line demarcated the surface of the palatal bone at the moment of surgery from the subsequent bone deposition. The mid-palatal suture was normal. From the cervical part of the periodontal ligament, collagenous fibres were fanning out into the gingiva and the palatal connective tissue. Bone resorption was observed at the cervicopalatal and the apicobuccal regions of the alveolar socket, while deposition of bone occurred in the other regions of the socket. During the transition of posterior teeth the connection of the deciduous molar to the alveolar bone was severed by the erupting premolar. Shortly after the exfoliation of the deciduous molar no fibre connection between the erupting premolar and either the alveolar bone or the mucoperiosteum was present. This connection occurred during the later stages of the eruption and developed into the periodontal ligament.
All experimental groups, although operated on at different ages, showed comparable mature tissue conditions. In the scar tissues at the lateral aspect of the palate elastic fibres were absent and the periosteum was firmly connected to the palatal bone by Sharpey's fibres. The system of blood sinuses and the major palatine arteries and nerves were still located medially. No deposition or resorption of bone was found anymore. The periodontal ligament showed a firm attachment between the teeth, and the gingiva, the mucoperiosteal connective tissue and the alveolar bone respectively.

Discussion

For the aim of the studies the presence of a bony palatal cleft was not essential, because the closure of a human palatal cleft is generally achieved by mucoperiosteal manipulation alone and not by osseous surgery.
Elevation of the mucoperiosteum alone (sham group) disturbed the palatal mucoperiosteum initially. The growth and development of bony and dentoalveolar structures appeared, however, to be normal. This is in contrast with the studies of Herfert (1958), Kremenak et al. (1967, 1970), Kremenak and Searls (1971) and Kremenak (1984), who reported that unilateral elevation and repositioning of the mucoperiosteum resulted in growth disturbance of the operated side.
In the experimental groups the two methods of recording the contraction of the healing mucoperiosteum resulted in similar patterns. There were, however, differences with regard to the period and the amount of wound contraction. These findings suggested that the largest amount of wound contraction occurred in the mucosal region of the mucoperiosteum. This is contrary to the results of an electron microscopic study (Squier and Kremenak, 1980), which suggested that myofibroblasts, thought to be responsible for wound contraction, were mainly located in the periosteal region of the palatal mucoperiosteum. It is difficult to draw conclusions from these controversial results because the mechanism of wound contraction is still not fully understood.
The present implant studies can hardly be compared with implant studies on other craniofacial bones or long bones because the palatal periosteum differs from periosteum at other sites by the firm connection to the palatal mucosa. Moreover, there is the unique feature of palatal rugae. Nevertheless, the observation that in control animals the migration pattern was unevenly distributed over the palate is in agreement with studies on other craniofacial bones (Koskinen-Moffett et al., 1981; Roskjaer, 1977) and on long bones (Kuijpers-Jagtman et al., 1988; Theunissen, 1973). They all concluded that the rate and direction of periosteal migration was dependent on the rate of bone growth and the relative position of the periosteum markers with respect to the growth sites. In the experimental animals of the present study during the first month after the operation the migration pattern of the mucoperiosteum along the palatal bone was disturbed systematically. Other studies on long bones (e.g. Crilly, 1972; Kuijpers-Jagtman et al., 1988; McLain and Vig, 1983) have shown that periosteal manipulation influenced bone growth. From these studies it was assumed that the palatal mucoperiosteum plays a rôle in the regulation of maxillary bone growth. Possibly the disturbances of the migration pattern of the mucoperiosteum, introduced by palatal surgery, can disturb this regulation mechanism. Furthermore, the composition of the connective tissue in the healed areas differed from that in the control animals by the absence of elastic fibres and the attachment to the palatal bone by means of

Sharpey's fibres. This might result in a more rigid type of tissue and different mechanical circumstances in the lateral parts of the mucoperiosteum.

The surgery did not noticeably influence antero-posterior and vertical craniofacial growth; the effect was mainly restricted to transverse growth of maxillary structures. It was concluded that the surgery predominantly affected the tissues close to the surgical area. On the oral aspect of the palatal bone in the youngest groups rapid trabecular growth was found during the early postoperative period. This observation is in agreement with that of Barro and Latham (1981), who showed evidence of a prolific cellular response of the inner periosteal layer and renewed osteogenic activity on the third day after the operation in which the palatal mucoperiosteum was elevated and replaced. The transverse growth in the mid-palatal suture in experimental groups 1 and 2 decreased in the period from 16 to 22 weeks of age. This suggests that the influence of the surgery on suture growth is restricted to a distinct stage of development, irrespective of the different postoperative times. The present sample did not afford a histological quantification of the osteoblastic activity in the sutures. Since the surgery had only a minor influence on suture growth, it was assumed that the surgery mainly affects the dentoalveolar structures.

Early palatal surgery did not influence the deciduous arch dimensions systematically, but from the transition on the permanent arch width became reduced. This observation is in agreement with clinical conclusions about a severe occlusal impairment which occurred during the transition of teeth (Bergland and Sidhu, 1974). In the present study both younger groups, though operated on at different ages, showed comparable changes during the transition of the teeth. It is therefore suggested that the influence of the surgery on dentoalveolar structures is restricted to this transitional stage of development, irrespective of the different postoperative times.

During the period soon after the operation bone resorption was found at the cervicopalatal and the apicobuccal regions of the alveolar socket of posterior teeth, while bone deposition was found in other areas. It is suggested that contraction in the healing mucoperiosteum, which is continuous with the periodontal ligament, can result in a medially directed tensile force on the posterior teeth. This initial effect did not, however, cause a systematically reduced arch width in the deciduous dentition. Van der Linden (1986) suggested that transverse growth of the maxilla is correlated with mandibular dental arch width by the interdigitation of the posterior teeth. Since in Beagle dogs a scissors bite exists between the deciduous molars, it is assumed that this co-ordination mechanism can compensate for unfavourable environmental factors such as palatal surgery. From the transition on, however, an open bite exists between the first, second and third premolars, while more posterior teeth erupt in a solid interdigitation. It is suggested that, due to the loss of overlap of these premolars, the co-ordination mechanism cannot compensate anymore for possible effects of the surgery Consequently, the arch width between the fourth premolars and the first permanent molars - the occluding posterior teeth - did not differ from that in the control group Furthermore, the transition of the premolars corresponds roughly with the period from 16 to 22 weeks During this period in our bone marker study a decreased transverse growth of the mid-palatal suture was found It was concluded that the effect of the surgery on dentoalveolar structures and on palatal sutures became evident during the transition of the posterior teeth

With regard to the mechanism of the disturbance of the dentoalveolar growth and development in the premolar area, the following theory is postulated: during the later stages of tooth eruption the periodontal ligament develops; the cervical periodontal fibres are fanning out into the deeper layers of the palatal mucoperiosteum In the experimental animals the healed mucoperiosteum consists of a relatively rigid type of tissue which is firmly connected to the palatal bone by Sharpey's fibres The different mechanical properties of this tissue impede the premolars during their further eruption Since a co-ordination mechanism of the mandibular teeth is absent in the open bite premolar region, the maxillary premolars erupt vertically and medially instead of vertically and laterally This results in medial tipping of the premolars and a reduced arch width.

In summary the following conclusions can be drawn·

1 Palatal surgery on Beagle dogs, performed before or during the transition of teeth, disturbed growth and development of mucoperiosteum, maxillary bones and dentoalveolar structures
2 Surgery which was delayed until completion of the permanent dentition did disturb the mucoperiosteum, but did not result in noticeable disturbances of growth and development of bony and dentoalveolar structures of the maxilla.

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CHAPTER 10

Summary

Summary

Clefts in lip, alveolus and/or palate are malformations which occur during the embryonic development. Patients with untreated facial clefts have a relatively normal maxillofacial growth, except for the cleft area. Patients whose clefts were closed surgically show, however, disturbances of maxillofacial growth It is concluded that the surgery repairs the malformation but it might disturb growth. Although these growth disturbances have been the subject of many studies, there continues to be disagreement about the timing and the technique of surgery. This might be due to the large number of variables impeding clinical studies. In animal experiments the number of variables can be limited to some extent

Using Beagle dogs as experimental animals, a macroscopic and microscopic investigation of growth and development of maxillary structures after palatal surgery was conducted. The closure of a palatal cleft according to the Von Langenbeck technique was simulated on a normal palate after excision of a medial strip of mucoperiosteum The surgery was performed on the dogs at different ages, corresponding with the following stages of development of the dentition: 1) the eruption of the deciduous dentition, 2) the transition of teeth, 3) the completion of the permanent dentition. The animals were studied from the time of surgery until maturity at the age of 37 weeks.

Chapters 2-8 are papers that describe specific parts of the investigation.

Chapter 2 describes wound healing of the palatal mucoperiosteum, studied by means of clinical observations and intraoral photographs. During the operation tattoo points were placed at the wound margins. They served as measuring points on longitudinal series of photographs. After a few weeks the wound areas had healed, but the clinical appearance of the scar tissue differed from normal mucoperiosteum Wound contraction was measured as the approximation of tattoo points at opposite wound margins, it occurred during the first week after the operation. It was concluded that the reduction of the denuded bony surfaces shortly after the operation proceeded by wound contraction and, later on, by epithelial cell proliferation.

Chapter 3 describes the migration of the palatal mucoperiosteum, studied by means of dorso-ventral radiographs. During the operation metallic implants were placed in the mucoperiosteum. They served as measuring points on longitudinally taken radiographs. By using this method, the migration could be studied over a considerably longer period than by using tattoo points, which faded away after about 6 weeks Wound contraction was measured as the approximation of implants in opposite wound margins, it occurred during the first two weeks after

the operation. The effect was larger in the anterior than in the posterior region of the palate. All experimental groups showed a similar pattern. The surgery did not influence antero-posterior distances between mucoperiosteum implants.
Chapter 4 describes growth of maxillary structures and especially growth of palatal sutures, studied by means of lateral and dorso-ventral radiographs. The overall growth of maxillary structures in antero-posterior and vertical directions was measured on longitudinally taken lateral radiographs. The palatal surgery had no measurable influence on these skull dimensions.
During the operation metallic implants were inserted in the palatal bone. They served as measuring points on longitudinally taken dorso-ventral radiographs. Growth of palatal sutures was measured as the increase of distance between implants at both sides of the suture. In the experimental groups of animals, which were operated on during the eruption of the deciduous dentition or during the transition, growth in the mid-palatal suture was smaller than in the control group from 16 to 22 weeks of age.
Chapter 5 describes the migration of the mucoperiosteum along the palatal bone, studied by means of dorso-ventral radiographs. For this purpose the metallic implants in the mucoperiosteum and in the palatal bone were used. The migration of the mucoperiosteum along the bone was measured by changes of the distance between mucoperiosteum and bone implants. In normal animals this migration appeared to be unevenly distributed over different regions of the palate. In the experimental animals the normal pattern became disturbed during the first month after the operation.
In studies concerning the periosteum on long bones, some investigators stated that this periosteum plays a rôle in the regulation of bone growth. From these studies it was assumed that the palatal mucoperiosteum might play a similar rôle in the regulation of growth of maxillary bones. Possibly, the disturbances of its migration pattern, introduced by palatal surgery, can influence this regulation mechanism.
Chapter 6 describes the changes of maxillary arch dimensions, studied by means of dental casts. Impressions were taken regularly until the age of 37 weeks. The maxillary arch dimensions in the deciduous dentition were hardly influenced by early palatal surgery. During the transition of posterior teeth the arch width in the premolar region became, however, decreased. It was concluded that the effect of palatal surgery on dentoalveolar structures was restricted to the period of transition of teeth. Surgery performed after completion of the permanent dentition did not change maxillary arch dimensions.
Chapter 7 describes the histological part of the investigation. Two weeks after the operation the denuded bony areas were covered with young connective tissue and epithelium. The composition of the scar tissue differed permanently from normal mucoperiosteum because blood sinuses and elastic fibres were absent. In

addition, the scar tissue was firmly attached to the palatal bone by Sharpey's fibres. It is suggested that this tissue possesses different properties from the original tissue. The adjacent dentoalveolar structures were connected to the scar tissue by supra-alveolar cervical fibres from the periodontal ligament which were fanning out into deeper layers of the mucoperiosteum. This relatively rigid connection might impede the normal vertical and lateral development of the dento-alveolar structures.

Chapter 8 describes the skull dimensions of the dogs at 37 weeks of age. The antero-posterior and vertical dimensions were not influenced by the palatal surgery. The animals, operated on before or during the transition, showed decreased width of the snout and the maxillary dental arch in the second and third premolar region. Palatal surgery performed after completion of the permanent dentition did not cause measurable changes of the skulls.

Chapter 9 summarizes and discusses the series of studies described in chapters 2-8. It was concluded that the influence of palatal surgery on dentoalveolar structures is restricted to the period of transition of teeth, irrespective of the time span between the operation and the transition. During the first weeks after the operation wound contraction in the healing mucoperiosteum might result in a medially directed tensile force on posterior teeth by the connection between mucoperiosteum and periodontal ligament. Such forces might cause displacement of deciduous molars or premolars. This theory is supported by the histological study, which showed bone resorption at the cervicopalatal and apicobuccal region of the alveolar socket. The measurements on dental casts and skulls showed, however, that maxillary arch dimensions in the deciduous dentition were hardly influenced by the surgery. Only from the transition on, the dental arch in the region of the first, second and third premolars became decreased. Since in Beagle dogs a scissors bite exists between the deciduous molars, it is postulated that the overlap of these teeth can prevent collapse of the maxillary arch. From the transition on, an open bite develops in the region of the first, second and third premolars, while more posterior teeth erupt to a solid interdigitation. It is suggested that due to the loss of overlap of these premolars, the described mechanism, which should prevent maxillary collapse, cannot function. This theory is supported by the finding that the maxillary arch width at the fourth premolars and the first permanent molars did not differ from that in the control group.

To explain the displacement of the first, second and third premolars, the following theory is postulated: during the later stages of tooth eruption the periodontal ligament develops; supra-alveolar cervical periodontal fibres are fanning out into deeper layers of the palatal mucoperiosteum. In the experimental animals the scar tissue adjacent to the alveolar process consists of a relatively rigid type of tissue which is firmly connected to the palatal bone. The different properties of such tissue impede the adjacent premolars during their further eruption. In

the open bite region the absence of the co-ordination mechanism of occlusion and/or interdigitation results in eruption of these premolars in vertical and medial directions instead of vertical and lateral directions. This results in medial tipping of the premolars and a reduced arch width.
In summary the following conclusions can be drawn:

1 Palatal surgery on Beagle dogs, performed before or during the transition of teeth, disturbed growth and development of mucoperiosteum, maxillary bones and dentoalveolar structures.
2 Surgery which was delayed until completion of the permanent dentition did disturb the mucoperiosteum but did not result in noticeable disturbances of growth and development of bony and dentoalveolar structures of the maxilla.

Samenvatting

Samenvatting

Spleten in lip, kaak en/of gehemelte zijn afwijkingen die tijdens de embryonale ontwikkeling ontstaan. Patiënten bij wie dergelijke spleten niet behandeld worden, vertonen een relatief normale groei van het gelaat, met uitzondering van het gebied rond de spleet. Patiënten bij wie de spleten operatief worden gesloten, vertonen echter een verstoorde groei van het gelaat. Hieruit wordt geconcludeerd dat de operatieve behandeling de afwijking weliswaar kan herstellen, maar de gelaatsgroei kan verstoren. Deze groeiverstoring is jarenlang klinisch onderzocht, maar men werd het niet eens over de techniek van de operaties en de leeftijd waarop deze uitgevoerd moeten worden. Deze meningsverschillen zijn misschien het gevolg van het grote aantal variabelen waardoor het klinisch onderzoek bemoeilijkt wordt. Bij experimenteel onderzoek op dieren is het mogelijk dit aantal variabelen te verkleinen.

Met Beagle-honden als proefdieren werd daarom een macroscopisch en microscopisch onderzoek naar de groei en ontwikkeling van maxillaire structuren na palatum-operaties opgezet. De sluiting van een palatumspleet volgens de techniek van Von Langenbeck werd in dit onderzoek op een normaal palatum gesimuleerd, na excisie van een mediale strip mucoperiosteum. De operaties werden uitgevoerd op verschillende leeftijden van de proefdieren, overeenkomend met de volgende stadia in de ontwikkeling van het gebit: 1) de doorbraak van het melkgebit, 2) de wisseling van het gebit, 3) de voltooiing van het blijvend gebit. De dieren werden bestudeerd van voor de operatie tot het volwassen stadium op de leeftijd van 37 weken.

De hoofdstukken 2 tot en met 8 worden gevormd door artikelen die ieder een bepaald deel van het onderzoek beschrijven.

Hoofdstuk 2 beschrijft aan de hand van klinische observatie en intraorale foto's de wondgenezing van het palatinale mucoperiosteum. Tijdens de operatie werden tatoeagepunten op de wondranden geplaatst. Deze dienden gedurende zes weken als meetpunten op de longitudinaal gemaakte fotoseries. Na enkele weken waren de wondgebieden genezen, maar het littekenweefsel had een ander klinisch beeld dan normaal mucoperiosteum. Wondcontractie werd gemeten door de onderlinge nadering van tatoeagepunten aan weerszijden van de wond. Deze nadering trad op gedurende de eerste week na de operatie. De conclusie was dat de verkleining van de ontblote botgebieden kort na de operatie een gevolg was van wondcontractie en later van epitheliale celgroei.

Hoofdstuk 3 beschrijft aan de hand van opbeet-röntgenfoto's de verplaatsingen van het palatinale mucoperiosteum. Tijdens de operatie werden metalen implan-

taten in het mucoperiosteum geplaatst. Deze dienden als meetpunten op de longitudinaal gemaakte röntgenfoto's. Met deze benadering kon de bestudering van de veranderingen aanzienlijk langer worden doorgevoerd dan met tatoeagepunten die na zes weken vervaagden. Wondcontractie werd gemeten door de onderlinge nadering van implantaten aan weerszijden van de wond. Deze nadering trad op gedurende de eerste twee weken na de operatie. De meeste wondcontractie werd gevonden op het voorste gedeelte van het palatum. Alle experimentele groepen toonden hetzelfde beeld. De operaties bleken verder geen invloed te hebben op afstanden in de lengterichting tussen mucoperiosteum-implantaten.
Hoofdstuk 4 beschrijft aan de hand van laterale schedel- en opbeet-röntgenfoto's de groei van maxillaire structuren en in het bijzonder die van palatinale suturen. De totale lengte- en hoogtegroei van de maxillaire structuren werd gemeten op de longitudinaal gemaakte laterale schedelfoto's. De palatum-operaties hadden geen meetbare invloed op deze schedelafmetingen.
Tijdens de operatie werden metalen implantaten in het palatinale bot geplaatst. Deze dienden als meetpunten op de longitudinaal gemaakte opbeetfoto's. Groei van palatinale suturen in het wondgebied werd gemeten door toename van de afstand tussen implantaten aan weerszijden van de sutuur. Bij de experimentele groepen die werden geopereerd tijdens de doorbraak van het melkgebit of tijdens de wisseling van het gebit was gedurende de leeftijd van 16 tot 22 weken de groei in de mid-palatinale sutuur kleiner dan bij de controlegroep.
Hoofdstuk 5 beschrijft aan de hand van opbeet-röntgenfoto's de verplaatsing van het mucoperiosteum ten opzichte van het onderliggende bot. Hiervoor werden de metalen implantaten in zowel het mucoperiosteum als het bot gebruikt. De verplaatsing van het mucoperiosteum ten opzichte van het bot werd gemeten door veranderingen van de afstand tussen mucoperiosteum- en bot-implantaten. Bij normale dieren bleek deze verplaatsing ongelijk verdeeld te zijn over verschillende gebieden van het palatum. Bij de experimentele dieren werd dit beeld gedurende de eerste maand na de operatie verstoord.
In de literatuur over het periosteum van pijpbeenderen wordt gesteld dat dit periosteum een rol speelt bij de regulatie van de botgroei. Naar aanleiding van deze literatuur werd verondersteld dat het palatinale mucoperiosteum die rol zou kunnen spelen bij de groei van de benige maxilla. Vervolgens zou verstoring van de normale verplaatsing van het mucoperiosteum als gevolg van palatum-operaties deze regulatie kunnen beïnvloeden.
Hoofdstuk 6 beschrijft aan de hand van gebitsmodellen de veranderingen van de tandboog in de maxilla. Hiertoe werden van vlak voor de operatie tot de beëindiging van het onderzoek regelmatig gebitsafdrukken gemaakt. De afmetingen van de tandboog in het melkgebit werden nauwelijks beïnvloed door vroege palatum-operaties. Tijdens de gebitswisseling werd echter de breedte van de tandboog ter plaatse van de tweede en derde premolaren aanzienlijk verkleind.

Daaruit werd geconcludeerd dat de gevolgen van palatum-operaties voor de dentoalveolaire structuren beperkt blijven tot de wisselfase. De palatum-operaties die na voltooiing van de gebitswisseling werden uitgevoerd, leidden niet tot veranderingen in de tandboog

Hoofdstuk 7 behandelt het histologische deel van het onderzoek. Twee weken na de operatie waren de ontblote botgebieden bedekt met jong bindweefsel en epitheel De samenstelling van het littekenweefsel verschilde blijvend van normaal mucoperiosteum doordat bloedsinussen en elastische vezels ontbraken en doordat het met vezels van Sharpey in het bot verankerd was Dit leidde tot de suggestie dat dit weefsel andere eigenschappen moet hebben dan het normale weefsel De aangrenzende dentoalveolaire structuren bleken verbonden te zijn met dit weefsel doordat supra-alveolaire cervicale vezels van het parodontium uitstraalden in diepere lagen van het mucoperiosteum Deze relatief starre verbinding zou de normale verticale en laterale ontwikkeling van de dentoalveolaire structuren kunnen belemmeren

Hoofdstuk 8 beschrijft de afmetingen van de schedel van de honden op de leeftijd van 37 weken De lengte- en hoogte-afmetingen van de schedels waren niet beinvloed door de palatum-operaties. De breedte van de snuit en van de maxillaire tandboog ter plaatse van de tweede en derde premolaren was kleiner bij de dieren die voor of tijdens de gebitswisseling werden geopereerd. Palatum-operaties die werden uitgevoerd na doorbraak van het blijvende gebit, leidden niet tot meetbare veranderingen in de schedel.

In hoofdstuk 9 worden de artikelen die in de hoofdstukken 2 tot en met 8 werden beschreven, samengevat en bediscussieerd Hierbij wordt geconcludeerd dat de invloed van palatum-operaties op dentoalveolaire structuren beperkt blijft tot de periode van gebitswisseling, onafhankelijk van de tijdsspanne tussen de operatie en de wisseling Gedurende de eerste weken na de operatie zou wondcontractie in het genezende mucoperiosteum een trekkracht in mediale richting op melkmolaren of premolaren kunnen uitoefenen via de verbinding van het mucoperiosteum en het parodontale ligament. Dergelijke krachten zouden kunnen leiden tot verplaatsing van melkmolaren of premolaren. Deze theorie wordt ondersteund door de histologische bevindingen waarbij, gedurende de periode van wondcontractie, botresorptie werd gevonden in de cervicopalatinale en apicobuccale gebieden van de alveole. De metingen op gebitsmodellen en schedels toonden echter aan dat de maxillaire tandboog in het melkgebit nauwelijks beinvloed werd door de palatum-operaties. Pas vanaf de gebitswisseling was de tandboog smaller ter plaatse van de eerste, tweede en derde premolaren Verondersteld wordt dat de schaarbeet tussen de melkmolaren bij Beagle-honden een versmalling van de maxillaire tandboog kan voorkomen. Vanaf de gebitswisseling ontstaat echter een open beet tussen de eerste, tweede en derde premolaren terwijl de vierde premolaren en blijvende molaren na eruptie interdigiteren.

Gesteld wordt dat, door het ontbreken van overlapping van de eerste, tweede en derde premolaren, het beschreven mechanisme ter voorkoming van de maxillaire collaps niet functioneert. Deze theorie wordt ondersteund door de bevinding dat de breedte van de tandboog ter plaatse van de vierde premolaren en de eerste blijvende molaren niet verschilde van de controlegroep.
Ter verklaring van de verplaatsing van eerste, tweede en derde premolaren wordt uitgegaan van de volgende theorie: gedurende de latere fase van de eruptie wordt het parodontale ligament gevormd; hierbij stralen supra-alveolaire cervicale vezels uit in diepere lagen van het palatinale mucoperiosteum. Bij de geopereerde dieren bestaat het littekenweefsel naast de processus alveolaris uit een relatief stug soort weefsel dat stevig verankerd is in het palatinale bot. De afwijkende eigenschappen van dit weefsel beperken de premolaren tijdens hun verdere eruptie. Het ontbreken van het coördinatiemechanisme van occlusie en/of interdigitatie in het open-beet-gebied leidt ertoe dat deze premolaren in verticale en mediale in plaats van in verticale en laterale richting erupteren. Het gevolg is mediale tipping van de premolaren en een smallere tandboog.
Samenvattend kunnen de volgende conclusies worden getrokken:

1 Palatum-operaties bij Beagle-honden die voor of tijdens de gebitswisseling werden uitgevoerd, verstoorden de groei en ontwikkeling van mucoperiosteum, benige en dentoalveolaire structuren van de maxilla.
2 Tot na voltooiing van de gebitswisseling uitgestelde palatum-operaties veroorzaakten wel een verstoring van het mucoperiosteum, maar leidden niet tot een aantoonbare schadelijke beïnvloeding van de groei en ontwikkeling van benige en dentoalveolaire structuren van de maxilla.

Curriculum vitae

Maarten Gerard Marcel Maria Wijdeveld werd op 17 mei 1957 geboren te Nijmegen. In 1975 legde hij aan de scholengemeenschap Nebo-Mariënbosch-Gabriël-college te Nijmegen het eindexamen Atheneum B af. Vervolgens studeerde hij tandheelkunde aan de Katholieke Universiteit te Nijmegen. Het doctoraal-examen werd in 1979 afgelegd en het tandartsexamen in 1980. Na een periode waarin hij in verschillende tandarts-praktijken kon waarnemen, volgde hij van 1981 tot 1985 aan de afdeling Orthodontie van de Katholieke Universiteit te Nijmegen de opleiding tot specialist. Sinds 1985 is hij in Roermond en Weert werkzaam als orthodontist, in samenwerking met Drs. Ellen M. Grupping.

Stellingen

BIJ HET PROEFSCHRIFT
GROWTH OF MAXILLARY STRUCTURES
AFTER PALATAL SURGERY ON DOGS

Maarten G.M.M. Wijdeveld, 17 juni 1988

1 The major challenge for the management of patients with cleft lip and palate in the 1980's is to settle the controversy on timing and type of palate repair.
Witzel MA, Salyer MD, Ross RB: Delayed hard palate repair: the philosophy revisited.
Cleft Palate J 21: 263-269; 1984.

2 Wondcontractie na excisie van palatinaal mucoperiosteum bij Beagle-honden treedt alleen op gedurende de eerste twee weken.

3 Bij Beagle-honden verplaatst het mucoperiosteum zich tijdens de groei over het palatinale bot; deze verplaatsing is ongelijk verdeeld over verschillende gebieden van het palatum en wordt beïnvloed door palatum-operaties.

4 Cervicale parodontale vezels verbinden bij Beagle-honden de molaren en premolaren met diepe lagen van het palatinale mucoperiosteum.

5 Tijdens de gebitswisseling raakt bij Beagle-honden de maxillaire tandboog in de premolaarstreek versmald als gevolg van vroege palatum-operaties; de schaarbeet tussen de melkmolaren kan een dergelijke versmalling in het melkgebit voorkomen.

6 De samenstelling van littekenweefsel op het palatum van Beagle-honden verschilt blijvend van normaal mucoperiosteum omdat elastische vezels ontbreken en het weefsel door vezels van Sharpey in het palatinale bot is verankerd.

7 Uitstel van palatum-operaties tot na de doorbraak van het blijvend gebit bevordert bij Beagle-honden de normale groei en ontwikkeling van de benige en dentoalveolaire structuren van de maxilla.

8 De behandeling en begeleiding van patiënten met spleten in lip-, kaak-en/of gehemelte (schisis) dient plaats te vinden in gespecialiseerde centra.

9 Voor de goede kwaliteit van patientenzorg en wetenschappelijk onderzoek is ten minste een bepaald aantal patienten vereist; een capaciteit van ten hoogste zes a zeven centra in Nederland is daarom voldoende voor de ongeveer 300 schisis-baby's die jaarlijks worden geboren

10 Patienten die geen stabiele occlusale contacten tussen molaren en/of premolaren hebben, moeten bij een orthodontische behandeling van tevoren worden gewaarschuwd voor een relatief grote kans op recidief.

11 Extractie van melkhoektanden aan het eind van de eerste wisselfase bij ruimtegebrek in het onder- en/of bovenfront verschuift het probleem in plaats en tijd

12 De toepassing van composieten ter verbetering van afwijkende grootte, vorm en/of kleur van voortanden kan de „kroon op het werk" van de orthodontist zijn

13 Verdeling van onderwijs en onderzoek over verschillende assistenten in opleiding tot specialist in de orthodontie komt de kwaliteit van beide werkzaamheden ten goede

14 Bij een promotie op basis van een onderzoek dat begeleid wordt vanuit verschillende vakgebieden zou het promotieregelement meer dan twee co-referenten moeten toestaan

15 De tandarts als eigenaar en directeur van een zelfstandige onderneming is onvoldoende opgeleid voor zijn bedrijfskundige taken.

16 Kaakgewrichtsklachten bezorgen menig tandarts hoofdpijn.