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THE COURSE OF THE PREMAXILLARY AND MAXILLARY VESSELS AND NERVES IN CLEFT JAW

by

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INTRODUCTION

Harelip is very frequently associated with a cleft in the alveolar process, through the region of the upper lateral incisor. In most cases the malformation is moreover associated with a cleft palate. A central incisor will usually be present, sometimes a lateral too, in the premaxilla between the cleft and the median suture. These teeth are often deformed and more or less displaced, *slanting towards the cleft*. They are generally considered to be of poor quality, be susceptible to caries and apt to be lost early. It is, however, remarkable that they have developed at all when a complete cleft of the jaw has blocked the normal supplies through the anterior superior alveolar artery and nerve. A number of hypotheses about this extraordinary odontologic fact have been advanced, but the few investigations undertaken have not fully explained the innervation and blood supply of these teeth.

Albrecht (1901) believes that because the arteries of the vomer and premaxillae in bilateral clefts are confined to the median segment it becomes overnourished and protruding. Due to the cleft, it has room for abnormal enlargement and may be capable of producing a lateral incisor which, according to this author, is atavistic, as the site of the ordinary lateral incisor is on the distal side of the cleft. *Cadenat* (1930) points out the difference

between the embryonic blood supply, with the septal artery from the internal carotid to the median nasal process, and the final system in which branches of the external carotid take over. During the transitional stage, about the middle of the second fetal month, all sorts of disturbances causing deficient blood supply may occur and even, perhaps, cause clefts. *Cadenat* also maintains (1962) that because the anterior superior alveolar artery cannot reach the premaxillary teeth, these tend to become undernourished and poorly developed. Instead, the artery will increase the maxillary supplies and thus be conducive to development of a precanine tooth. *Keith* (1948) alleges that premaxillary teeth medial to a cleft are of little value. When the maxillary process fails to reach and fuse with the median nasal process the incisors are destitute of their arteries and nerves and the surgeon usually excises them when he seeks to restore the palate. *Cook* (1949) expresses a common assumption in stating that there is well supported evidence for the theory that the nasopalatine nerve alone supplies sensory fibres to the maxillary incisors in persons with bilateral cleft lip and cleft palate.

Whittles (1908) examined histologically frontal sections from a premaxilla removed under operation of a three months old boy with bilateral cleft. A crayon diagram shows the temporary central incisors lying very close to the median suture with little or no jaw bone distally. Photomicrographs depict irregular epithelium of the mucous membrane, atrophy of odontoblasts, and irregular dentin formation with an absorption process going on from the follicular side. He does not, however, mention the neurovascular supply of the teeth. *Veau* (1926 a, b, c) is the author who has gone most thoroughly into the question of innervation and blood supply to bone and teeth in the cleft area and his conclusions have probably had widespread influence. He has reported numerous observations from his macroscopic and microscopic studies on both normal and cleft jaws. In bilateral clefts the bone and teeth of the median tubercle tend to degenerate with advancing years. In a growing person this tubercle is not an anatomic entity, as it was during a short period in the embryonic stage, and it has no neurovascular system of its own to ensure its vitality. The posterior septal artery is too insignificant for the task as is also the nasopalatine nerve. Nor is either of

them capable of compensatory hypertrophy. The soft facial tissue of the tubercle is, on the other hand, better off being supplied from the facial vessels and nerves. The prognosis for the premaxilla and its teeth on the cleft side is likewise poor in unilateral cases, since the premaxillary median suture will usually completely block any connection between the vessels and nerves of the two sides, in cleft as well as in normal jaws. Adult patients with clefts nearly always have an atrophic premaxilla due not to operations, which was *Veau's* first assumption, but to deficient neurovascular supply. How development of premaxillary incisors in the vicinity of a cleft is possible without sufficient supplies is not clear. He leaves it an open, well defined if unsolved question whether or not they after all have some sort of innervation. He further holds that there is a fundamental difference between the incisors medial to the cleft and the precanine and canine teeth on the distal side. The latter are there to stay, due to unhampered normal blood and nerve supplies. In a later publication (1934) *Veau* writes that the medial incisor close to a cleft may sometimes receive insignificant branches from the supplies of the nasal septum, through a small foramen on the lingual side of the premaxilla. From their study of human specimens, *Slaughter et al.* (1960) conclude that in bilateral clefts the philtrum and premaxilla receive their principal blood supply from the posterior septal artery and that, in operations, due care must be taken not to compromise the blood supply to the median segment.

Considered together, the inference from the literature is that the premaxillary teeth immediately adjacent to a jaw cleft are insignificant formations of little or no lasting value to the patient. The reason for this is deficient supplies caused endogenously. Due to progress in the orthodontic treatment of patients with harelip and cleft palate, observations and experience during recent years in this country have made a reappraisal of the old concept necessary.

In the primary dentition the central incisor in the vicinity of a cleft is usually well developed. A lateral incisor in the same premaxilla may even be larger than normal (*Böhn* 1950, 1963). It is mostly in the secondary dentition that the central and, in particular, the lateral incisor may be missing or display poor

quality due to development disturbances. This far the hypothesis of decreasing vitality is confirmed, whether or not surgery is to blame. However, other circumstances seem to contradict the opinion of *Veau*. The teeth in the secondary dentition may sometimes be fairly well developed, even in complete clefts of the alveolar process and, besides, if the teeth are hypoplastic and malformed they nevertheless usually possess a vital pulp and a blood supply. In addition, the newer methods of repositioning of the maxillary complex (*Harvold* 1947, 1949, 1954) and retention in harelip and cleft palate (*Böhn* 1949, 1951, 1955) have established that the premaxillary teeth close to the cleft are usable and very important to the final result. Both are of value during regulation and the central incisor in particular has better chance of becoming permanently useful than one should think possible from the estimates of *Veau* and *Keith*. The position and function of the teeth become more normal after the orthodontic treatment and this is undoubtedly beneficial: it stimulates the jaw bone and periodontium, raises the resistance of the teeth and enhances the possibilities of further management of the dental problems. These results are not compatible with the old concept. The neurovascular pattern in cleft jaw must vary from the normal, but the question of course, contributions and reinforcement arises anew. More detailed knowledge on these points would benefit both the surgeon and the dentist.

In a preliminary study forming the basis of the present investigation, *Böhn* (1961) in normal material from newborn infants found that arteries and nerves in the incisive canal communicate across the premaxillary median suture. Together they moreover formed a median artery (a. praemaxillaris mediana) and a median nerve (n. praemaxillaris medianus) in the suture, in connection with the maxillary supplies of both sides. More direct anastomoses between the latter could not be excluded. Thus, the median suture is not such an effective barrier between the right and the left premaxillary nerves and vessels as *Veau* maintained.

No report is found in the literature concerning the development of, or even existence of, an anterior superior alveolar artery and nerve when a cleft cuts them off from a considerable part of their supply area.

By the kind permission of the anatomy and pathology departments of the University of Oslo the present author had occasion to examine a number of specimens from newborn infants with jaw clefts; among whom were two pairs of conjoined twins, one in each pair with a facial cleft. The present investigation is an attempt to answer the following questions:

1. What is the course of the premaxillary nerves and vessels in bilateral and unilateral cleft jaw?
2. Are there an anterior superior alveolar artery and nerve to supply a precanine tooth in a cleft jaw?
3. Are there neonatal (preoperative) signs of deficient development of the osseous tissue and tooth germs adjacent to a cleft?
4. Does the histologic examination reveal anything else of significance for the understanding of the lines of development of the teeth and clefts?
5. Is there any irregularity to indicate a predisposition to harelip in the twin without a visible cleft in either of the pairs?
6. Is increased knowledge on any of these points of importance for the methods of treatment?

MATERIAL AND METHODS

Eight formalin-fixed upper jaws from human fetuses were studied macroscopically and microscopically. The smallest fetus and one of the larger ones had no other known malformation than harelip and cleft palate. Two others had lethal malformations in addition to the facial clefts; one had acrania and the other anencephalia and bifid spine. Four jaws belonged to two pairs of »Siamese» twins. According to the morphologic conditions, from one to four specimens were taken out of each jaw for histological examination. Each specimen will be described and direction of section indicated in connection with the examination and the histological findings. The preparations were decalcified, dehydrated and embedded in paraffin wax. After sectioning, complete series were mounted and stained with hematoxylin-eosin or Goldner stain, the latter giving better contrast in the nerves. Section thickness was 5—6 μ . Camera lucida and photo-

graphs were used to a great extent to obtain a general view of the sections. The course of the arteries and nerves in the premaxilla was schematically reconstructed.

Inventory of the jaws examined

Jaw No.	Jaw cleft	Other malformations	Measurements ¹	Number of specimens
1	bilateral		a.p.c.: 10 cm	4
2	bilateral	acrania	c.t.: 23 cm	2
3	left unilat.		a.p.c.: 3.8 cm	1
4	left unilat.	anencephalia and bifid spine	c.t.: 21 cm	2
5	non-cleft	} ischio-thoracopagus	c.t.: 31 cm	1
6	right unilat.			1
7	non-cleft	} thoracopagus	c.t.: 32 cm	1
8	left unilat.			2

¹ a.p.c.: antero-posterior length of head
c.t.: crown-tail length

Further, the cranium has been examined from an adult with a complete leftsided jaw cleft but without a cleft palate.

The recorded course of the nerves has been tested by altering the ordinary technique of local anesthesia in dental treatment of 25 patients with clefts similar to those in the study material.

OBSERVATIONS

Jaw no. 1

This upper jaw comes from a fetal head with the following measurements:

length (front to back of the head) 10 cm
width (temple to temple) 9 cm
height (without neck) 10 cm.

The jaw presents a complete bilateral combined cleft, without epithelial bridge connections (Fig. 1). The nasal septum is oversized, in particular anteroposteriorly. Its lower rolled border lies between the defective palatal shelves, with a wide opening

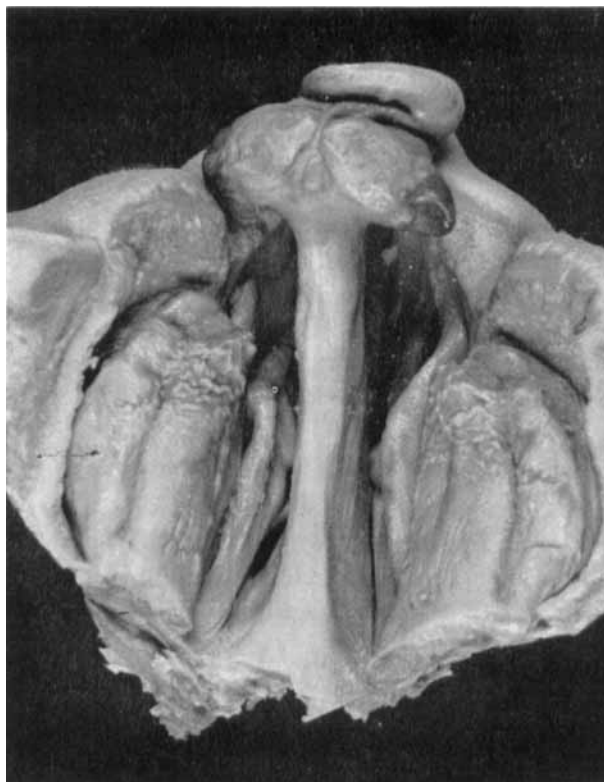


Fig. 1. Jaw No. 1. Bilateral total harelip and cleft palate.

into the nasal cavity on both sides. Anteriorly and basally the septum carries the »premaxilla» or »incisive process»; *i.e.* the median segment of the upper jaw, appearing as a tubercle which is advanced by about 1 cm compared to a normal position between the lateral maxillary segments. Anteriorly on this median part of the jaw, is seen the central part of the lip (often called philtrum or prolabium) attached just below the nasal apex as the columella is practically non-existent, and to the front of the segment forming a diminutive vestibulum. The frenulum of the upper lip has an ordinary extension across the alveolar process in the median plane to a normally placed incisive papilla. On both sides the median segment presents an erupted incisor. The right tooth is rotated about 90° distolingually. The left one is

also somewhat distolingually rotated and moreover placed with the longitudinal axis inclined about 40° towards the cleft. The radiograph reveals scant premaxillary bone with two small crypts in which are lying the unerupted temporary central incisors with calcified crowns. Seen from the side, their longitudinal axes run practically vertically. The lateral segments are in normal position. In both, radiography reveals the ordinary molars and canine tooth in the primary dentition, and also a precanine tooth. All are unerupted. The degree of calcification is the same as in a normal newborn infant.

The case represents the most severe of the common facial clefts, *i.e.* complete bilateral combined cleft in its purest, most typical, symmetric form.

The following four specimens were taken out for histological examination:

Specimen 1 a: The median segment with its lip section and a part of the nasal septum, approximately 2 cm in anteroposterior length and 1,7 cm in oronasal height. It was cut horizontally from the alveolar edge.

Specimen 1 b: The left jaw segment with a height of about 1.5 cm, cut frontally.

Specimen 1 c: The right jaw segment with the same measurement as the latter, cut horizontally from the alveolar edge.

Specimen 1 d: A small piece of the central part of the nasal septum in full extent, cut frontally.

Specimen 1 a

The jaw bone of the median segment is less extensive than in normal premaxillae. This is particularly apparent laterally on both sides in that both the erupted incisors lie completely outside the osseous tissue.

The premaxillary crypts over the temporary medial incisors are likewise less extensive than is found in normal jaws of the same age particularly labioincisally and medioincisally.

The premaxillary frontal processes are completely missing while the Stenonian processes are enlarged in the anteroposterior direction.

The median suture of the premaxilla is on the whole very narrow, but otherwise shows the normal pattern of periosteal connective tissue fibres crossing each other in all directions. Branches of nerves and blood vessels become easily perceptible only above the greatest curvature of the crowns of the temporary central incisors which lie closer together than in normal jaws. Both these teeth are at the normal developmental stage for newborn infants. Their longitudinal axes show a slight distal inclination and both are slightly mesiofacially rotated. The permanent central incisors are at an advanced bell stage. They are in normal position behind their precursors, lying perhaps rather more crowded than usual, with the longitudinal axes diverging downwards and laterally.

The crown bases of the erupted lateral incisors are attached to the gingival connective tissue and no trace of bony alveolar formation for them is visible. Their development seems to be arrested, or nearly so, with the odontoblastic layer showing marked signs of degeneration. It seems reasonable to regard these teeth as prematurely erupted temporary incisors. On the right side is seen a small successor in the bud stage. On the left side the successor is missing.

The bones and teeth of the median segment derive their innervation and blood supply from the nasopalatine nerve and posterior septal artery, without demonstrable contributions from other sources. The pattern is schematically reconstructed in Figures 2 and 3 and can be described as follows:

The nasopalatine nerve runs as a solid bundle downwards and forwards on the vomer. In the premaxillary part of the septum it runs forward just above the lower, thickened border to the incisive process. Here the nerves of the two sides converge slightly and run parallel in a more vertical direction, downwards on the back of the incisive process, close to the median suture. They each send off a branch which join to form a small median nerve. This passes into the suture, and then bends upwards and forwards. Close to the lower edge of the alveolar crest, at the approximate level of the incisal third of the anlage of the permanent medial incisor, is another juncture. One branch passes laterally to the palatine gingiva. Another branch continues downwards into the incisive papilla, and then passes forwards and laterally

in the frenulum. The largest branch, however, pierces the posterior wall of the premaxilla, and goes upward inside the bone. Here it sends one branch to the anlage of the permanent medial incisor and then, on the left side of the specimen, another to the median nerve. It further sends off a branch which leaves the pre-

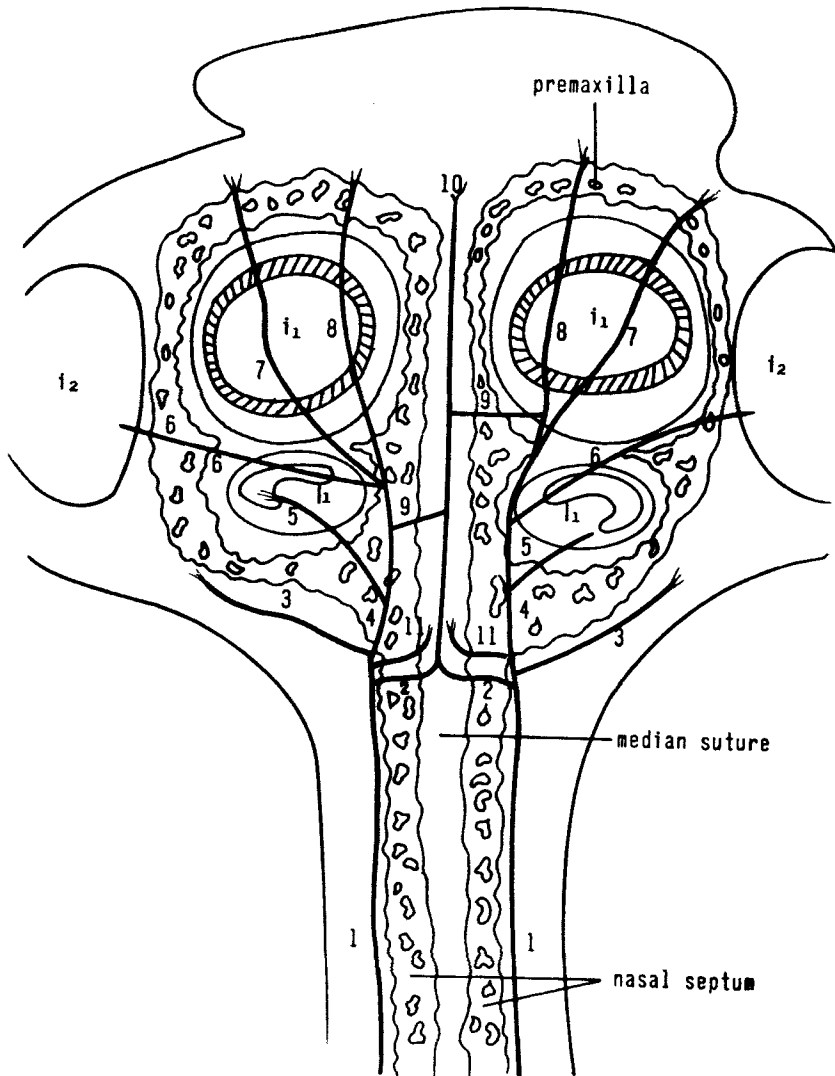


Fig. 2. Diagram of the nerves (and arteries) in specimen 1a, seen from above.

maxilla through the lateral wall to continue towards the lateral temporary incisor. In two still solid bundles, one distal and one medial, the nerve finally passes upwards and forwards, straight across the anlage of the temporary medial incisor where it sends off branches to the pulp. It then again turns downwards on the

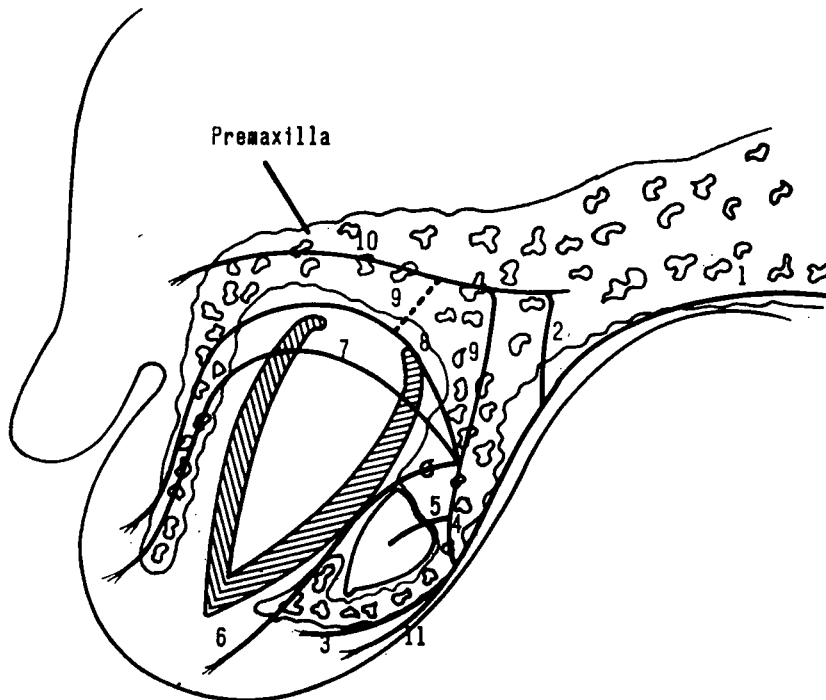


Fig. 3. Diagram of the nerves (and arteries) in specimen 1a, seen from the left.

Fig. 2 and 3.

The numbered nerve branches:

1. Nasopalatine nerve
2. Branch forming the median nerve
3. Branch to palatal gingiva
4. Main branch into premaxilla
5. Branch to I_1 , the permanent central incisor in bell stage
6. Branch to i_2 , the temporary lateral incisor
8. Medial } branch to i_1 , the temporary central incisor
7. Distal }
9. Branch to median nerve
10. The median nerve
11. Branches to incisive papilla.

inside of the frontal wall of the premaxilla, which it penetrates or passes, to emerge in the gingiva in front of the incisive process. Its terminal ramifications end in the gingival margin. The right side of the specimen has also a branch to the median nerve, but this originates from the highest part of the medial of the two terminal branches. There are backward threads into the suture from the highest portion of the median nerve, but the main stem runs forwards giving up its terminal ramifications in front of the upper part of the premaxillary bone.

The posterior septal artery follows essentially the same course.

The medial part of the lip mainly consists of poorly differentiated connective tissue with numerous glands and hair follicles. There is no muscular tissue. The above-mentioned neurovascular ramifications hardly enter this part which probably derives its principal supplies from the terminal branches of the anterior ethmoidal artery and nerve.

Specimen 1 b

Frontal sections, through the left segment, soon encounter the precanine deciduous tooth which is the lowest, most anterior and most lingual of the teeth. It is normally developed without degenerative changes in the pulp, and calcified to about the same degree as the erupted temporary incisor. However, it lies unerupted in the alveolus which is open orally and medially toward the gingival mucous membrane. The alveolus is also open upwards and outwards toward the anlage of the temporary canine which is at a somewhat less advanced stage of calcification. The permanent precanine tooth is just entering the bud stage. The neurovascular supplies to these teeth come from above, through the anterior superior alveolar nerve and artery each of which sends one branch to the canine and one to the precanine tooth.

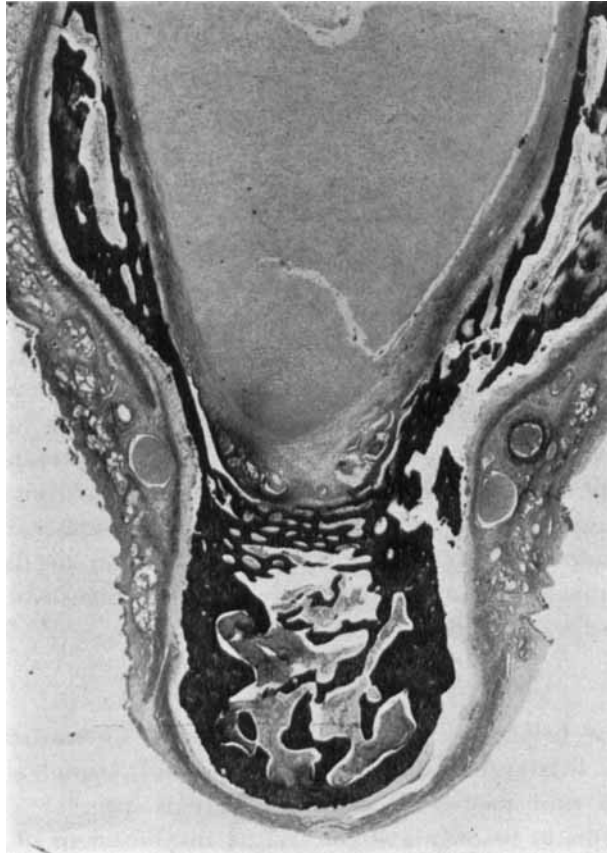


Fig. 4. Inferior part of vomer in frontal section. The nasopalatine nerve and its artery are lying in a groove on each side. $\times 17$.

All the three specimens mentioned above present a large number of the typical gingival epithelial pearls, particularly along the cleft edges.

Specimen 1 d

Frontal sections through the centre of the nasal septum show cross sections of the nasopalatine nerve and the posterior septal artery lying in a groove in the vomer, just above its thickened lower border (Fig. 4).

Histological examination of an upper jaw with a complete bilateral combined cleft in a fetus about 9 months old shows that several teeth are at a normal stage of development. Exceptions are the premaxillary lateral temporary incisors, which are prematurely erupted and whose development seems to be arrested with the crown formation, and also their successors of which one is rudimentary and the other missing. The median segment derives its neurovascular supply from the nasopalatine nerve and the posterior septal artery which, from an approximately normal course on the vomer, pierce the alveolar process near its lower border and close to the median suture. From there they enter the premaxilla in a curved course; upward—forward and then downward again. En route, they send branches to the palatal gingiva, to all dental germs, and to form the median nerve and artery in the suture. These details have been charted. The incisive canal, suture and foramen were all non-existent. A pre-canine tooth is present in both dentitions at a normal stage of development in both the lateral segments which also possess anterior superior alveolar nerves and arteries.

Jaw No. 2

The jaw belongs to a fetus with acrania. Crown-tail length is 23 cm. Bilateral lip-jaw clefts are present, complete on the right side and partial in the left alveolar process (Fig. 5). There seems to be only a slight frontal displacement of the median segment. The right-side cleft appears as though part of the jaw had been left out. Lingually in the bridge of the partial cleft is seen a small, tumour-like formation. The hard palate is irregular and sagittally thickened along the midline. Radiographic examination revealed only the two temporary central incisors in the median segment; both somewhat distolingually rotated and somewhat inclined to the side of the cleft. The lateral segments have temporary molars and canine tooth. Only the left side has a precanine tooth mediolingually to the canine. This precanine is distolingually rotated and inclined to the cleft too. The degree of calcification is lower than in jaw No. 1.

The central part of the lip is relatively large, but practically without vestibulum. The frenulum of the lip is tightly stretched across the alveolar process.



Fig. 5. Jaw No. 2. Bilateral lip-jaw cleft, total on the right and partial on the left side.

The following specimens were taken out:

Specimen 2 a: The median segment with about 1 cm of the nasal septum together with enough of the left segment to include the precanine and canine teeth. The specimen was cut horizontally, from below.

Specimen 2 b: The anterior two thirds of the right segment in about 1 cm height, cut in the same way.

Specimen 2 a

The premaxillary bone is scantily developed and provides the temporary central incisors with only small apical alveoli. The teeth seem to be normally developed, corresponding to about seven months fetal age. In this specimen too, the median suture

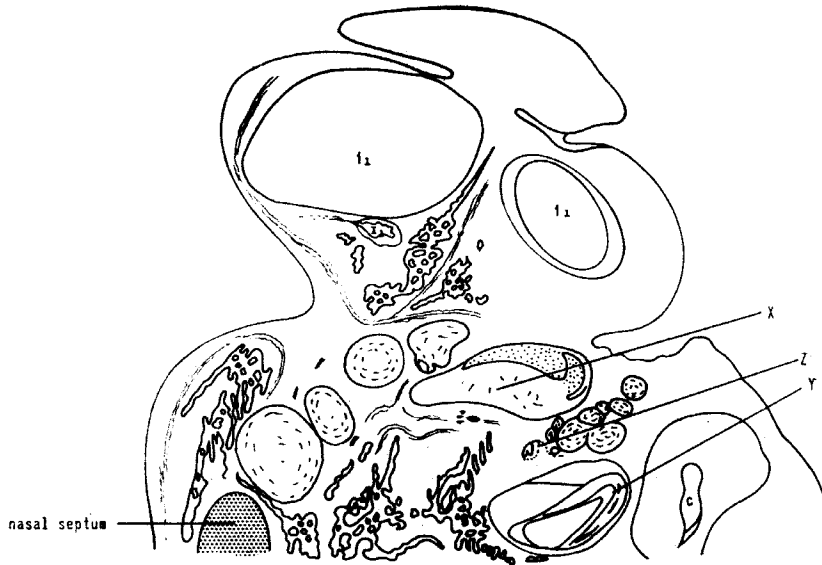


Fig. 6. Horizontal section from specimen 2a.

- x = Follicle with cystic contents and destroyed anlage, between two cystic belts
 y = Temporary precanine tooth
 z = Permanent tooth bud

is very narrow and the teeth lie close together. The permanent central incisors are present in normal position in the early bell stage. No other dental germs are present between the clefts.

The area of the partial cleft is characterized by large and small epithelium-lined cysts, forming belts before and behind the tumour-like formation (Fig. 6). The latter contains a large but uncalcified dental germ whose enamel organ has, to a large extent, been destroyed by a similar cyst partly encircling the anlage. Distal to this, is seen the precanine tooth which is at the same stage of calcification as the incisors. Between them is a single anlage of a permanent tooth in the cap stage. The posterior cyst belt can be followed into the floor of the left nasal cavity where it ends in a nasoalveolar cyst which is internally lined with ciliated columnar epithelium.

In this case it has not been possible to trace branches of either

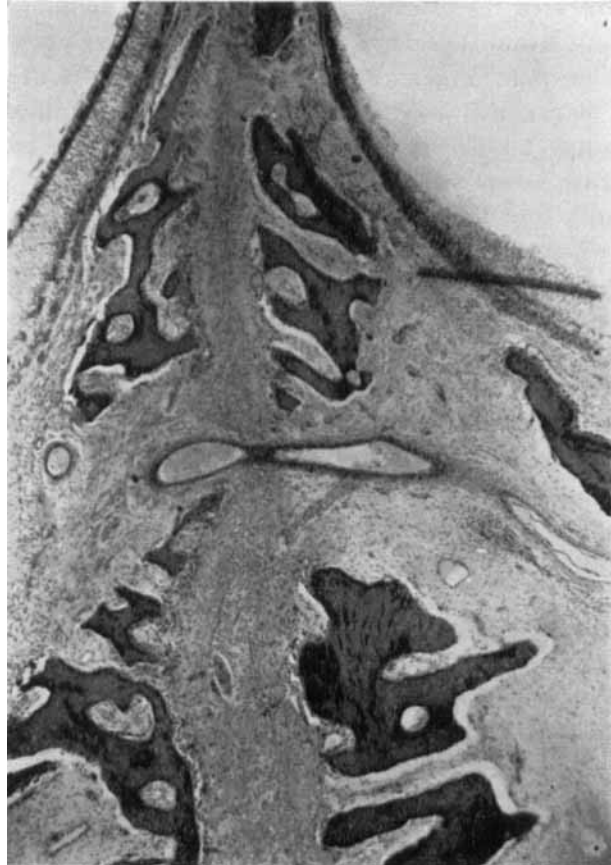


Fig. 7. Horizontal section from premaxilla in jaw No. 2, seen from below. Nerve and artery supply to the right side, crossing the median suture from the left. $\times 150$.

the right or the left nasopalatine nerve and accompanying posterior septal artery to the premaxilla. Nor is the incisive canal or suture present. Here the entire neurovascular supply is taken care of by the left anterior superior alveolar nerve and artery. The bridge across the partial cleft contains some bony substance at the level of the apical part of the precanine tooth. Just below this bony bridge, large branches of the alveolar vessels and nerves of the maxilla cross over to the median segment, pass across the apical part of the anlage of the left permanent central

incisor and into the mediolingual part of the temporary incisor's follicle. From there, one blood vessel and one nerve branch cross the median suture (Fig. 7) to ramify in the area above the right permanent central incisor and in the follicle of the corresponding temporary tooth. During their course across the midline, both vessel and nerve send off a branch backwards and these ramify into the jaw bone on both sides. From the supply to the left incisor, somewhat higher up and further back, similar branches are sent off into the median suture where they form the median vessel and nerve, following an upward and forward course into the soft tissues anterior to the premaxilla.

The medial lip segment presents practically the same picture as in specimen 1 a. The relatively abundant supply of vessels and nerves do not give any traceable contribution to the premaxillary bone and teeth.

Specimen 2 b

The right segment was cut horizontally from below. There is not the slightest trace of a precanine tooth. Due to a mishap, the specimen did not yield particulars about nerves and vessels.

An upper jaw from a fetus with a bilateral lip-jaw cleft, complete on the right side and partial in the alveolar process on the left, presents teeth at a developmental stage corresponding to about 7 months fetal age. The median segment has only the central incisors, and in the right segment the precanine tooth is missing. The tissues in the partial cleft are arranged in two belts of smaller and larger epithelial pearls. The anterior belt extends inwards into the nasal septum, while the posterior belt can be followed upwards to the floor of the nasal cavity where it ends in a typical nasoalveolar cyst. Between the cyst belts is a large, uncalcified dental germ compromised by a cyst. Between this anlage and the precanine temporary tooth is found the anlage of a single permanent tooth in the cap stage. It is not possible to trace the nasopalatine nerve and the posterior septal artery as far forwards as the premaxilla. The maxillary vessels and nerves on the left side traverse the bridge over the partial cleft to the bone and teeth of the median segment on both sides of the midline.

Jaw No. 3

The jaw belongs to a small fetus with no other visible malformations than a left-sided combined cleft. The head has the following measurements:

length (front to back of the head) . .	38 mm
width (temple to temple)	29 mm
height (with the neck)	46 mm

The cleft is complete and wide, both in the lip, jaw and palate. The frontal region of the largest jaw segment is thrust forward, especially the premaxillary part of the cleft side. The lower edge of the nasal septum is connected with the palatal shelf of the non-cleft side.

The case represents a typical form of the most common congenital facial cleft. The ordinary neonatal characteristics are unmistakable at a fetal age of 3—4 months.

Specimen 3: For the histological examination, the entire upper jaw was taken out in one block, inclusive of the orbital floor on both sides. The specimen was cut horizontally from below.

Specimen 3

Ten temporary tooth germs in different phases of the cap and bell stages are present. The two central incisors are at the most advanced developmental stage, but there is no sign of calcification and they are still connected with the dental lamina. The permanent central incisors are found in an early bud stage. The premaxillary bone is forming. Traces of the dental lamina, but no bone and no definite dental anlage can be seen in the premaxillary part, lateral to the central incisor on the cleft side. In the smaller jaw segment are found a temporary and a permanent precanine tooth developing normally in the cap and bud stage respectively. All the essential nerves to the maxilla and its teeth can be followed from the pterygopalatine fossa. The vessels are not as clearly defined, as is usual at this stage. Besides the posterior superior alveolar nerve, both the middle and the anterior nerves are present, on the cleft side as well as on the non-cleft side. From the infraorbital nerve, the latter two nerves run downward, each in its wide bony canal. On the cleft side, the anterior nerve extends to the germ of the precanine

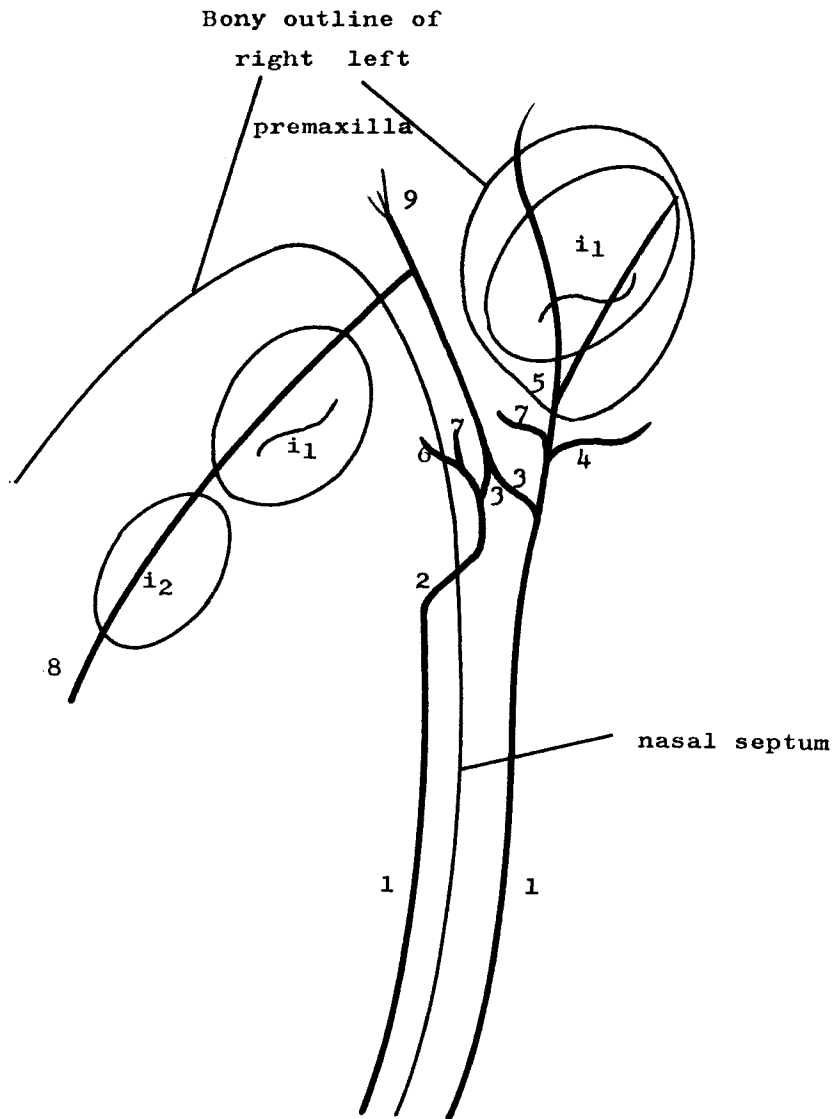


Fig. 8. Diagram of the nerves (and arteries) in specimen 3, seen from below.
The branches are numbered:

1. Nasopalatine nerve
2. Short incisive canal on the right side
3. Branch forming median nerve
4. Branch to palatinal gingiva
5. Main branch into left premaxilla
6. Small branch into right premaxilla
7. End branches in incisive papilla
8. Upper branch of right superior anterior alveolar nerve
9. End branches of median nerve.

tooth. On the non-cleft side it sends off an upper branch passing to the anterior part of the median suture where it joins the median nerve in its horizontal section. Together they continue forwards into the soft tissues below the anterior nasal spine. From its course on the vomer, the right nasopalatine nerve is seen to pierce the bone anteriorly in the angle between the nasal septum and the left palatal shelf and to continue down the back of the premaxilla close to the midline. The left nasopalatine nerve passes from the side of the vomer to take a parallel course down the back of the left premaxilla close to the midline. During this nearly vertical course, just below the mucous membrane on the back of the alveolar process, are seen anastomoses across the midline. In addition the median nerve and artery to the suture branch off fairly high up. On the left side, the septal nerve and vessel send off solid branches which together penetrate the wall of the jaw close to the incisive papilla and ascend again behind and above the anlage of the left temporary central incisor. The right septal nerve and vessel send off similar, but far smaller, branches on their side of the midline. The incisive suture is clearly defined on the right side in the part corresponding to the short incisive canal. The neurovascular pattern is charted in Fig. 8.

The upper jaw of a foetus of about 4 months with a left-sided unilateral cleft lip, jaw and palate shows all the dental germs, exclusive of the lateral incisor in the premaxilla on the cleft side, but inclusive of the precanine tooth on the same side. The incisive canal and suture are present on the right side only, for a very short distance. The septal nerves and vessels of the two sides run parallel under the mucous membrane, downward, behind the premaxilla and along the median suture. They send off a joint median nerve and artery to the median suture and, close to the edge of the jaw, each sends off branches to the jaw bone on the same side; the left constituting the principal supply to the left premaxilla while the right is only an insignificant supplement to the maxillary supply on that side. The left precanine tooth derives its innervation from the left anterior-superior alveolar nerve. The corresponding right maxillary nerve and artery send off a branch to the median suture from the apical part of the premaxilla.

Jaw No. 4

This fetus presented gross malformations, among others anencephalia and bifid spine. Crown-tail length was 21 cm, corresponding to about 6 months fetal age according to Keibel-Mall's table. The jaw had a left-sided cleft, complete in the lip and alveolar process, while the palate was intact.



Fig. 9. Jaw No. 4 x-rayed from above. Left unilateral cleft lip and jaw.

A radiograph of the upper jaw (Fig. 9) reveals that the degree of calcification of the teeth seems more advanced than is usual at 6 months fetal age. All the temporary teeth are present, including the lateral incisor on the medial side of the cleft and a precanine tooth on the distal side. The segments of the upper jaw are compressed and the premaxillary part of the cleft side is turned forwards and upwards while the anterior nasal spine is displaced to the right in the typical way. There is marked crowding of the anterior teeth. On the non-cleft side, the central incisor and the canine are practically in contact. The lateral incisor is intruded. On the cleft side, the central incisor and, in particular, the lateral incisor are inclined toward the cleft. The latter tooth is also markedly rotated distolingually, its crown base nearly touching the distolingual surface of its neighbour. The precanine tooth is seen mesiolingual to the canine tooth, slanting towards the cleft.

Two specimens were taken out:

Specimen 4 a: The largest segment with the front teeth and part of the nasal septum, cut sagittally from the border of the cleft.

Specimen 4 b: The smallest segment with the precanine and canine teeth and the first molar, cut horizontally from below.

Specimen 4 a

As usual with unilateral clefts, the premaxillary median suture has an oblique and somewhat twisted course; primarily due to displacement of the jaw bone in front, perhaps also owing to crowding of the front teeth (Fig. 10). The section plane is therefore only approximately parallel to the median suture. The crowns of the temporary teeth are at the stage of calcification

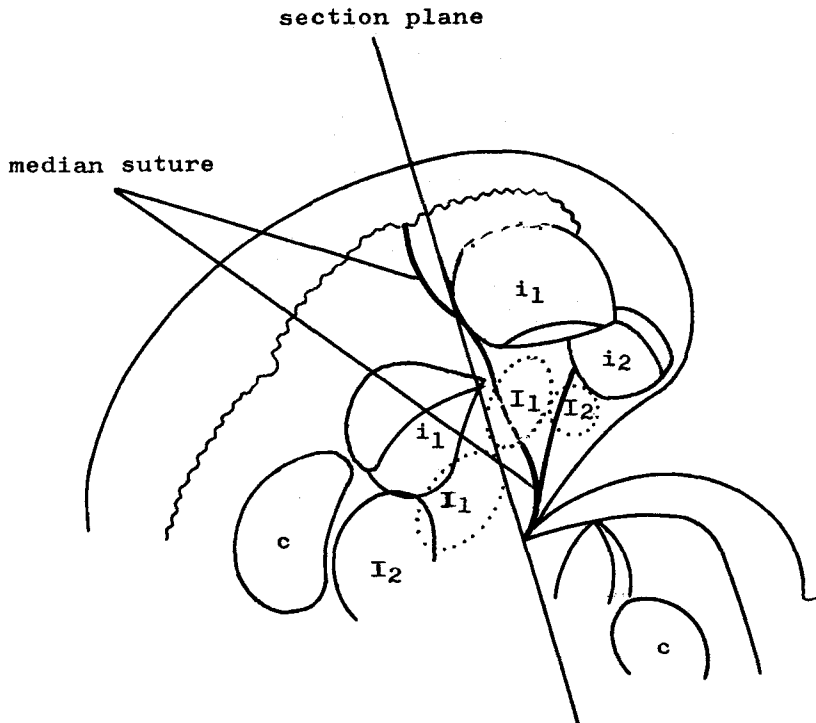


Fig. 10. The site of the tooth germs in jaw No. 4, seen from below. The section plane of specimen 4a is indicated.

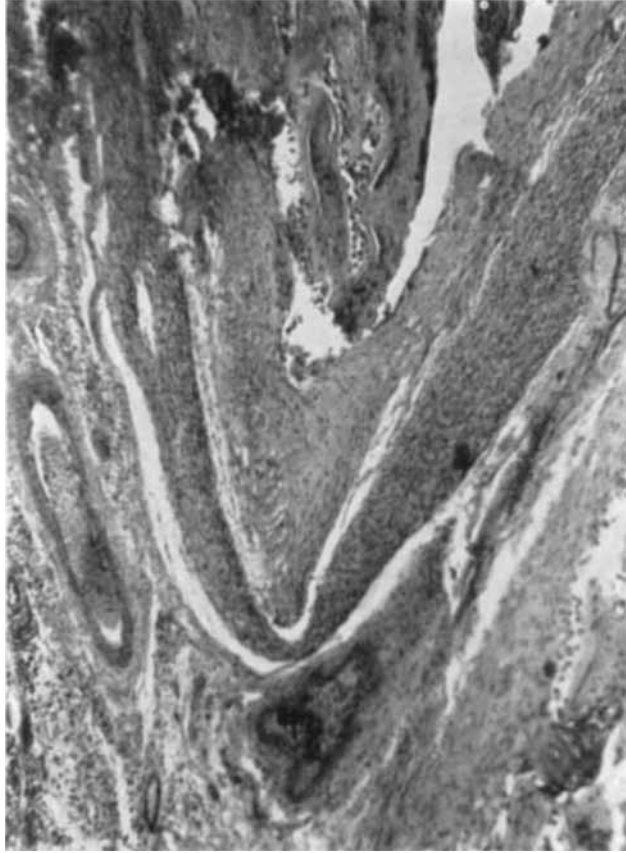


Fig. 11. Sagittal section from the left premaxilla in specimen 4a. Main stem of left nasopalatine nerve, accompanied by its artery, directed downwards (from upper right), perforates the lower part of the lingual wall of the left premaxilla near the median suture, and curves at an acute angle upwards in the bone. $\times 50$

usually found at 9 months fetal age. Both permanent central incisors are in the bell stage without demonstrable developmental differences. The germs of the central incisors on the cleft side lie in alveoli whereas the permanent lateral incisor, barely in the cap stage, and its corresponding temporary tooth are enclosed in soft tissue, entirely outside the premaxillary bone. None of the germs show signs of degeneration. The left incisors lie with

their incisal ridges near the gingival epithelium and are closest to eruption.

The neurovascular supply is well developed. The left nasopalatine nerve and the posterior septal artery descend below the mucous membrane, unprotected by any bony canal, from the nasal septum down behind the median suture of the premaxilla to the incisive papilla. At an acute angle, the main part then turns a little to the left and upwards again (Fig. 11), through the left premaxilla inside the bone, and up across the apical bases of the left central incisors, sending branches to the lateral tooth germs. The same nerve and vessel on the right side follow an unprotected parallel course on the back of the premaxilla after having passed from the nasal to the oral cavity through a very short incisive canal. Together the septal vessels and nerves send off a median artery and nerve to the median suture just after entering their parallel course down the premaxilla. Before the terminal ramifications in and close to the incisive papilla, the right septal nerve and artery also send branches into the premaxilla, but these are much smaller than on the left side. In the median suture the median nerve and artery receive contributions from the right anterior superior maxillary nerve and artery. High up in its vertical course, the median nerve splits into a forward branch terminating under the anterior nasal spine and another branch passing upwards and backwards. Just above the apical bases of the germs of the permanent central incisors, the maxillary vessels and nerves on the right side have a direct connection over the median suture to the left premaxilla.

Specimen 4 b

The sections first encounter the precanine tooth which is placed somewhat lingually and tilted forwards. Its neurovascular supply branches off from the anterior superior alveolar nerve and artery which, this apart, pass directly to the germs of the canine teeth.

An upper jaw with a left-sided cleft in the lip and alveolar process only, from a probably nearly fullterm small fetus with other gross malformations, has all the dental germs including that of a supernumerary tooth in the cleft area. The incisive

canal is present on the right side only and is very short. Both septal nerves and vessels descend behind the median suture of the premaxilla, just below the mucous membrane sending off, en route, a median nerve and artery to the suture. On the cleft side, the vessel and nerve of the septum supply the premaxillary bone and its teeth through a foramen under the incisive papilla near the median suture. On the right side are found similar, but much smaller branches of the septal vessel and nerve from this side. The maxillary nerves and vessels on the right side communicate with the median nerve and artery and cranially have a direct connection across to the premaxilla on the cleft side.

Jaw No. 5 and 6

These two upper jaws come from a pair of conjoined twins, two relatively well developed probably fullterm female fetuses with ischio-thoracic fusion. Only the upper jaw of the left head presents a cleft, viz. right-sided complete cheilo-gnatho-palatoschisis (Fig. 12). The non-cleft jaw, No. 5, is evenly symmetric, frail, with a normal palatal arch. The nasal apex is somewhat displaced to the left in relation to the palatal median line and the frenulum's insertion in the lip. The total length of the alveolar and the pseudoalveolar processes, measured along the lower edge, is 5.2 cm. The greatest width of the lower edge of the alveolar arch is 2.3 cm. The cleft jaw, No. 6, presents the usual picture in this type of cleft, *i.e.* the premaxilla of the cleft side is displaced forwards and upwards and the vomer is connected with the palatal shelf of the non-cleft side. Anteriorly, between the alveolar processes of the two sides, the width of the cleft is 6 mm and posteriorly in the hard palate it is 8 mm. The alveolar edges of the smaller and larger segment are 2.2 cm and 3.2 cm respectively and the greatest width of the alveolar arch is 2.5 cm measured as in the previous case.

Comparison between Nos. 5 and 6 does not, apparently, show particular expansion or compression of the segments of the latter, the transverse measurement of the alveolar arches being approximately the same. However, separate comparison between the smaller segment and the corresponding part of No. 5 clearly shows that both the labial and the lingual gingival ridges are

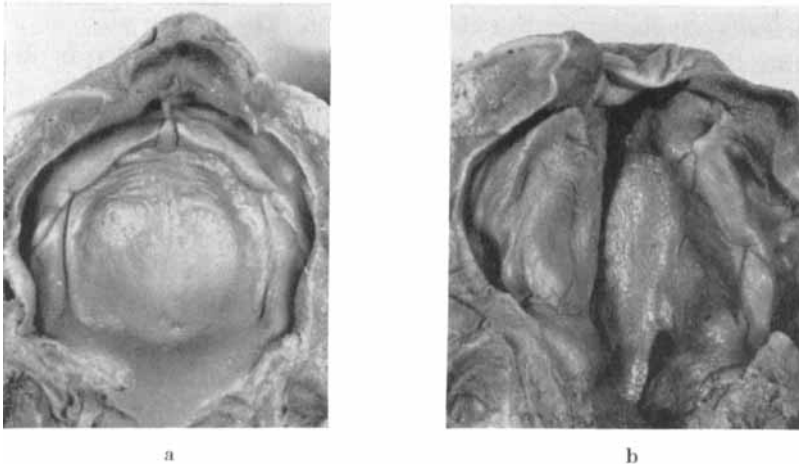


Fig. 12 Upper jaws from twins with ischio-thoracic fusion.

- a. Jaw No. 5 from the right twin, non-cleft
- b. Jaw No. 6 from the left twin with right unilateral harelip and cleft palate.

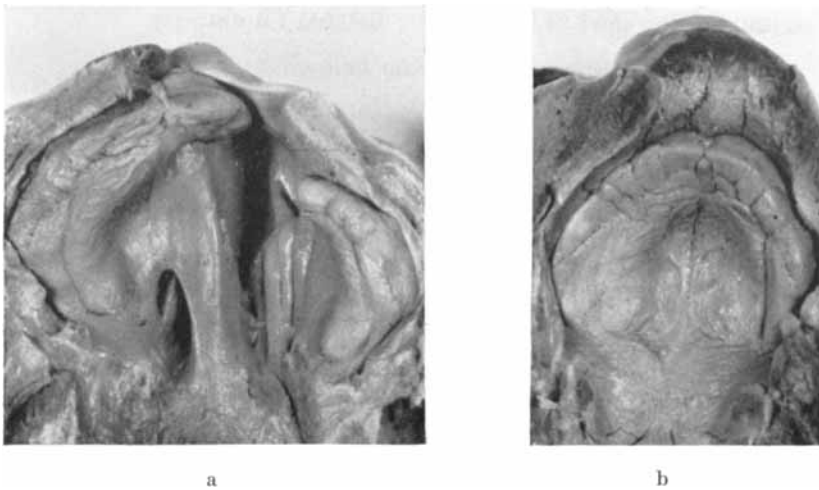


Fig. 13. Upper jaws from twins with thoracic fusion.

- a. Jaw Nr. 8 from the right twin with left unilateral harelip and cleft palate
- b. Jaw No. 7 from the left twin, non-cleft.

tilted somewhat outwards; the dental furrow is more open and buccally displaced on the cleft specimen. The larger segment is quite the opposite: While its anterior part is tilted forwards and upwards the bulk of the gingival ridges is pushed inwards so that the alveolar arch is straightened out.

The radiographs show that the calcification of the teeth is at the usual stage for 9 months fetal age. In jaw No. 5, the front teeth are crowded, both lateral incisors being lingually displaced. The median suture is fairly wide with a distance of 2 mm between the central incisors. Jaw No. 6 has a precanine tooth linguomesially to the canine tooth. A lateral incisor, markedly rotated mesiofacially and inclined towards the cleft, is present at the medial border of the cleft. The median suture is narrow; the smallest distance between the two central incisors is 0.5 mm. The right central incisor is rotated mesiofacially and seems to be in contact with the canine tooth, while the lateral incisor lies lingually to them.

Specimen 5: The anterior part of jaw No. 5 including the temporary first molar on each side; height, 1.5 cm.

Specimen 6: The anterior part of the larger segment of jaw No. 6 inclusive of the temporary first molar together with the accompanying part of the vomer; height, 1.5 cm.

Both were cut horizontally from below.

Specimen 5

All the temporary teeth present histological conditions which must be considered normal for the newborn stage. Both permanent central incisors are in an advanced bell stage and the corresponding lateral incisors and canine teeth are in the cap stage, the canines being the more developed. The jaw bone is well developed, but the crowded position of the teeth leaves little room for bony partitions between the germs. On the whole, the median suture presents the normal extension and structure of tissues. The course of its posterior part relative to the median plane is, however, more sinuous than is usual. From its nasal opening downwards, the left incisive canal is markedly wider than the right one. The lateral part of the latter with a small nasopalatine

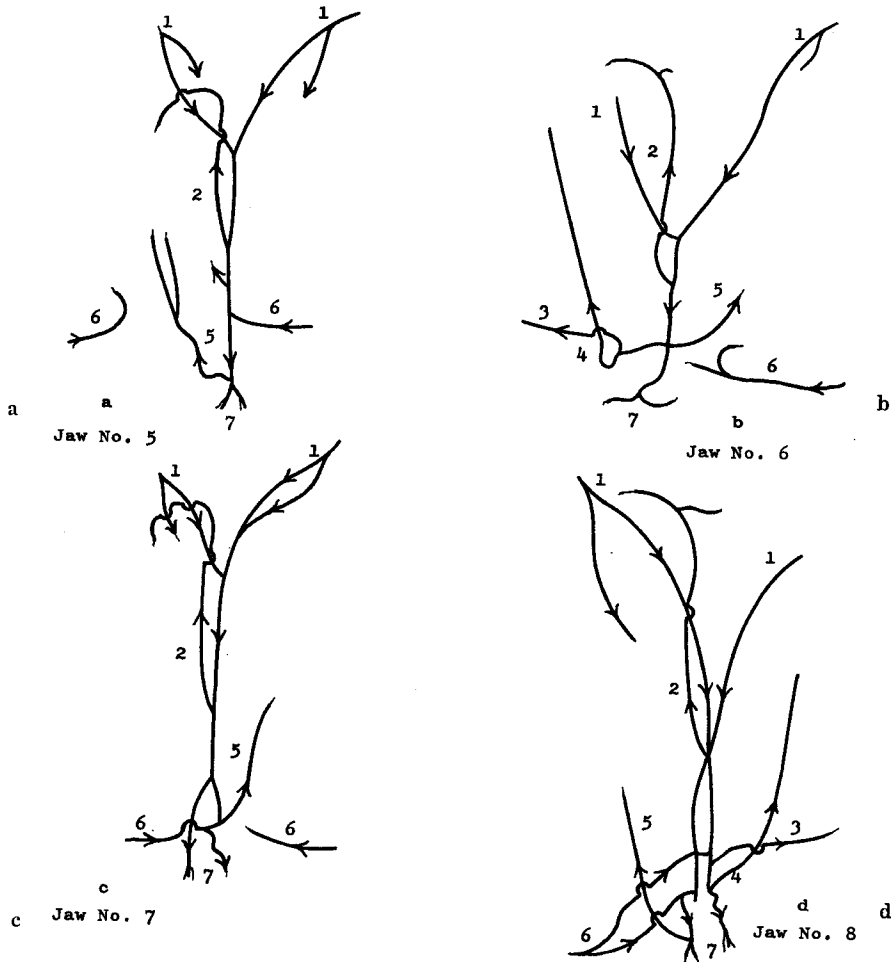


Fig. 14 a, b, c, d. Schematic reconstructions of the premaxillary artery courses in the four upper jaws represented in Figs. 12 and 13, seen frontally. The arteries are numbered:

1. Posterior septal artery
2. Median artery
3. Branch to palatal gingiva
4. Main branch to premaxilla on cleft side
5. Small branch to non-cleft premaxilla
6. Major palatine artery
7. Terminal branches in and near incisive papilla.

duct rapidly disappears. At the same time, the medial part with the main stem of the nasopalatine nerve merges with the connective tissue capsule of the left canal, and the two nasopalatine arteries unite after which the duct of the left canal soon disappears too. Further down, in the greater part of the course along the back of the premaxilla, there is a single incisive canal in the midline with a common central artery and a right and left nerve stem on each side of the artery. The a. praemaxillaris mediana with accompanying nerve branches off above the incisive foramen, *i.e.* somewhat higher up than usual, but describes an otherwise normal course in the median suture with some communications to the premaxilla on both sides. A tentative median artery is present a bit further down, but it soon fades away. Only the left greater palatine artery reaches the common artery in the incisive foramen. Of the terminal ramifications of the common artery and the nasopalatine nerves in the incisive papilla, one nerve with accompanying artery is seen to enter the right premaxilla just in front of the incisive foramen and then to ascend again. This branch joins the neurovascular supply to the germs of the temporary and permanent central incisor. The arterial pattern is charted in Fig. 14 a. The chart also gives the course of the nerves, except that the common central artery is accompanied by the nasopalatine nerves of both sides which, with some anastomoses across the midline, run separately in the common canal. The anterior superior alveolar artery and nerve follow the normal course to the premaxilla and the teeth, but the anastomosis between the nasopalatine nerve and the upper anterior branch of the maxillary nerve is missing. The maxillary nerves give up their terminal ramifications to the median suture as usual, and with no demonstrable anastomoses over the midline.

The incisive suture follows the ordinary course on both sides.

Specimen 6

The temporary teeth are at the same developmental stage as in the previous specimen and there is no demonstrable difference in this respect between the front teeth of the cleft and the non-cleft sides. The corresponding permanent tooth germs likewise present the same picture as in Specimen 5, except for the lateral

incisor near the cleft which has just barely reached the bud stage. The alveolar process on the non-cleft side shows a fairly normal development. On the cleft side it is much less developed, providing only the germs of the central incisors with alveolar bone while the lateral tooth germs lie surrounded by their follicles and the gingival tissues, with a rudimentary alveolus. The premaxillary median suture is very narrow with a sinuous course. Its posterior part is somewhat displaced towards the non-cleft side. On the left side, a very short incisive canal penetrates the bone in the anterior part of the arched nasal septum and emerges on the back of the premaxilla. The anterior lateral part of the canal with the duct disappears at the lower opening of the canal, while the contents of the posterior medial part of the canal, *i.e.* the main nerve and artery surrounded by a capsule of connective tissue, continue immediately joined by the corresponding nerve and artery from the right side of the nasal septum. The latter, without any sort of incisive canal, run downwards only protected by the naso-oral mucous membrane. Immediately after the junction, the septal arteries from the two sides form a common artery which, a little further down, sends off the median artery accompanied by nerve fibres from the nasopalatine nerves from both sides to the premaxillary median suture. The two septal nerves run close together on each side of the common artery. Just before the terminal ramifications in the incisive papilla, the vessel and nerve on the cleft side send off branches to the gingiva on the back of the premaxilla. At the same time, the main part of the right nasopalatine nerve together with a branch of the artery ascends in the right premaxilla with the principal supplies to the teeth and jaw bone. A tiny neurovascular branch with a similar course is present on the non-cleft side. The greater palatine artery does not advance far enough to anastomose. The vascular pattern has been charted (Fig. 14 b). The maxillary nerve and artery on the left side have a normal course, but there is no anastomosis with the septal nerve in the nasal cavity, and a solid neurovascular branch crosses the median suture apically, apparently only supplying the upper part of the premaxilla on the cleft side.

The incisive suture is present only corresponding to the short incisive canal on the left side.

The premaxilla from a monozygotic twin, probably fullterm, without facial cleft (the right head of an ischiothoracopagus) presents marked crowding of the anterior teeth on both sides, and possibly a somewhat retarded development of the permanent lateral incisor germs. The two incisive canals and their main arteries are confluent to a large extent, and the premaxillary median artery and nerve branch off at a higher point than usual. The nasopalatine ducts are poorly developed, particularly on the right side. Only the left greater palatine artery reaches the incisive foramen to anastomose with the nasopalatine artery. On the right side, the nerves and vessels anastomose from the incisive foramen with the maxillary nerves and vessels in the right premaxilla.

The premaxilla from the other twin with unilateral rightsided complete harelip and cleft palate (the left head of an ischiothoracopagus) presents crowded anterior teeth and possibly a somewhat retarded development of the permanent lateral incisor germ on the non-cleft side. On the cleft side, a well developed temporary lateral incisor lies outside the jaw bone with its permanent successor barely in the bud stage. A short incisive canal with corresponding incisive suture is present on the non-cleft side only. The main septal arteries from both sides run together from the inferior opening of the incisive canal and continue just under the mucous membrane on the back of the premaxilla. The median nerve and artery to the premaxillary median suture branch off fairly high up. The premaxilla and teeth on the cleft side derive their principal nerves and vessels from the nasopalatine supplies through branches taking off near the incisive papilla. Similar, but far smaller, branches go to the non-cleft side. The greater palatine artery and nerve do not continue forward to anastomose. The left anterior superior alveolar artery and nerve send branches across the median suture to the upper part of the right premaxilla.

Jaws Nos. 7 and 8

These two jaws come from a pair of fullterm conjoined twins, two male fetuses united in the thoracic region. The right head has a complete combined cleft on the left side, whereas the other is

seemingly normal (Fig. 13). The non-cleft jaw, No. 7, has a sturdy, well developed alveolar process; 6.0 cm measured along the lower margin. Largest width of the measuring line is 2.6 cm. The palatine raphe divides the jaw so that the right half is slightly wider than the left. The dental groove and the elevations of the temporary teeth are, however, fairly symmetric on both sides, as are the gingival grooves. The most conspicuous difference between the two sides is that the part between the gingival groove and the raphe is 2 mm wider on the right side, measured along a line from the right to the left maxillary tuberosity. In addition, there is a depression in the central part of the palate, larger on the left than on the right side.

The cleft jaw, No. 8, presents the ordinary picture, *i.e.* the premaxilla on the cleft side thrusts forwards and upwards, the vomer being connected with the palatal shelf of the non-cleft side. The gap between the alveolar processes of the segments is 9 mm anteriorly and 17.5 mm posteriorly, corresponding to the a-line. The length of the alveolar process of the smaller segment is 2.7 cm, of the larger segment 4.1 cm, and the largest width between the alveolar edges at the tuberosities is 3.8 cm. Comparison between the two jaws shows a marked lateral expansion of the segments of No. 8 and also that each of these has a longer alveolar process than the corresponding section of the non-cleft jaw No. 7. The larger segment does not show particular signs of being tilted. The smaller segment, however, seen from below, shows a greater part of its vestibular surface than the corresponding part of the non-cleft jaw and therefore appears wider.

The radiographs reveal that the teeth are at about the ordinary stage of calcification for newborn infants. In jaw No. 7, the anterior teeth are crowded, both lateral incisors standing lingually and rotated distolabially. There is little room between the central incisor and the canine tooth on either side. The median suture is of normal width. Jaw No. 8 has a precanine tooth linguomesial to the canine tooth and sharply inclined to the cleft. In the premaxilla of the cleft side, the lateral incisor and, to some extent, the central incisor are inclined toward the cleft too. The front teeth on the non-cleft side have approximately the same position as in jaw No. 7, with the difference that the central incisor is rotated mesiofacially.

Specimen 7: The anterior part of jaw No. 7, inclusive of the canine teeth, height: 1.5 cm. Cut horizontally from below.

Specimen 8 a: The larger jaw segment inclusive of the right canine tooth and the nasal septum, height: 1.5 cm. Cut horizontally from below.

Specimen 8 b: The smaller jaw segment inclusive of the temporary first molar and the floor of the orbit. Cut horizontally from above.

Specimen 7

The temporary incisors and canine teeth are at the normal stage of development for newborn infants. Both permanent central incisors are in an advanced bell stage. The lateral incisors and the canine teeth are in the cap stage. The premaxillary jaw bone is well developed on both sides. The median suture is somewhat narrow, but otherwise normal. There are not two separate incisive canals. The septal nerves and vessels pass directly into a common canal below the septum, midway between the germs of the permanent lateral incisors. The division between an anterior part with the duct and a medial part with the nerve is missing on both sides and a short duct is present on the right side only. The arteries of the two sides soon unite in a common central artery which sends off the median artery to the premaxillary median suture, but does not otherwise ramify till near the incisive foramen. The nerve bundles run close together anterior to the central artery, separated by the median plane, but with a few anastomoses. The canal is trapeziform with the ordinary contents of glandular, connective, and fatty tissues, small cystic cavities and small vessels. In the incisive foramen there is anastomosis with the right greater palatine artery and nerve. Only on the left side is a neurovascular branch found ascending from the incisive foramen into the premaxilla and forwards near the follicle of the anlage of the permanent central incisor where it soon terminates. The arterial pattern is charted in Fig. 14 c. The maxillary vessels and nerves present the usual course in both premaxillae, except that there is no nasal anastomosis between the nasopalatine nerve and the upper branch of the anterior superior alveolar nerve. The latter passes directly to the upper anterior part of the premaxillary median nerve.

Specimen 8 a

The temporary tooth germs are at the ordinary neonatal stage of development as are the permanent teeth. One lateral incisor, however, is missing as there are only rudiments of the successional dental lamina on the medial border of the cleft. The central incisors on the cleft side have a normally developed alveolus, while that of the temporary lateral tooth is completely missing. The median suture is very narrow and, in horizontal section, has the shape of a reversed S. The medial premaxillary walls are incomplete, but the structure of the tissue in the suture is normal. The right incisive canal is very short, about 1 mm. The left septal nerve and artery run just below the mucous membrane and join the right nerve and artery at the point where they emerge from the incisive canal. In a common connective tissue capsule they follow a parallel course down the premaxilla immediately behind the median suture, where they anastomose and send off a strong median nerve and artery to the premaxillary suture. Further down, they anastomose with the palatine artery and nerve from the right side. On the left side, the palatine gingiva derives its neurovascular supply from branches of the nasopalatine nerve and artery. The main part of the latter ascends in the premaxilla to the jaw bone and teeth. On the other side, the nasopalatine nerve and artery give off tiny terminal ramifications to the right premaxilla in a similar manner. Schematic reconstruction of the course is seen in Fig. 14 d.

Specimen 8 b

Both the anterior and middle superior alveolar nerves can be followed from the infraorbital nerve downwards in the segment. The anterior superior alveolar nerve goes to the germs of the canine teeth with a branch forwards to the precanine tooth.

The premaxilla from a monozygotic twin without cleft (the left head of a thoracopagus) presents marked crowding of the anterior teeth. There is one common, central incisive canal with a common central artery. The median artery and nerve to the premaxillary suture branch off high up in the course. An insignificant nasopalatine duct is seen on the right side only. Ana-



Fig. 15 a.

stomosis with the greater palatine artery is present on the right side. On the left side, the premaxilla receives a small contribution of vessels and nerves from the incisive foramen.

The premaxilla from the other twin who has a left-sided unilateral combined cleft (the right head of a thoracopagus) presents approximately the same crowding of the anterior teeth on the non-cleft side as the left head. In the premaxilla of the cleft side only the central tooth germs are provided with alveoli. The temporary lateral tooth lies outside the bone and a successor is missing. The median suture is narrow and sinuous. The incisive canal with accompanying, incisive suture is only present on the non-cleft side and is very short. Behind the premaxillary median suture the septal nerves and arteries follow a parallel course under the mucous membrane, sending off a common median nerve and artery. The premaxilla on the cleft side derives its principal supply of nerves and arteries from its septal branches

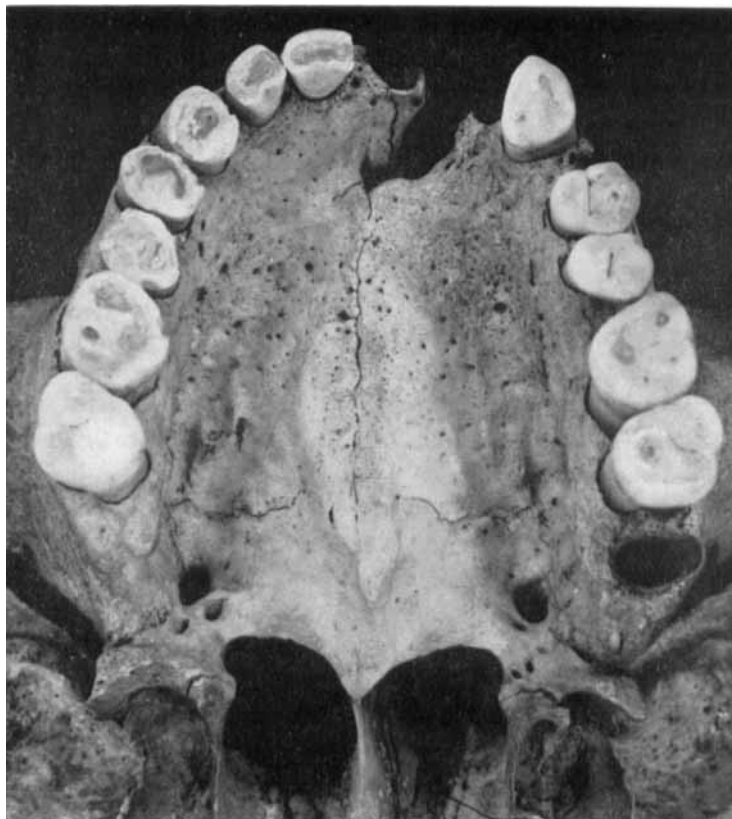


Fig. 15 b.

Fig. 15, a and b. Skull from adult with untreated left unilateral cleft.

medially and near the crest of the alveolar process. A similar, smaller branch is seen on the non-cleft side. The anterior superior alveolar nerve and artery are found in the lateral segment with branches to the precanine tooth.

FINDINGS IN GROSS SKELETAL MATERIAL

Fig. 15 a and b are close-ups of a cranium from the collection in the Anatomic Institute of the University of Oslo. It exhibits an untreated, left-sided cleft in the alveolar process. The skull is that of an adult person. The frontal picture, Fig. 15 a, shows that the left central incisor and precanine tooth have disappeared

after death, in all probability due to the incomplete alveoli. The latter clearly show that both teeth were in functionally unfavourable positions. The upper anterior part of the median suture with the nasal spine is markedly shifted to the right; the lower part is seen in the medial wall of the empty alveolus. The obliquely placed premaxillary bone of the cleft side is of small size and the left nasal aperture lacks part of its normal inferior and lateral border. Fig. 15 b shows the lower opening of the short right incisive canal. This is located somewhat higher up and further to the side in relation to the median suture than a normal incisive foramen. Close to the alveolar margin are seen two other foramina, one on each side of the median suture. The left foramen is the larger. These foramina correspond to openings for the septal arteries and nerves of which the left branch is presumably the more important.

INJECTION TESTS

It is a common experience that the ordinary injection technique with infiltration in the vestibulum for anesthetization of premaxillary teeth near a cleft is most painful to the patient. This is probably because the gingiva, to a large extent, consists of oversensitive scar tissue. After the course of the premaxillary nerves in the specimens had been charted, the injection technique was altered. In the first 25 patients all details were recorded. Twenty had complete clefts of their alveolar processes (5 bilateral and 15 unilateral) and five had partial clefts. The treatment consisted partly of preparing full crowns for central incisors, partly of extractions and, in three cases, of extirpation of the pulp before root filling. In all cases, about one fifth (0.04 ml) of the amount of fluid ordinarily used in infiltration anesthesia of the pulp was first injected, and only close to the incisive papilla on the cleft side. In all cases except 5 unilateral clefts, this proved sufficient for pulpal anesthesia of the central incisor and, when present, for the lateral incisor in the premaxilla on the cleft side. The 5 cases were given an additional vestibular injection over the central incisor on the non-cleft side, after which pulpal anesthesia was obtained on the cleft side. Where anesthesia of the labial gingiva was necessary this had to be administered separately.

DISCUSSION AND CONCLUSIONS

The histologically examined material was taken from stillborn fetuses, some of which had gross malformations besides the facial clefts. It is open to question to what extent the findings in the field particularly examined in these non-viable individuals are representative of what microscopic examination of viable infants with cleft, might have revealed.

From the viewpoint of macroscopic morphology, none of the jaw clefts in the present study material differ much from what can be observed in liveborn, viable infants with the same types of cleft. Histologically, the structure of the tissues examined is analogous with that found in normally developed jaws; it is the degree of development, distribution and arrangement of the separate tissues that show marked differences. In the present material, signs of deficient development have especially been demonstrated in the premaxillary bone immediately adjacent to the cleft. This is in agreement with what can be observed, macroscopically and radiographically, in patients with cleft upper jaws. There may be a difference in degree, *i.e.* the growth potential in this bone in the non-viable individuals may be even lower than in ordinary cleft patients. What is more important, the main features in the arrangement of the tissues for the different individuals in the study material show pronounced similarity. They follow a common pattern which in certain ways deviates from the normal pattern. Furthermore, with regard to certain important features it has been possible, to some extent, to compare them with the findings on patients of different ages. In addition it was possible to study them on a cranium from an adult individual, and, in both instances, there was good agreement. It seems justifiable, on this basis, to draw certain conclusions of general validity from the present material.

The charting of the neurovascular supplies of the premaxilla, in bilateral and unilateral clefts, elucidates some obscure points in the hypotheses and studies mentioned in the introduction.

In five out of six cases, the present material has shown that when the normal maxillary supplies of the premaxilla (the anterior superior alveolar artery and nerve) are cut off by a cleft, then the nasoseptal vessel and nerve (the posterior septal artery

and the nasopalatine nerve) on the same side expand their scope and function. On the back of the premaxilla they send branches to the palatal gingiva and, from a point near the margin of the alveolar process close to where they normally end, they take over the principal neurovascular supply to the teeth and the jaw bone near the cleft. In this way a specific pattern is formed, which has not previously been described. In unilateral cases the nasoseptal vessel and nerve of the non-cleft side form similar, but smaller, extra branches to the premaxilla. Besides extending the function of the septal arteries and nerves, the cleft also causes the branches to lie in an exposed position. Normally, they are well protected, first in the nasal cavity above the hard palate, and then in the incisive canal before the terminal ramifications. When a cleft is present, they are far more vulnerable both on the vomer and on the back of the premaxilla for they lie just below the mucous membrane bordering the oral cavity until they enter the premaxilla for the final, important part of their course. The study has further shown that in unilateral cases the nasoseptal vessel and nerve on the non-cleft side do not have the protection provided by a complete incisive canal. On the back of the premaxilla they lie just as exposed as on the cleft side.

It had been established beforehand that there was a possibility that in unilateral cases the maxillary supplies of the non-cleft side might send contributions across the midline to the premaxilla on the cleft side. As distinct from what was maintained by *Veau*, the preliminary part of the present investigation revealed that there are possibilities for development of cross-connections in normal premaxillae. Furthermore, all cases in the present study presented such communication across the median suture. Only in one case, *i.e.* jaw No. 2, in which the nasoseptal supply of the premaxilla failed, does the maxillary nerves and vessels constitute the only supply. Here the contralateral maxillary supplies may represent the last possibility for development of bone and teeth in the premaxilla. The only other potential source of some significance that has been found, is the anterior palatine nerve and vessel which, on the non-cleft side, sometimes advance far enough for anastomosis, but ordinarily this source seems to play a smaller and more uncertain role in the supply system of the premaxilla than the first mentioned.

The injection tests suggest that the nasopalatine nerve is the only supply to the premaxillary teeth in bilateral cases with complete cleft of the jaw bone. In unilateral cases the nasopalatine nerve seems to be the most important source of innervation of the premaxillary teeth near the cleft.

The median premaxillary nerve and artery have proved to be a constant feature in all the cleft jaws examined as well as in the normal material in the preliminary study. Just as in normal cases, the degree of development of these structures varies, from insignificant to fair-sized, and all show communications to the jaw bone on both sides. The point of origin usually lies at a somewhat higher level than that corresponding to the incisive foramen in normal cases, probably because the two sides' septal nerves and arteries meet earlier than when there are two incisive canals of normal length. This apart, the course follows approximately the same track in the median suture: upwards—forwards and out into the mucous membrane under the anterior nasal spine.

The study of the nerve and blood supply of the lateral segment in cleft alveolar process has only tried to answer the question of whether the anterior superior alveolar artery and nerve are present when most of the teeth and jaw bone for which they are normally destined lie outside their reach and they can only attain the canine and the precanine tooth. The cases examined showed that both the anterior and the middle superior alveolar branches were present. Due to a technical accident, the specimen from jaw No. 2, where the precanine tooth was missing on the right side, could give no answer here. However, the important thing to have established is that the maxillary plexus and its arterial arcade do not have to be without their anterior tributaries because a complete cleft of the lip, jaw and palate is present.

Definite signs of missing, abnormally weak, or retarded development of the teeth were only found in the lateral incisor of premaxillae close to a cleft, *viz.* in 5 of 8 dental germs in the primary dentition and in all 8 in the secondary dentition. In addition to this, there was one case of missing precanine tooth in both dentitions. In no case could such signs be demonstrated with certainty with regard to the central incisor germs. At as early an age as that of the youngest specimen, the front teeth were not irregularly placed in the alveolar process, but in all the

others the lateral incisors, both on the cleft side and on the non-cleft side, were in a particularly crowded position.

The premaxillary bone on the cleft side is defective in all cases. In general, little more than a somewhat incomplete alveolar bony crypt has been formed for the central incisors of both dentitions. There is neither incisive canal nor Stenonian duct. Part of the bone which should form the incisive canal is also missing on the non-cleft side in unilateral cases, as is the corresponding section of the duct. The incisive suture is only found together with and connected with the incisive canal. The palatine orifice of the latter on the side of the median suture cannot quite be said to represent the ordinary incisive foramen which normally should have been situated in the midline further down. Now it is missing, in unilateral as well as in bilateral cases. The cranium findings show that these conditions are the same even if the cleft has only affected the primary and not the secondary palate.

In the lateral segment of the upper jaw, signs of deficient development are limited to the anterior wall of the alveolus of the precanine tooth. In no specimen has there been found support for the old contention (*Albrecht* 1901) that the incisive suture in man should be found in the lateral segment, behind the precanine tooth.

It is doubtful to what extent the specific picture of hampered development in the area of the partial cleft in jaw No. 2 can be considered as usual in formation of a cleft. The finding may, however, be regarded as an illustration of *Steiniger's* frequently quoted theory about the origin and significance of »Hasenschartenzysten» during the fusion of the embryonic facial swellings. Incomplete mesodermal penetration of the so-called epithelial wall results in »bridges» across the cleft, as pointed out by *Veau*. If epithelial remnants of the wall persist, the »Hasenschartenzysten» that *Steiniger* demonstrated in mice and which he and other investigators believe may be present in human fetuses do, in fact, develop. The cysts may grow and lead to complete cleft or they may shrink. They may cause anomalies in the formation and position of the teeth or result in paradental maxillary cysts (*Steiniger* 1940). It is of interest that jaw No. 2 also showed a nasoalveolar cyst, 'Gesichtsspaltenzyste' as described by *Klestadt* (1913).

It seems reasonable to regard the disintegrated dental anlage between the cyst belts in specimen 2 as representing a lateral incisor really belonging in the median segment.

The examination of the non-cleft jaws from two pairs of twins was of particular interest in that there was reason to believe that they had only just escaped a cleft and thus represented potential 'microforms' of the disorder. The histological examination showed striking similarity between the premaxillae of the two jaws, *viz.* an intermediate stage between the usual, normal pattern and the general pattern found in cleft. The most characteristic feature of the intermediate stage is that the incisive canals in their descending course very soon unite, forming a common canal. This is not usual in normal cases. *Le Double* (1906) reports a common canal during the entire course in 21 of 760 crania; *i.e.* in 2.8 per cent. The likeness to the cleft pattern is particularly apparent in that the right and left nasoseptal nerves and vessels draw close to each other at a very early stage of the course down the back of the premaxilla. Further evidence was formed in that the median nerve and artery to the median suture branch off early, the Stensonian ducts are particularly insignificant, the nasopalatine nerve is not found to communicate with an upper branch of the anterior superior alveolar nerve anywhere in the nasal cavity, and all temporary lateral incisors are rotated and in a lingual position. Finally it must be mentioned that a small edition of the above described extra branch of the nasoseptal supply is present in both jaws, and only on the same side of the face as the cleft is in the twin. Thus, the small edition of the extra ramification has been demonstrated on the 'cleft side' in the non-cleft jaws and on the non-cleft side in unilateral cases. If this branch is not common in ordinary non-cleft jaws, and it has not previously been described, it seems natural to regard the extra branch as the reaction of the nasoseptal supplies to a predisposition to the formation of a cleft. If the cleft becomes a fact, the extra branch increases in extent and importance. It should, however, be noted that on one point the findings are the opposite of what might have been expected, a fact which renders our interpretation to some extent uncertain: *Birkenfeld* (1927) has maintained that monozygotic twins present a reflected image occurrence of a cleft. Thus, when the right head has a left-

sided cleft the microform should have appeared on the right side in the left head. However, the small edition of the extra branch appeared on the same side as the cleft in both pairs of twins.

Macroscopic comparison between the cleft and the non-cleft jaws in the monozygotic twins reveals that the cleft, *per se*, does not cause a weaker development of the jaw, rather the opposite. Microscopically, however, a decreasing developmental potency can be demonstrated from the median suture towards the medial border of the cleft. According to the experience gained in the treatment of adolescent patients in Norway, however, there is no particular reason to believe that the demonstrated neonatal defects in the cleft area necessarily have an endogenous tendency to worsen with time, provided the treatment is appropriate. On the other hand, it should be stressed that important vessels and nerves lie even more exposed than previously demonstrated. Thus injuries due to operations may have been a more frequent cause of impairment of the vitally important premaxillary region and its teeth than was assumed formerly.

SUMMARY

1. In bilateral cleft cases, the premaxilla and its teeth derive their neurovascular supplies from the nasopalatine nerve and the posterior septal artery. They follow the normal course on the vomer and then continue down along the posterior border of the premaxillary median suture, where there is no trace of the incisive canal, suture, or foramen, to the incisive papilla. Approximately midway in this nearly vertical course, they send off a common median nerve (n. praemaxillaris medianus) and a median artery (a. praemaxillaris mediana) to the median suture. In the further descent, they send branches to the gingiva and terminal ramifications to the frenulum, but the bulk of the nerves and arteries pierces the jaw bone, near the crest of the alveolar process and close to the median suture, to ascend again sending branches to supply jaw bone and teeth and a solid extra contribution to the median artery and nerve.

In unilateral cleft cases, the premaxilla on the cleft side usually derives its main supplies from the nasopalatine nerve and posterior septal artery of the same side. The course is analogous

to that in bilateral cleft cases. There are, however, also contributions across the midline from the anterior superior alveolar nerve and artery on the non-cleft side, usually high up, under the nasal septum. The nasopalatine nerve and posterior septal artery on the non-cleft side penetrate the bone, in a very short canal at the foremost point where the palatal shelf joins the nasal septum. They then continue, without Stensonian duct or bony canal, down behind the premaxilla along the median suture close to and parallel with their contralateral fellows. Together they soon send off the median nerve and artery to the suture. Among the terminal ramifications on the non-cleft side are found similar, but far smaller branches of nerve and artery as on the cleft side, which extend inwards and upward into the jaw bone. Thus, complete incisive canals and ordinary incisive foramina are not present in jaws with unilateral clefts either.

2. The cases examined show that the anterior superior alveolar nerve and artery are found on the distal side of the cleft, and that they send direct supplies to the precanine tooth.

3. Developmental disturbances have been demonstrable in all germs of the premaxillary permanent lateral incisor near the cleft side, which extend inwards and upwards into the jaw bone. premaxillary jaw bone close to the cleft is poorly developed, and deficient bone formation is found on the non-cleft side also, lingually and near the median suture behind the premaxilla, in that the inferior part of the incisive canal is missing.

4. Development of teeth has only been found when well defined supplies of nerves and vessels were present. A partial cleft seems to be illustrative of *Steiniger's* hypothesis about cleft due to »Hasenschartenzysten» and in addition presented a naso-alveolar cyst (a *Klestadt* 'Gesichtspaltenzyste').

5. In two pairs of conjoined twins, of whom one in each pair had unilateral combined cleft, the premaxillae of the non-cleft jaws presented a number of common features. These were, to some extent, different from the ordinary normal pattern and corresponded to the cleft pattern.

6. The findings furnish a basis for a simpler and less painful injection technique in anesthetization of the anterior teeth near a cleft. They clearly show how easily the development of valuable teeth and jaw bone may be impaired or damaged by surgical

intervention if due care is not taken to the particularly exposed course of nerves and vessels on the vomer and the back of the premaxilla. They support the experience that the central incisor near a cleft in particular, if appropriately treated, is of far greater lasting value than has previously been assumed.

RESUMÉ

TRAJET DES VAISSEAUX ET DES NERFS DU PRÉMAXILLAIRE ET DU MAXILLAIRE SUPÉRIEUR DANS LES CAS DE FENTES MAXILLAIRES

1. Dans les cas de fissures bilatérales, la vascularisation et l'innervation du prémaxillaire et des dents qui y sont situées proviennent de l'artère de la cloison et du nerf naso-palatin. Ceux-ci suivent le trajet habituel sur le vomer et continuent vers le bas le long du bord postérieur de la suture médiane prémaxillaire où il n'existe aucune trace du canal palatin antérieur, ni de la suture incisivo-maxillaire ni du trou palatin antérieur, et jusqu'à la papille rétro-incisive. Environ à moitié chemin de ce parcours presque vertical, ils émettent un nerf commun médian (n. praemaxillaris medianus) et une artère médiane (a. praemaxillaris mediana) qui vont à la suture médiane. Pendant le reste de la descente, ils émettent des branches pour la gencive et des ramifications terminales pour le frein de la lèvre, mais la masse des nerfs et des artères perforent le maxillaire au voisinage de la crête du procès alvéolaire et près de la suture médiane, pour remonter ensuite, émettant des branches destinées au maxillaire et aux dents et une contribution supplémentaire robuste pour l'artère et le nerf médians.

Dans les cas de fentes unilatérales, l'innervation du prémaxillaire du côté de la fissure provient en général du nerf naso-palatin et sa vascularisation de l'artère de la cloison du même côté. Le parcours est analogue à celui des cas de fentes bilatérales. Il existe cependant des apports franchissant la ligne médiane, provenant du nerf dentaire antérieur et du rameau dentaire antérieur de l'artère sous-orbitaire du côté opposé à la fissure, en général assez haut, sous la cloison des fosses nasales. Le nerf naso-palatin et l'artère de la cloison du côté opposé à la fissure pénètrent l'os, dans un canal très court au point le plus

antérieur de la jonction de l'apophyse palatine avec la cloison des fosses nasales. Ils continuent leur parcours, sans canal nasopalatin ni canal osseux, descendant derrière le prémaxillaire le long de la suture médiane, tout près du nerf et de l'artère controlatéraux et parallèlement à eux. Avec eux, ils émettent bientôt l'artère et le nerf médians allant à la suture. Parmi les ramifications terminales du côté opposé à la fissure, on trouve des branches de nerf et d'artères semblables à celles du côté de la fissure, mais nettement plus petites, qui continuent vers l'intérieur de l'os et vers le haut. Ainsi, il n'existe pas non plus de canal palatin antérieur complet ni de trou palatin antérieur ordinaire dans les maxillaires présentant une fente unilatérale.

2. Les cas étudiés montrent que le nerf dentaire antérieur et le rameau dentaire antérieur de l'artère sous-orbitaire sont situés du côté distal de la fissure et qu'ils assurent l'innervation et la vascularisation directes de la pré-canine.

3. Des troubles du développement ont pu être mis en évidence dans tous les germes d'incisives latérales permanentes situées sur le prémaxillaire près de la fente; le plus souvent il en était de même pour la dent de lait correspondante. L'os du prémaxillaire près de la fente était mal développé, et on a aussi trouvé des défauts de formation osseuse du côté opposé à la fente, du côté lingual et près de la suture médiane derrière le prémaxillaire, en ce sens que la partie inférieure du canal palatin antérieur était absente.

4. On n'a pu constater de formation dentaire que dans les cas où il existait une vascularisation et une innervation bien nettes. Un cas de fente partielle semblait être une illustration de l'hypothèse de *Steiniger* sur les fissures dues aux "Hasenschartenzysten", et présentait en outre un kyste séro-muqueux du seuil narinaire ("Gesichtsspaltenzyste" de *Klestadt*).

5. Chez deux couples de jumeaux accolés dont un des jumeaux de chaque couple présentait une fente unilatérale totale, les prémaxillaires des maxillaires n'ayant pas de fissure présentaient de nombreux traits communs. Ces traits différaient dans une certaine mesure des caractères habituels normaux et correspondaient aux caractères des cas de fissures.

6. Il est possible de baser sur les résultats de cette étude une

technique plus simple et moins douloureuse d'injection pour l'anesthésie des dents antérieures au voisinage d'une fissure. Ces résultats montrent clairement avec quelle facilité une intervention chirurgicale risque de perturber le développement des dents et du premaxillaire lorsque l'on ne prend pas suffisamment de précautions à l'égard du parcours particulièrement exposé des nerfs et des vaisseaux situés sur le vomer et sur la partie postérieure du prémaxillaire. Ils viennent à l'appui d'un fait d'expérience: l'incisive centrale située près d'une fissure, lorsqu'elle est traitée d'une manière appropriée, représente une valeur permanente beaucoup plus grande qu'on ne l'a supposé précédemment.

ZUSAMMENFASSUNG

VERLAUF DER GEFÄSSE UND NERVEN DES ZWISCHENKIEFERS UND DES OBERKIEFERS BEI KIEFERSPALTEN

1. Im bilateralen Spaltfall wird der Zwischenkiefer und dessen Zähne von n. nasopalatinus und a. nasalis posterior septi versorgt. Sie verlaufen, wie im Normalfall am Vomer entlang, und dann weiter nach unten längs dem hinteren Rand der prämaxillaren Mediansutur. Jedwede Spur von can. incisivus, sut. incisiva und foramen incisivum fehlt. Beinahe halbwegs an dem ungefähren vertikalen Verlauf wird ein gemeinsamer Mediannerv (n. praemaxillaris medianus) und Medianarterie (a. praemaxillaris mediana) zur Mediannaht abgegeben. Ferner werden Seitenäste zur Gingiva und Endäste zum Frenulum im weiteren Verlauf abgegeben. Aber die Hauptmasse der Nerven und Arterien perforieren den Kieferknochen nahe am unteren Kieferrand und nahe der Mediansutur, wovon sie wieder aufsteigen und sich zu Versorgungsästen für Kieferknochen und Zähne verteilen. Hier geben sie auch kräftigen Zuschuss zur Medianarterie und zum Mediannerv.

Im unilateralen Spaltfall empfängt die Prämaxilla an der Spaltseite am häufigsten ihre Hauptversorgungen von n. nasopalatinus und a. nasalis posterior septi derselben Seite, in einem analogen Verlaufe wie bei bilateralen Spalten. Ausserdem werden Zuschüsse von n. und a. alveolaris anterior superior der spaltfreien Seite gefunden, am häufigsten hoch oben, unter der Nasenschei-

dewand. *N. nasopalatinus* und *a. nasalis posterior septi* der spaltfreien Seite perforieren den Knochen, wo die Gaumenplatte ganz vorn in die Nasenscheidewand übergeht. Sie verlaufen in einem sehr kurzen Kanal und dann ohne Ductus und ohne Knochen-*decke* weiter nach unten hinter der Prämaxilla längs der Mediansutur, hier nahe und parallel mit dem kontralateralen Nerven und dessen Arterie. Gemeinsam geben sie bald Mediannerv und Medianarterie ab. Unter den Endverzweigungen auf der spaltfreien Seite wird ein ähnlicher, aber viel kleinerer Nervenzweig und kleinere Arterie wie auf der Spaltseite gefunden, mit Verlauf ein- und aufwärts in den Kieferknochen. Ein vollständiger *can. incisivus* und ein normales *foramen incisivum* sind also nicht in den unilateralen Spaltfällen vorhanden.

2. Die untersuchten Fällen zeigen, dass *n.* und *a. alveolaris superior anterior* an der distalen Spaltseite vorhanden sind, und dass sie direkte Versorgungen an den präcaninen Zahn abgeben.

3. Entwicklungsmässige Störungen sind gezeigt worden bei allen Anlagen von prämaxillaren lateralen permanenten Incisiven nahe der Spalte, am häufigsten auch bei den entsprechenden Milchzahnanlagen. Der prämaxillare Kieferknochen nahe der Spalte ist wenig entwickelt. Ungenügende Knochenbildung gibt es auch auf der spaltfreien Seite, palatinal und nahe der Mediansutur hinter der Prämaxilla, wo der untere Teil vom *can. incisivus* fehlt.

4. Zahnentwicklung ist lediglich bei wohldefiniertem Zufuhr von Nerven und Arterien vorhanden. Eine partielle Spalte zeigt zahlreiche Zysten im Spaltgebiet, Steiniger's "Hasenschartenzysten" ähnlich.

5. Bei zwei siamesischen Zwillingpaaren, wovon der eine von jedem Paar eine unilaterale Kombinationsspalte hatte, zeigten die spaltfreien Individuen in ihren Zwischenkiefern eine Reihe gemeinsamer Züge. Diesen waren zum Teil abweichend vom gewöhnlichen Normalmuster und entsprechend übereinstimmend mit dem Spaltmuster.

6. Die Befunde ergeben die Grundlage für vereinfachte und weniger störende Injektionstechnik bei der Pulpaanästhesie von Frontzähnen im Spaltfall. Sie zeigen deutlich, wie leicht wertvolle Zähne und Kieferknochen beschädigt oder zerstört werden können bei operativen Eingriffen die nicht genügend Rücksicht neh-

men auf den besonders verwundbaren Verlauf der Nerven und Arterien am Vomer und an der Rückseite des Zwischenkiefers. Die Befunde bestätigen die Erfahrungen, dass besonders der centrale Incisivus nahe einer Spalte bei adäquater Behandlung von dauerhaftem Wert ist, weit mehr als früher angenommen war.

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