Concerning the Innervation of the Upper Dentition in Man

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CONCERNING THE INNERVATION OF
THE UPPER DENTITION IN MAN

by

Jess Hayden, Jr.

A Dissertation in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
Field of Anatomy

June, 1962
60364
I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mervyn G. Hardinge, M.D., Ph.D. Professor of Pharmacology

Guy M. Hunt, M.D. Associate Professor of Anatomy

Otto F. Kammeyer, M.D., Ph.D. Professor of Anatomy

Robert L. Schultz, Ph.D. Assistant Professor of Anatomy

J. Earl Thomas, M.D. Professor of Physiology
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CHAPTER I

INTRODUCTION

The primary objectives of this study were to determine: 1) the pathway of the superior alveolar nerves and their relation to the maxillary molar tooth buds in the fetal and neonatal specimens and in the child, and 2) whether nerve fibers entered any microscopically-observed tooth buds.

The reason the problem was investigated is that local anesthetics* have been important in the control of pain during dental procedures, and such anesthetics perform most effectively when they have been deposited at locations dictated by the anatomical structure of the area. In the majority of cases the accepted technics have produced adequate anesthetization of the dental structures to be cut. But, clinicians who have had experience with this have noted recurring exceptions which have intrigued them as well as other individuals in anatomical and physiological laboratories. In this context, the statement of Thomas becomes the guiding principle of exploration; "The interpretation of neurological disturbances in any region is

*In the United States local anesthesia is employed rather than the precise term, local analgesia.
dependent to some extent upon definite information as to the histomorphology of the nerves which innervate that region.\textsuperscript{113}

The problem discussed in the present thesis has had as its point of departure the distribution of those branches of the maxillary nerve which innervate the primary\textsuperscript{*} dentition in the maxilla. The exact innervation of the primary molars has not been determined. Clinically, during the administration of local anesthetics, it has been assumed that the innervation of the primary molars and the premolars is the same. Careful and precise deposition of anesthetic solutions has revealed that the innervation of the maxillary primary molars and premolars may be bilaterally dissimilar, and certainly varies among individuals. The evidence has been that: 1) the infraorbital nerve block will generally produce profound anesthesia of the dental pulp of the maxillary primary molars; however 2) at times it is necessary to supplement the infraorbital nerve block (as in the adult dentition) to obtain profound anesthesia; 3) the posterior superior alveolar nerve block will not of itself routinely produce profound pulpal anesthesia of the maxillary first and second primary molars.

Human material, rather than animal, was utilized because of its unique morphology. Although homologies and similarities

\textsuperscript{*}Primary dentition is the accepted clinical term for the deciduous teeth.
are to be found in the cartilaginous and adult skulls of various species, each skull is characteristic for its species, and easily identifiable. Therefore, no attempt has been made to draw inferences from other species.

The present investigation dealt mainly with prenatal and neonatal (at term) specimens, because young postnatal material was almost unobtainable. Brodie stated that normal babies do not die except from acute infections or from accidents, so that conclusions drawn from such specimens should be considered in the light of an accompanying medical history. Salzmann (p. 102), citing Mall, stated that the largest number of pathologic embryos are found during the first seven weeks of pregnancy. The majority do not develop beyond the second month, and the pregnancies end in abortion.

An investigator generally chooses specimens which appear to be well formed grossly, and which then, upon microscopic examination, are accepted as normal or rejected as abnormal.

All fetal as well as neonatal tissues were examined by means of 1) dental radiography and by the study of serial stained sections, from which graphic reconstructions of the pertinent structures were made, or 2) gross microscopic dissection. The investigation also dealt with the analysis of the results obtained in the living child by the use of selective nerve blocking technics.
In order to provide an adequate understanding of the morphology of the area in which the nerves developed, the growth processes of the maxilla and mandible and their dental components are considered in the following review of the literature.
CHAPTER II

REVIEW OF THE LITERATURE

The Development of the Dento-Facial Complex

General statements. The relation of the trigeminal nerve to the teeth can be understood only by accepting the concept that the parts of the dento-facial complex must grow in mutual interdependence if a harmonious development of the face is to be achieved. The face, jaws, teeth and nerves are discussed in terms of their changing relationship.

The skull of man is composed of two parts: 1) the cranial, and 2) the facial portion which bears the teeth and is to a large measure developed in accord with dental size and the functions of mastication, deglutition and respiration. The bony skeleton of the face begins to develop close to the primordial facial skeleton which is composed of the cartilaginous nasal capsule and Meckel's cartilage. The centers of ossification of the mandible, maxilla, and palatine bones are related in position to the inferior alveolar and infraorbital nerves.

The province of this discussion does not include the actual beginning of the face and the development of its five
primordia (the bilateral maxillary and mandibular and the unpaired fronto-nasal) which are grouped about the stomodeum. There, active growth from the ventral part of the embryonic head begins about the end of the third week of life, and by the end of the second month the basis of the facial portion of the head is formed. The primordial maxillary and mandibular processes springing from the first branchial arch form the maxillae proper and the early lower jaw.

To describe the developmental anatomy of the human facial skeleton during the fetal period, Noback first examined a fetus of approximately 64 days. The mandible, nasal, palatine, zygomatic, internal pterygoid plates, premaxilla and maxilla were present, the last already having well-developed frontal, alveolar, zygomatic and palatine processes and the infraorbital canal grooving its orbital facies. All these facial bones were more fully differentiated than the calvarial and basicranial bones. During the next two weeks the lacrimal bone appeared, and at 78 days the facial bones have increased in absolute size, and in relative size with respect to the total facial area: in other words they have reached a size that is almost proportional to their definitive area.

Noback and his coworker have given an orderly account of the time at which ossification centers appear in prenatal life, and a synopsis of the development of the entire human
skeleton up to and including the time of birth. For this purpose the literature on the development of the skeleton was divided into two periods: first, that prior to 1895, which contains outstanding verbal and pictorial representations of gross dissections of embryonic and newborn skeletons, and secondly that after 1895. The methods of study employed during the latter period have been those of 1) sectioning (few studies), 2) clearing with potassium hydroxide and staining with alizarin red S (few studies), and 3) radiography. Of these the first proved to be the most accurate. The lag in the stated time of the initial appearance of the ossification centers as determined by methods 2 and 3, is at least one week. Noback's critique of the literature dealing with the times of appearance of ossification centers accented four points; 1) though age was given the method used to calculate fetal age or linear dimensions was not; 2) a statement of the numbers of specimens examined was frequently omitted; 3) the reports noted the earliest appearance of the ossification centers, when present, but did not indicate their absence; 4) it was frequently overlooked that technics vary in their sensitivity for determining the stage or the degree of ossification.

Meckel’s cartilage. The mesenchymal core of the mandibular process chondrifies, thus forming a bar which extends to the tympanic cavity of the ear (Arey pp. 417-8; Hamilton,
Boyd and Mossman\textsuperscript{48} p. 345). First described in 1805 by Johann Friederich Meckel the younger, in his "Abhandlungen aus der vergleichenden und menschlichen Anatomie",\textsuperscript{106} the cartilage is formed prior to the 14 mm stage (Galvez).\textsuperscript{43} Low\textsuperscript{73} reported that it is present in a precartilaginous or blastemal stage in an embryo of 12 mm, in a cartilaginous stage in the 14.5 mm, and at 15 mm is well formed and continues ventrally toward the midline where the two ends almost meet.

"... the course and shape of Meckel's cartilage also seems to be largely modelled by the nerves which are relatively large. Thus there is a bend inwards of the cartilage at the point where the posterior division of the inferior maxillary nerve comes into relation with it ... . The lingual and inferior dental nerves pass forward, the former closely applied to the inner aspect of the cartilage, the latter to the outer aspect. Where the lingual nerve passes in its final distribution to the tongue, there is another sharp bend of the cartilage round the nerve. The ventral end of the cartilage not only bends inwards, but upwards, at the same time becoming enlarged and flattened."

In the 24 mm embryo the bends are more pronounced, one of which is in the region of the mental foramen. This foramen is produced by the fusion of the margins of the mental groove about the mental nerve. Ossification, which will be considered in the account of the growth of the mandible, first appears in the embryo of 18 mm on the outer aspect of the ventral extremity of Meckel's cartilage. From that time the formation of bone assumes increasing significance and the role of the cartilage diminishes.\textsuperscript{73}
Meckel's cartilage in the 40 mm fetus extends from the otic region to the site of the future mandibular symphysis, being irregularly covered by bone. The rod is of fairly even diameter, and a cross section of it reveals a mature type of cartilage. (Macklin). Membrane bone replaces the cartilage in the stretch between central incisor and canine tooth germs in the 80 mm specimen, but cartilage still exists behind the canine at 230 mm. By the time of birth the portion of Meckel's cartilage invested by bone disappears and contributes nothing (Arey p. 418) to the permanent jaw, except possibly at the tip, or chin. Frazer also reports that its greater part atrophies, while the front portion probably is represented in the bone between the mental foramen and symphysis, and it may be responsible for the formation of these two structures (p. 219).

The spatial relationship of the sensory nerves of the third division of the trigeminal to Meckel's cartilage in the 17 mm (CR) stage are illustrated in a reconstruction by Fawcett. The course of the cartilage at the end of the third month of fetal life is represented in two illustrations in the "Human Embryology" of Keibel and Mall.

Mandible. Meredith presented an almost overwhelming amount of exemplary material to document his definition of physical growth as: "The entire series of anatomic and physiologic changes taking place between the beginning of prenatal
life and the close of senility." Within this concept of anatomic and physiologic change it was apparent that the growth of Meckel's cartilage and the mandible are so closely integrated that the attempt to relate their growth as separate entities could be justified only because it aided in the organization of the presented material.

The single center of ossification for each half of the mandible appeared as early as the fortieth day (Schaeffer). Fawcett, in 1930, demonstrated ossification in the 17 mm (CR) embryo with Mallory's stain which was then the most delicate stain for bone, and is still an excellent method to reveal developing bone. As previously mentioned, Low observed ossification, appearing in the 18 mm embryo as a delicate lamella of bone that develops in the mesenchyme on the outer aspect of the ventral extremity of Meckel's cartilage, and under the inferior dental nerve and its incisive branch. The fairly stout lamella extended posteriorly nearly half the length of the cartilage. In the embryo of 28 mm each half of the lower jaw was mapped out as one complete membrane bone with a dental shelf beginning to overhang Meckel's cartilage. In the 31 mm embryo the cartilage cells enlarge in the area between the tooth germs of the lateral incisor and canine and in the 36 mm embryo ossification may be seen in the perichondrium of the upper and lateral aspects of Meckel's cartilage. The findings of Fawcett and Low are in agreement with those of Mall but
are more detailed. Noback and Robertson who examined 136 cleared and alizarin stained specimens found, however, that the centers of ossification do not appear at a predictable CR length. The earliest indication of ossification of the mandible was seen in a 20 mm embryo and it was always apparent at 24 mm. The appearance of prenatal centers of ossification cannot be tabulated with the accuracy achieved in postnatal determinations.

The mandible in the 30 mm embryo is of enormous relative size (Fawcett), presenting a ventral foramen, inner alveolar border, incisor canal, and commencing coronoid process although the condyle is absent. The sockets for the teeth may be seen before the end of the second month. In the specimen of 40 mm (63 days) the mandibular plate of membrane bone lies lateral to Meckel's cartilage, separated from the cartilage by connective tissue except in the region of the primary canine and lateral incisor tooth germs where the bone is directly applied to the cartilage and appears like ossified perichondrium (p. 421). The condyloid and coronoid processes are clearly indicated at the beginning of the third fetal month. The two processes are essentially formed by the middle of the third month, and the mandible, now approximately 14 mm long, has achieved its characteristic shape (p. 440).

At birth the form of the mandible is not markedly different from that in the adult, except that the alveolar process is absent, thus creating a disporportionate relation between
the ramus and body. The gum pad occupies the place of the alveolar process and beneath the thick connective tissue of the pad lie the crypts of the teeth near the free border of the mandible. The condyle is ball-shaped in the shallow but relatively large temporal fossa.15,98 The mandibular body is almost parallel to the Frankfurt horizontal at birth.52,98

During the first year of life the mandible grows at its symphysis, surfaces and borders. By the second year the symphysis is closed and the main growth center is in the hyaline cartilage of the condyle and its fibrous connective tissue covering. This late cartilaginous center in an intramembranous bone is neither epiphyseal nor articular in its histologic composition, and it expresses its peculiarity by growing both interstitially (as its deeper layers of cartilage are replaced by bone) and appositionally (as the deepest layers of the covering tissue are being converted to cartilage). The condyle is the last growth center in the body to stop growing.52

Maxilla. Developmentally, the irregularly-shaped maxilla, with its several parts, may be divided into: "(a) a neural part which is developed in relation to the infraorbital nerve and its branches: (b) an alveolar part which has developed as a protective and supporting mechanism for the teeth."29

The bone of the maxillae is developed in membrane98 from the mesenchyme of each maxillary arch. Unlike the mandible,
no trace of cartilage appears in the maxillae (Arey\(^2\) p. 416). Ossification commences in the sixth week.\(^{29}\) Frazer\(^{40}\) (p. 193) described this initial ossification as being lateral to the dental groove, in the region of the future canine, and as extending to the molar and incisor areas. Or, in other words, the center of ossification is near the termination of the infraorbital nerve and is in the area of the anterior superior alveolar nerve.\(^{29}\) The ossification may be the result of a fusion of the premaxillary and maxillary centers of ossification, although a number of such centers have been ascribed to the bone.\(^{40,76}\) As the maxilla grows backward below the level of the infraorbital nerve, it splits into outer and inner neural plates allowing the nerve to pass through bone on its downward path to the incisor teeth.\(^{29}\) Cleared and alizarinized specimens showed ossification centers in the maxillae as early as 23 mm, and always at 28 mm.\(^{83}\) In the specimen at 30 mm the maxilla has all of its processes excepting the inner alveolar, which have grown from a single center. The small triangular orbital surface presents an uprising of bone on the outer side of the nerve, outlining the beginning infraorbital groove. Earlier, the infraorbital nerve was separated by a wide interval from the maxilla.\(^{35}\) After the fourth month the infraorbital vessels and nerves are enclosed by the lamina of bone that has extended upward on the lateral side and then grown medially. In the
adult, a suture, which is superior and medial to the canal, marks the extent of the inward growth of the bone. Bochdalek\textsuperscript{10} described the maxilla in the fetus and neonate in terms of "Zahnf"ächerbogen," that is, only large enough to support the teeth. The lateral orbital floor and the infraorbital nerve are very close to the alveolar process in the fetus. The maxillary sinus as it develops, separates them (Mall\textsuperscript{76} p. 438 and Frazer\textsuperscript{40} p. 193). The sinus reportedly influences the path of the nerve in the fetus of six months\textsuperscript{41} and also the separation of the infraorbital nerve into its dental nerves.\textsuperscript{25} The growth of the sinus, the increase of maxillary height, and the concomitant separation of the neural and alveolar portions of the maxilla were illustrated by Dixon (fig. 9).\textsuperscript{29}

Early anatomists recognized the maxillary sinus, and it was clearly figured by Leonardo Da Vinci,\textsuperscript{106} but Nathaniel Highmore in his "Corporis Humani Disquisito Anatomica" (1651), recognized the now commonly accepted relation of the maxillary sinus to the dentition,\textsuperscript{115} and gave the structure its eponymic title.\textsuperscript{42,87}

During fetal life... "the maxillary sinus is represented by a depression on the lateral wall of the nose in the fourth month."\textsuperscript{40} In the newborn, in which its dimensions are about 8 x 4 x 6 mm, it occupies the medial portion of the maxilla. Its relations to the orbital, nasal and facial structures were shown in the frontal section by Frazer\textsuperscript{40} (fig. 214) and by
Orban⁸⁷ (fig. 260). After birth the sinus extends laterally into the maxilla, reaching the situation of the infraorbital canal during the first year, so that during and after the second year the route of this nerve is indicated by a bony ridge in the roof of the cavity (Frazer⁴⁰ p. 208). Growth of the sinus and the maxilla is rapid up to the eighth or ninth year, and then is relatively slower, corresponding to the slower eruption of the teeth. The form attained during puberty is only slightly altered by the addition of a postero-inferior angle associated with the development of the third molar.

The three indefinite stages of growth that have just been presented, can be related to three recognized periods of tooth activity which are: 1) a rapid growth up to the period of the mixed dentition, 2) a slower growth, and 3) the post-pubescent growth. Ridges in the floor of the sinus mark these periods of growth; one ridge being in the premolar area, and the other in the molar area.¹¹⁵ Another visible ridge marks the course of the infraorbital nerve, and crests descending from it mark that of the anterior and middle dental nerves. The sinus is some distance above the nasal floor at birth. At approximately eight years of age the floor of the maxillary sinus is on the same level as the nasal floor, and then begins to sink somewhat beneath the level of latter.⁴⁰ Bilateral dissimilarity and numerous variations in the size, level and shape of the sinus⁸⁷ are produced by many diverse factors, such as age, heredity, and
extraneous influences affecting the dento-facial complex.

The facial skeleton of the baby seems to be all orbits, for most of the height of these openings in the adult has been reached at birth. As the naso-maxillary complex grows in height, apposition of bone modifies its superior or orbital surface. At the same time sutural adjustments are being made between the orbital surface of the maxilla and the zygomatic, lacrimal, ethmoid, and palatine bones. Lateral radiographs reveal all of the primary teeth in their various stages of development. Brodie describes them as follows:

The upper incisors are found between the floor of the nose and the free border of the alveolar processes, but well behind a line dropped from the anterior nasal spine. From here back the teeth lie at progressively higher levels with the second deciduous molar at or above the level of the nasal floor. Posterior to this tooth and at a still higher level will be seen the crypt of the upper first permanent molar, just anterior to the pterygo-maxillary fissure. It should be remembered that the maxillary sinus hardly exists at this age.

The maxilla grows in width by surface apposition on its lateral walls. It increases in height and width through sutural growth and localized surface apposition. In fact: "most of the height increment of the naso-maxillary complex is obtained through apposition of alveolar bone to accommodate erupting teeth." Alveolar process. Near the end of the second month of intrauterine life a groove that at a later stage contains tooth germs, vessels and nerves is formed in the bones of the maxilla.
and mandible. Developing bone forms septa between the tooth germs and, much later, a horizontal plate of bone that separates the primitive mandibular canal from the dental crypts. Alveolar bone develops only during the eruption of teeth, and, it may grow so rapidly at its free border that chondroid tissue is formed. The growth at the alveolar border accounts for the increase in mandibular height, as may be demonstrated strikingly in Madder-fed animals. The function of the alveolar bone is to form sockets for the teeth, and, in the economy of the body, part of the alveolar process is indistinguishably blended with the maxilla or mandible, leaving 1) alveolar bone proper (a thin pararadicular lamina of bone giving attachment to the principal fibers of the periodontal membrane), and 2) supporting bone (presenting spongy bone between its compact facial and lingual plates and the alveolar bone proper). As already implied, the development of the alveolar process is complete when the teeth have erupted. 13,87

**Teeth.** Oral ectoderm provides the enamel organ that determines the morphological outline of the crown of the tooth. Mesoderm enfolded within the enamel organ differentiates into the dental papilla, forming pulp and elaborating dentin. Mesoderm surrounding the enamel organ forms the dental sac which elaborates the radicular cementum and the periodontal membrane.

During the sixth week of embryonic life (11 mm), the
ectodermal primordium of the teeth, the dental lamina, begins to proliferate at ten points in each arch, giving rise to the buds of the primary teeth. Since the follicles are formed as extensions of the dermis of the mucous membrane, the teeth may therefore be considered as developing and calcifying within the mucous membrane.102

The cap stage represents, as the result of unequal growth, an invagination on the deep surface of the bud, which now presents an outer short row and an inner tall row of peripheral cells, the outer and inner enamel epithelium, respectively. Between the two layers of enamel epithelium the stellate reticulum develops as a network of cells which become separated by a mucoid fluid, rich in albumin, to which a protective function is ascribed.

The proliferating epithelium exerts an organizing influence on the adjacent mesenchyme, and thus the dental papilla and the dental sac commence differentiation and organization.

A tooth germ is formed by these three briefly described components: 1) enamel organ; 2) dental papilla; and 3) dental sac.

The next, or bell stage, describes a period of histo- and morpho-differentiation. The organizing influence of the ameloblasts (now approximately 40 microns high) reportedly stimulates the formation of odontoblasts from the peripheral cells of the dental papilla. The dentino-enamel and dentino-
cemental junctions, which are characteristic for each tooth, set the pattern by which ameloblasts, odontoblasts and cementoblasts deposit their products to give the eventually completed tooth its characteristic shape and size. About this same time, (bell stage) the dental lamina proliferates at its deep or innermost margin to give rise to the enamel organ of the permanent teeth, except the molars, while disintegrating between the enamel organ and the oral epithelium. The enamel organ becomes separated from the dental lamina about the time the first dentin is formed. Appositional growth now follows, with rhythmic incremental deposition of the matrix of the hard dental structures.  

The generally accepted concept of the development of the human dentition was questioned by Krause who employed magnifying lenses to observe the tooth germs both in situ and after their removal from the bony dental crypts in 95 fetuses, ranging from 8-18 weeks of age, which had been cleared and stained with alizarin red S. The maxillary teeth calcified prior to the mandibular, except that the mandibular canine precedes the maxillary, and the second primary molars calcify simultaneously. The onset of calcification in the maxillary central incisors varies from the 12th to 16th weeks, with a mean of 14 weeks. The first molar, lateral incisor, canine and second molar follow in rigid sequence. In another study of primary teeth, Krause reported that the mesiodistal
calcification is more rapid than the vertical, and that the maxillary central incisors calcify at a faster rate than other teeth. Lateral radiographs of the jaws of a newborn subject reveal evidence of calcification of all the primary teeth, and not infrequently the first permanent molars.\textsuperscript{15}

Hess, Lewis and Roman\textsuperscript{53} in their authoritative report on postnatal calcification of the teeth stated that calcification is always much more advanced than radiographs indicate because the pulp is covered with an inorganic cap too thin to project a radiographic shadow, whereas approximals, which represent a double thickness, stand out sharply, giving a true index of the total area calcified. In their opinion calcification of the primary dentition is largely postnatal.

The initiation of the entire primary dentition from the dental lamina, to which we have already alluded, occurs during the second month in utero, and is followed by the lingual growth of the lamina from the enamel organ of each primary tooth to the succedaneous teeth, beginning at about five months in utero for the central permanent incisors and continuing to the tenth postnatal month in the case of the second premolars. Next, the lamina grows distally to the enamel organ of the second primary molar at about the stage of the 140 mm fetus, and the permanent molars arise directly from it. The first permanent molar begins its initiation in the fetus of approximately 160 mm (4 months), the second, in the first year and the third
at four or five years. Galvez, in a study of serial sections, demonstrated a permanent molar developing at 120 mm while the outlines of the primary teeth were defined at 35 mm. Although the dental lamina grows over a period of five years, it is characterized by a shorter period of proliferation when initiating any one group of teeth, such as incisors, premolars, or molars. The activity of initiation and differentiation of any portion of the lamina is followed by its degeneration.

**Summary of early dento-facial growth.** At birth the face is not as well developed as the cranium, and it is apparent that the face, during fetal life, has achieved its greatest dimension in width, followed in sequence by height and depth. The growth of the face is dependent on: 1) the growth of the cranium and its base, and 2) the increase in size of the facial bones. The orbits, nose and jaws are the essential components of the face. And their pattern of growth is influenced by function, enlargement of the sinuses, development, form and position of the teeth; musculature of the face and tongue, and by numerous other physical and environmental factors. A most critical period in the formation of the face is the 3rd to 8th week of intra-uterine life, when the chief development of the face occurs, with the maxilla forming by the end of the fourth week and the mandible slightly earlier. The membranous bone of the mandible at first surrounds the later resorbed Meckel's
cartilage. The bilaterally formed segments of the mandible unite at the sixth fetal month, and bone closes the symphysis by the end of the second year.15,52,95

As has been previously stated, the form and size of the crown portions of the primary teeth have been established by late fetal life. During the late fetal and early infant periods, the rate of growth of the adjacent tissues, including alveolar bone, is more rapid than that of the tooth germs. If differential growth does not provide the proper correlation between the time of eruption and jaw size, the pre-eruptive condition of tooth crowding will persist in the functional dental arch.13 (p. 434).

At eight weeks the fetal face is characteristically human, however, the mandible appears retruded, overhung, as it were, by the frontal and nasal areas.95 Since the early mandible grows anteriorly under the influence of Meckel's cartilage, which becomes insignificant between twelve and twenty weeks, this is also a period of marked mandibular retrusion that is eventually modified by growth at the condyle and development of the temperomandibular joint.38 Obviously untoward influences, occurring during a growth period when the mandible is in retrusion, may have life-long effects. Brash and his co-workers13 have cited the opinions of many investigators concerning the developmental pattern of the mandible.
Rabkin\textsuperscript{93} cleared, alizarinized and studied 125 white embryonic and fetal specimens between six weeks and six months of age. In addition, twenty-two heads of babies from term to three months of age were radiographed. The many irregularities exhibited in the specimens bore close resemblance to physical differences present in the living, with regard to the shape and proportions, as well as to the relationships of the jaws to each other and led to the conclusion that, "on the basis of the evidence presented, the indications are that morphogenesis of the skeletal structure and the shaping of the individual follow an inherently established pattern during embryo-fetal life."\textsuperscript{93}

At birth there is an intermaxillary space in the future incisor region.\textsuperscript{118} In the majority of specimens examined the gum pads of the maxilla and mandible are in apposition unless there is a tendency for protrusion of one jaw.\textsuperscript{15,93} However, when the mandible is in its position of rest the gum pads of the infant are not in contact at any point,\textsuperscript{22,105} because the relatively large tongue flares out over the alveolar processes and supports the lips in back.

The face at birth. According to Frazer,\textsuperscript{40} the character of the face in the newborn depends almost entirely on the immature condition of the maxilla and mandible. Lacking a developed maxillary sinus or alveolar process, and being bulged but slightly by the supra-alveolar tooth germs, the maxilla is
vertically flattened (p. 225). This maxillary shallowness is reflected by the nasal fossae which, at this stage, are broader compared to their height than in the adult. Naturally, the bones of the fossae are modified. On each side the zygomatic bones are seen to overlie the mouth, and the palate is flattened. In both cases the appearance is dependent on alveolar deficiency. The growth of the alveolar regions is dependent on the dentition and occurs most rapidly during eruption of the primary and permanent teeth. Full alveolar growth is reached about the twentieth year. As alveolar bone adds to the height of the maxilla and mandible, the downward and forward resultant of growth at the mandibular condyle allows vertical height for the teeth to erupt, with resorption taking place on the anterior surface of the ramus, and apposition on its posterior surface (p. 226).

The bilaterally-formed mandible exhibits a fibrous symphysis. The short rami join the poorly-developed bodies at an angle of 125°. The dental sacs are visible as prominences on the mandibular base.

Although the orbits are large only in relation to the smallness of the maxilla, they dominate the facial skeleton, for they are closer to their adult size than any other portion of the face.15,40
The Early Growth and Course of the Trigeminal Nerve

Growth of the trigeminal nerve fibers to teeth. The early development of the cranial nerves, especially of those supplying the dental structures, presents an almost paradoxical situation, for, as Harrison stated:

There is no system of organs in which proper function is so dependent upon the minute arrangement of its cellular elements as is the nervous system, and none, that approaches it in the complexity of the arrangement. In no other constituent of the body have studies of structure and of function gone so closely hand in hand. Yet many of the phenomena of development have no obvious relation to function as understood by the physiologist. The relative size of the nervous system in vertebrate embryos reaches its maximum before nervous function begins. Complicated neuro-muscular mechanisms in higher vertebrates are essentially completed structurally before they become active.

One of the most baffling questions in the development of peripheral nerves is the selectivity of the fibers in establishing their proper terminations—motor neurone with muscle fibers and sensory neurones with the epithelium of the skin or mucous membrane or with muscle spindles. There is even strict selectivity among sensory nerves, as pointed out by Cajal (1919), in connection with the nerves of the tongue, where the Trigeminus forms general sensory endings and the facial and glossopharyngeal run to the taste buds.

Since there is a relative as well as an absolute rate of growth in the developing nervous system, the embryo or the fetus must be considered as a whole if the behavior of the nervous system is to be understood. In other words, although the nerve tip may be only 10-50 microns from the site of its future end organ during the period of development, the time at which the nerve terminal reaches its ultimate destination is
dependent on the difference of growth of the nerve fibers and of the contiguous area. Discussing the "Principle of innervation by steps," Cajal wrote:

... The innervation, general at first, becomes progressively more individual and specific. Our observations allow us to distinguish three principal steps in this process, (a) at first... the fibers approach the organ or tissue for which they are destined without penetrating into it; (b) once the specific cells of the organ have appeared, such as... papillary dermoid tissue, etc., the nerve bundles arise through fibrillar multiplication and growth, and the plexuses that we have mentioned so often then become organized; (c) finally, once the structural differentiation of the tissue is terminated or almost terminated, the connections become specific and individualized and the definitive terminal arborization is formed. (p. 287)

Harrison's summary of his experiments on peripheral nerves, which supports the principles later enunciated by Cajal, emphasizes that Schwann cells have nothing to do with the genesis of the nerve, although they may play an important role in nutrition and function. Myelinization of nerves starts between the fourth fetal and third postnatal month.

Hogg studied sensory nerves and associated structures in the skin of human fetuses of 8-14 weeks determined by menstrual age, and correlated the findings with functional activity. Several interesting results had reference to the trigeminal nerve: 1), the earliest recognized response to external stimulation of the sensory nervous system was evoked by stroking that area of the face supplied by the maxillary division, and almost immediately thereafter the mandibular
area responded to the same stimulation, 2), the facial areas become reflexogenous at about 8½ weeks of fetal life. (Increasing slowly at first, the entire body became sensitive by the 13th-14th week.) 3), These areas became reflexogenous before any structures comparable to the sensory endings found in the adult were demonstrable histologically. Most of the nerve fibers terminated at a distance of fifty to sixty microns below the epithelial surface of the skin, and only a few extended to within five or six microns of the epithelial cells. The intriguing question of how nerve fibers finally reached their end point was discussed in terms of the reciprocal relationship between nerve fibers and other tissues, as emphasized by Cajal who believed that nerves are attracted to areas where the cells are rapidly proliferating, and that the presence of the fibers frequently caused a rearrangement of the cellular elements. Hewer reaffirmed the relationship between the developing nerves and the histogenesis of the tissue surrounding them, and gave particular emphasis to the influence which these tissues exert on the nervous elements. The reports of Hewer and Hogg were cited in the discussion of the directional growth of nerves given in the embryology textbook by Hamilton, Boyd, and Mossman.

Cajal, confirming the early observations of His stated that although the nerve could not grow in a straight line because of the subsurface topography of the surrounding
tissues, there did prevail a general direction of growth. He likened the developing nerve to a ship, traveling sometimes with, and sometimes against, the current of the tide; for, as the axon grows, the surrounding terrain enlarges by the processes of proliferation and differentiation, and thus affects the course of the nerve. (p. 386). Arey in his textbook, "Developmental Anatomy" restates this conclusion by saying that, "Nerve fibers can grow only when in contact with a solid medium, and the mechanical structure of the ground substance of embryonic tissue supplies the requisite substrate." However, the implied directing force was the high chemical activity of an active growth center, which had so altered the density and arrangement of the surrounding ground substance that structural pathways converged toward this active center. Therefore, the directing force was apparently not chemical or electrical, per se. Harrison's conclusion, that the reaction between nerve and end organ has not been discovered, summarizes the state of knowledge which still exists.

In order to describe the stages of development of the cranial nerves from the time when they can first be definitely outlined from the surrounding mesodermal tissue until the time they have reached adult conditions, Streeter made profile reconstructions of human embryos of three weeks to three months of age. After observations on nerves IX-XII, he reported that:
"The elements of the peripheral nervous system do not reach a degree of differentiation, which is sufficient for reconstruction, until toward the end of the third week. From then changes in the form and relation continue until the third month, when the structures have practically reached the condition found in the adult, and development may be considered as completed."110

Corroborative evidence was introduced by Galvez43 who examined 8-35 mm embryos by the method of wax plate reconstruction. Bradlaw12 cited Hoadley as the authority for the statement: "Neurofibrils are probably attracted to the tooth germ as the result of cell differentiation." A portion of Bradlaw's investigations purported to demonstrate nerves branching from the main trunk to supply the dental papilla and follicle prior to calcification in the jaws of a three-week-old kitten. The growth curve of the feline dentition is reportedly similar to that of man.103 Bradlaw summarized trophic function in these words: "We do not know what part the innervation takes in growth and development."12

Erausquin33 made sections of the Gasserian ganglion in rats and cats, and sections of the entire mandible of cats, showing the course of the inferior dental nerve and the relation of the structures which it supplied. The direction taken by the nerves to the primary teeth, and to the permanent teeth as far posterior as the premolars, was accounted for by those theories of His55 and Cajal17 which dealt with the growth of nerve fibers to the periphery. The problem of how nerves innervated the permanent molars engaged Erausquin's interest. Nerve fibers were
shown going to the molar of a cat three days old. In another
cat of "pocos dias", in spite of the presence of enamel and
dentin, there were no nerve fibers to the papilla. In a cat
of twenty days, all the papillae possessed nerves. A sketch
from DeCastro was included depicting the innervation of a dental
follicle of a cat of two days, before the commencement of calcif-
ication.

Hammar, investigating the human embryo, stated that the
anlagen and tooth germs were without nerves until the time of
the formation of the enamel organ, when sparse nerve fibers
(presumably trigeminal in origin) were seen in the region of the
enamel organ and the dentinal papilla, coursing with the blood
vessels (pp. 493-4). In his summary, Hammar confused the
reader with the statement that the tooth papilla appeared to
have nerve fibers from its beginning (p. 497). However, Was-
serman concluded that nerves do not enter the dental papillae
of rats until after birth and Bernick was in agreement with
this in regard to the somatic afferents. Glasstone cultured
tooth germs in vitro, and observed that "the dental papillae
developed normally, forming odontoblasts which deposited normal
tubular dentine." Edwards and Kitchen determined that uni-
lateral resection of the inferior alveolar nerve did not signi-
ficantly affect the development of the permanent tooth germ.
Clinical autogenous transplantation of developing human third
molar tooth germs has been practiced for years, exemplified by
the work of Clark\textsuperscript{20} and Fleming\textsuperscript{37} who transplanted human tooth germs to lower animals. Usually two to fourteen hours had elapsed before the teeth were transplanted after being taken from prenatal specimens of eight to twenty-one weeks of age. The tooth germs survived transplantation to the host animal and mature enamel and dentin were formed.

James and Hollingshead\textsuperscript{60} employing serial sections, studied the distribution of the inferior alveolar nerve in human fetal specimens ranging from 14 to 38 weeks of age. They wrote:

"While in even the earliest stages examined there was a close spatial relationship between the fibers of the inferior alveolar nerve and the developing deciduous teeth, no fibers were found actually within the embryonic dental pulp except in the 24-week-old (210 mm.) and 38-week-old (394 mm.) fetuses. In the examination of these two specimens, fibers within the young pulp were observed in the incisor region of the 24-week-old fetus, but found only in the molar region in the one aged 38 weeks. Whether or not the development of the innervation to the pulp of the deciduous teeth regularly varies in regard to which teeth receive nerves first cannot be definitely stated from this study, since only a single mandible of each group was examined. Within the limitation of the material, however, it seems that there may be considerable variation in the age at which nerve fibers first reach the dental pulp, and probably there is no close correlation between the development of the tooth and the development of its innervation."

Corbin\textsuperscript{24} Koch,\textsuperscript{66} and Windle,\textsuperscript{121} experimenting on cats and dogs, found evidence that the stem fibers reaching the apical area of the teeth contain practically no large myelinated fibers and very few unmyelinated ones. Bernick,\textsuperscript{7} Orban,\textsuperscript{87} Phillip,\textsuperscript{90} and Windle\textsuperscript{121} were in agreement with Schour's description of
the mature nerve trunk:

"The nerve trunk entering the pulp through the apical foramen divides into branches containing from eight to forty medullated fibers. They pass occlusally through the central portion of the pulp, but almost immediately begin to give off branches which pass toward the periphery, branching and anastomosing in their course. Most of the fibers lose their medullary sheath very soon after leaving the nerve trunk. Such nerve fibers are covered only by the sheath of Schwann or the neurolemma. . . . Other fibers retain their medullary sheath, following an independent course through the pulp tissue, until they reach the layer of Weil, where the sheath is lost and may join the plexus of non-myelinated fibers lying in this region. . . ." 99

Path of the nerves to the maxillary teeth. Bochdalek 10 (1836) observed several "Ganglien" above the teeth, their location corresponding to that of the individual tooth sacs which received nerve branches, as did the alveolar bone. He spoke primarily of the posterior and anterior superior alveolar nerves. The latter supplied all teeth medial to the premolars, and terminated at the incisive canal in the alveolar process. In 1892, Jaboulay and Villard 59 presented several variations in the anatomy of the posterior dental nerves, suggesting that these nerves might be an extension of the sympathetic system because of a ganglion in connection with them. However, no detailed account of the development of the branches of the fifth nerve in man had been published prior to that of Dixon in 1896, 28 who made an attempt

". . . to trace the development of the different branches of the fifth, starting with the embryo of four weeks, at which time the three main trunks are alone represented. Further, special attention has been paid to the development
of those nerves, which in the adult connect the fifth with other cranial nerves, as the often assumed transmission of taste impulses by the connecting nerves adds great interest to their mode or origin and earliest attachments. The connections of the accessory ganglia of the fifth nerve, and as far as possible the date of their appearance in the embryo, have been noted.

Using serial sections of 5 embryos ranging from 4 to 8 weeks of age he made enlarged (25-50X) camera lucida tracings with colored inks on glass plates which, when properly stacked, produced excellent, transparent, graphic reconstructions for study. The nerves to the teeth, though briefly mentioned, were not shown in the illustrations.

Funke, in his 1896 Inaugural-Dissertation described the infraorbital nerve in the six-month fetus as pursuing a straight course forward, lying above the so-called "Zahnsäckchen," and bending downward to the infraorbital foramen at a point whose position depends on the shape of the maxillary sinus. The posterior and anterior superior alveolar nerves were always demonstrable, while the middle superior alveolar branch was inconstant, and its point of departure from the floor of the canal was variable. Clermont (1907) stated that cocainization of the nasal fossae could result in the anesthetization of an area extending from the centrals to the canines and thus he recognized the clinical importance of the course of the anterior superior alveolar nerve. Benninghoven (1912) described the posterior, middle and anterior dental nerves as contributing to a network from which small
nerves coursed to the apices of the teeth. The posterior nerves supplied the molars, and branches from the anterior supplied the incisors, canines and premolars. Scharlau (1914-15) described the zones of innervation in the jaws, mentioning the posterior, middle and anterior superior alveolar nerves, and stating that the tuberosity injection may at times result in anesthetization of the premolars.

Hofer (1922), after clinical observations and dissections of cadavers, ascribed to the nasopalatine nerve the function of supplying the incisors. Von Simon (1927,29) described the posterior superior alveolar nerves as generally innervating the molars and premolars. The anterior superior alveolar nerves after supplying the canine to incisor teeth, terminated in the incisive canal. Two branches of the inconstant middle superior alveolar nerve were described, one entering the sinus from the tuberosity, and the other running anteriorly in a bony canal. When these nerves formed an anastomosis with the posterior superior alveolar nerves, they entered into the innervation of the premolars. The posterior and anterior superior alveolar nerves were portrayed as united in the well-illustrated original preparations of Von Simon.

Bergara (1929), too, observed that the application of cocaine in the nasal fossa leads to anesthetization of the maxillary incisors, and canine, and to incomplete anesthesia of the premolars of the same side. His anatomical study of the
course of the anterior superior dental nerve substantiates the clinical findings.

Cordier, et al. 1935 removed the sheath of the maxillary nerve, and examined its several fasicles. The adequately illustrated article outlined seven distinct types of innervation of the teeth. In Type 1, the anterior and posterior dental nerves entered the tuberosity below the infraorbital groove. The posterior nerve supplied all teeth distal to the canine. The posterior and anterior dental nerve reunited in the area of the anterior dental canal, and formed a plexiform trunk, which supplied the canine and the incisors. Type 2, represents the classic distribution in which the branches to the molars, premolars, and anterior teeth are given off in the infraorbital groove. In Type 3, the maxillary nerve divided just posterior to the maxillary tuberosity. The divisions were (a) the anterior dental (known to us as the infraorbital) and (b) the so-called sub-orbital. The anterior dental passed forward to give off the cutaneous and anterior dental branches. The suborbital divided three times to supply the molars and pre-molars. The posterior and middle dental branches passed anteriorly to fuse with the anterior dental nerve, and formed the incisor-canine trunk. In Type 4 posterior, middle and anterior dental nerves were given off prior to entering the infraorbital canal. Type 5 presented much the same configuration, the difference
between types 4 and 5 being centered in the number of fasicles present in the parent trunk. **Type 6** gave off the molar branches prior to entering the infraorbital canal, and the middle and anterior dental branches in the canal. In types 4, 5, and 6, the posterior, middle and anterior branches all united to form the incisor-canine trunk. However, **Type 7** depicts a different arrangement, in that all three branches supply the molars, premolars and anterior teeth with no anastomoses.

In summary, Cordier and his co-workers stated that the dental nerves should be given the same value as the so-called infraorbital terminal, and not be considered as mere collaterals. The incisor-canine nerve was not to be considered as the anterior dental nerve, but rather as a trunk formed in most cases by the posterior, middle and anterior nerves as evidenced by the anatomical arrangement and volume of the nerve. A most interesting conclusion was the statement that the developing sinus had an influence in separating the original trunk into its dental nerves.

Dieck and Fujita\(^2\)7 (1935-36) gave a conventional description of the nerves to the maxillary teeth, with the posterior supplying the molars, the middle being extremely variable, and the anteriors supplying teeth as far distal as the premolars.

Jones\(^6\)2 (1939) summarized the nerve supply to the maxillary teeth as follows:
It has always been a stumbling block for the student of anatomy that, while only posterior and anterior superior dental vessels are described, there are three groups of superior dental nerves—posterior, middle and anterior defined in every textbook. The posterior and anterior arteries and nerves are described as running in company; but the middle superior nerves are apparently unaccompanied by vessels. Moreover, it is apparent that the course of none of these nerves is given in any text-book with sufficient precision to satisfy the demands of modern surgery.

According to him, the posterior superior dental nerves arise from the infraorbital nerve just before this enters the posterior end of the bony canal. Three or four branches are present, not all of which supply the teeth. One notable exception is that branch referred to as the nervus buccalis or the ramus maxillaris externus (Rudinger). Two main branches usually constitute the nerve supply to the dentition and historically these were called the superior and inferior branches of the posterior dental nerve. The smaller superior branch runs in a tunnel on the lateral wall of the maxillary antrum at the level of the malar tuberosity. The inferior branch lies in a canal in the lateral wall of the antrum well below the malar tuberosity and the transverse facial part of the canal for the anterior nerve (which it parallels), and may be readily followed as far forward as the roots of the canine teeth.

Since 1840, when the first description of the middle superior dental nerve was published, the nerve has had a somewhat remarkable history in anatomical literature, which Jones summarized. Traditionally, anatomical texts have verbally
represented the middle superior alveolar as arising from the main trunk within the infraorbital canal, while the accompanying illustrations depict the anterior superior alveolar nerve as the only branch which the infraorbital nerve gives off in the infraorbital canal. He said:

"I have, so far, been unable to identify a classical middle superior alveolar nerve in dissections or to trace the canal, in which it is said to run, in dry bones. Its occurrence must, I think, be a matter of some infrequency, and it is to be doubted if its retention in normal descriptive anatomy is altogether desirable."62

Jones' description of the anterior superior dental nerve followed. It is, contrary to often published descriptions, the largest branch of the infraorbital nerve, approximately one-third the size of the parent trunk. Its point of origin from the lateral side of the parent trunk is usually posterior to the mid-point, and not infrequently it arises from the infraorbital trunk at the extreme posterior end. In either case the nerve then travels in its own canal.

"This bony canal on the orbital floor is usually some 10 mm or more in length and nearly 2 mm in diameter. It runs in a lateral direction and reaches the anterior margin of the orbit as much as 7 to 8 mm lateral to the lateral margin of the infraorbital foramen. The canal then turns downwards in the anterior wall of the antrum (fig. 2)... it frequently forms a prominent ridge or buttress on the inner aspect of the upper part of the antrum, between which and the buttress often formed by the infraorbital canal itself, there is commonly a deep recess... directly it has fallen some 3 or 4 mm below the level of the infraorbital foramen in a gentle curve and rising again as it passes towards the narial margin. This is the transverse facial part of its course (fig. 3). The average length of this portion of the canal is slightly over 2 cm and it
is to be noted that whilst the lateral three-fourths lie in the anterior wall of the antrum, the medial fourth lies in the lateral wall of the nasal chamber, medial to the antral cavity (see fig. 5)."

In its medial extremity, the transverse facial canal rises to the level of the anterior attachment of the inferior turbinate bone and the lower end of the naso-lacrimal duct, thereby making the lateral and medial portions of the canal almost at the same level. Nerves and vessels pass inward to this area of the nasal chamber. From this point (medial extremity) on the lateral nasal wall, the canal turns abruptly downward and tunnels along the curved margin of the narial opening. The start of the downward curve may be vertically oriented at a point just medial to and above the alveolus of the canine and, passing over the alveolus of the central incisor, it terminates at the septum of the nose just in front of the anterior palatine foramen. In the transverse facial part of its course, it gives off its first conspicuous dental branch to the canine, and smaller branches to the incisors. The entire course of the bony canal for the anterior superior vessels and nerve is about 55 mm long, 15 mm of this traversing the orbital floor, 20 mm the transverse facial, and 20 mm the curved circumnarial portions.

Phillips and Maxmen\(^9\) (1941) on the basis of cited embryologic evidence, anatomical dissections, as well as more than 2,000 extirpations of vital pulps from maxillary incisor
teeth, believed to have substantiated their claim that the nasopalatine nerve is the nerve supply to the incisors. It is significant to note that they had not been able to demonstrate nasopalatine nerve fibers to the lateral incisors, but had assumed that since the nasopalatine injection anesthetized centrals and laterals, the laterals must also have been innervated by the nasopalatine nerve.

Statements, such as Cook's (1949), supporting the assumption of the role of the nasopalatine nerve as the innervation for the maxillary incisors, generally mention four points: 1) it is not possible to routinely anesthetize the maxillary central incisors by blocking only the anterior superior alveolar nerve, but 2), if this is followed by an injection high in the incisive canal of the maxilla anesthesia of the incisors will result; therefore, the nasopalatine nerve must contribute to the innervation of the incisors. 3) It is assumed that cocaine packs placed in the nasal fossa could anesthetize only the nasopalatine, and not the anterior superior alveolar nerve. 4) Embryologically, the nasopalatine nerve is the logical source of supply.23

Two widely circulated textbooks of Pedodontic practice and technic exemplify the clinical viewpoint of nerve distribution to the maxillary teeth. McBride77 (1945) cited Steinfelder,111 who stated that nerves from the palate often penetrate to the periodental membrane, and that they supply also the
dental pulp by way of nerve fibers from the membrane. Brauer's text\textsuperscript{14} (1952) stated:

"... In the maxillary arch the supraperiosteal infiltration technique is used. A palatal injection lingual to the tooth which is being anesthetized is given also for a cavity preparation in the upper arch."

In 1948 Szabo\textsuperscript{112} reported a study of 16 maxillae, of which eight were edentulous, three presented mutilated dentition, and only five possessed a good alveolar process and dentition.

"The careful dissection of 14 human maxillae has resulted in a modification of the topography of the superior alveolar nerve, as given by Hirschfield in 1866 and recopied in most handbooks of our times. The middle branch of the superior alveolar nerve showed the most marked deviations from the existing descriptions. It is inconstant and may be considered a variation. The upper bicuspids are found to be supplied by the posterior superior alveolar nerve in 50% by a middle branch in 25% and by the anterior nerve in 25% of the cases. Loss of teeth seems to affect the alveolar nerves with degeneration."

Olsen, Teuscher and Vehe\textsuperscript{86} (1955) examined 26 decalcified specimens and concluded that the origin of the anterior superior alveolar nerve was from the lateral or inferolateral aspect of the infraorbital nerve somewhere between the latter's halfway point and its anterior terminus. There may be one to three branches, and these pass in a canal, as described by Jones. A close proximity of anterior superior alveolar and nasopalatine fibers was noted in relation to the apices of the maxillary incisor teeth. The supply to the upper anterior teeth is derived from the anterior superior alveolar nerves or
from filaments of the superior dental plexus. Interestingly enough, when the middle superior alveolar nerve was absent (53 per cent of the cases observed) the superior dental plexus was formed from the anterior and posterior superior alveolar nerves. If the middle were present, the three nerves comprised the elements entering into the plexus.

Fitzgerald (1956) examined dried specimens and found the middle superior alveolar nerves to show a variable course on the wall of the antrum, and to be absent in 18 per cent of the cases.

McDaniel, in 1956, once more directed attention to the clinical variability of anesthetic effects. His references included that of Steinfelder who stated the distribution considered as the classical one:

"The posterior superior alveolar injection... takes its name from the nerves which are thus blocked. These nerves supply the third molar, second molar and distobuccal root of the first molar, together with the investing structures. The mesiobuccal root of the first molar is, except in rare cases, innervated, along with the bicuspid teeth, by the middle superior alveolar nerves, which cannot be blocked by conduction anesthesia except by direct placement of the solution in the pterygopalatine fossa, or by purely fortuitous and incidental effect sometimes obtained upon administering an infraorbital injection. It is obvious therefore, that if a posterior superior alveolar injection be made for the purpose of removing the three upper molar teeth, there must be given a supplementary infiltration injection over the mesial half of the first molar..."

McDaniel found that the posterior superior alveolar nerves had one to three branches. In 13 of the 47 cases dissected,
branches from the posterior superior alveolar nerves appeared to run to the premolar area. The middle superior alveolar nerve was inconstant, and presented the classic pattern in only 15 per cent of the specimens studied. The anterior superior alveolar nerves conformed most closely to that pattern. Eighteen specimens provided an exception by exhibiting secondary branches to the premolar teeth when the middle dental nerves were absent. The superior dental plexus innervated the maxillary teeth in approximately half of the cases. It was composed of multiple posterior branches, a middle branch, or an anterior branch with multiple main branches.

This nerve in clinical practice. The trigeminal nerve was described by Galen in the second century A.D. and not until fourteen centuries later did Gabrielle Fallopio (1523-62), that self-styled student of Vesalius, re-describe it. In 1748 Johann Friederich Meckel (1724-74) graduated at the University of Göttingen with his noteworthy inaugural dissertation: "Tractatus de quinto pare nervorum cerebri." In the following year (1749) he described the sphenopalatine (Meckel's) ganglion on the 2nd division of the trigeminal nerve more specifically in the publication, "De ganglio secundi rami quinti paris nervorum cerebri nuper detecto," (pp. 334, 227). The genial and gifted Sir Charles Bell, whose ardent devotion to private investigations resulted in drawings so accurate and
artistically perfect that they have few equals in the history of anatomical dissection, demonstrated in 1829 that the fifth cranial nerve is sensory-motor.\textsuperscript{42, 75} (p. 446, 707). The delicacy of his drawings may be seen in his paper, "On the nerves of the face, being a second paper on that subject," recorded in the Philosophical Transaction of the Royal Society of London.\textsuperscript{3}

Such anatomical discoveries laid the foundation for further observations on nerve physiology which became significant and of practical value with the discovery of the first local anesthetic—Cocaine! Isolated in 1860 by Nieman, a pupil of Friedrich Wöhler, the credit for the realization of the significance of the anesthetic effects of cocaine is ascribed to Karl Koller,\textsuperscript{30, 45} a minor assistant in the Vienna General Hospital. Koller, not yet thirty years of age and lacking funds to travel to Heidelberg for an ophthalmological meeting, had to rely on his Austrian colleague Dr. Brettauer to read his manuscript describing the discovery.\textsuperscript{67, 114} The brief report is recorded in the "Klinische Monatsblätter für Augenheilkunde," 1884;\textsuperscript{67} and in other journals.

That the significance of cocaine, in the fight against pain was quickly grasped, may be seen by reading the letters of 26 November and 1 December, 1884 by Hall addressed to the editor of the New York Medical Journal, describing the effects of injecting cocaine in close proximity to the nerve at the infraorbital foramen, and the inferior alveolar nerve as it
enters the mandibular foramen. These comments, as well as the work of Halstead, were noticed in the Journal of December 6 in an editorial entitled, "The new local anesthetic."

"For several weeks past the medical press, including this journal, has teemed with testimony to the wonderful anesthetic effects of the hydrochlorate of cocaine. Under ordinary circumstances, we should have waited for as many months to elapse before formally granting the truth of such allegations as are commonly put forth in behalf of any new remedy. But, although the available supply of the salt has thus far continued to be exceedingly limited, but a very small quantity has been needed to establish its marvelous power, and that little has been used to good purpose. We have no longer any hesitation, therefore, in proclaiming the announcement of the anesthetic power of cocaine to be the most important that has been made in therapeutics since Morton astonished the world with his demonstration of the power of ether—the first and still the best general anesthetic."

Braun, in 1903, published his ingenious experiments with a cocaine-adrenalin solution, and with this combination simplified the technique of local anesthesia. The appearance of Novocaine, synthesized by Einhorn in 1905, made local anesthesia a reality upon which advances in surgery could be built, and the use of analgesic block in diagnosis, prognosis and therapy could be established.

Numerous papers dealing with the technics of administration of local anesthetics based on the anatomical framework have been published but only a few have proved of lasting value to the dental and medical professions. Among the published books we may mention Smith's ambitious work on block anesthesia, the voluminous contribution by Bonica, Monheim's
useful and compact text, and that of Nevin and Puterbaugh, who concern themselves primarily with local anesthetics in the dental office.

From the time of Hall's correspondence in 1884 which recounted his attempt to avoid pain during dental procedures, to the modern reports on the precise and systematic approach to anesthesia as outlined in the German publications, and by Jorgenson and Sicher in the United States, the literature has been flooded with articles concerning the effects of local anesthetics in dentistry. These are largely descriptions of anesthetic complications or generalized discourses on the applicability of local anesthesia to dental practice.
CHAPTER III

MATERIAL AND METHODS

Graphic Reconstructions From Serial Sections

The specimens used to study the innervation of the dental structures were obtained through the Department of Anatomy of Loma Linda University. The caucasian fetal specimens, examined microscopically, ranged from approximately four to seven months of age, were fixed in toto, the heads removed and the calvarium and brain discarded. The specimens were then radiographed, decalcified, washed, dehydrated and infiltrated in the usual manner for nitro-cellulose embedding. The progress of decalcification was checked by means of 5 x 7 inch Kodak Bluebrand Screen Film in a cassette with intensifying screens. The factors were 10 Ma.; 60 KVP, at 1/20 second, with a distance of approximately 15 inches between the radiation source and the film. The embedded blocks of tissue were sectioned in a frontal plane, stained, and mounted. The details concerning the material are indicated in Table I.

A discussion of the criteria involved in the "Selection of a standard dimension for comparison of measurements" was

*Distance in inches is customary in dental radiography although the use of the metric system is generally preferable in scientific work.
### TABLE I

**DATA CONCERNING HUMAN FETAL MATERIAL USED**

<table>
<thead>
<tr>
<th>Spec.</th>
<th>Sex</th>
<th>Length</th>
<th>Fixation</th>
<th>Decalcification</th>
<th>Determination of Extent of Decalcification</th>
<th>Thickness</th>
<th>Stains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>12.5 cm</td>
<td>Formalin 26</td>
<td>Formic acid-alcohol</td>
<td>Radiograph Weber Raydex Model 6R, 70 KVP 15 MA Peak</td>
<td>30 microns</td>
<td>(1) Hematoxylin &amp; Triosin (2) Krichesky's (3) Periodic acid Schiff's (4) Reserve section not stained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 mo.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>6 mo.</td>
<td>Formol acetic-alcohol</td>
<td>Formic acid 94 Hydrochloric acid in isopropyl alcohol.</td>
<td>Same</td>
<td>60 microns</td>
<td>Krichesky's 70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(History)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>35.5 cm</td>
<td>Formalin 26</td>
<td>Nitric acid-Formalin.</td>
<td>Same</td>
<td>120 microns</td>
<td>Pearson's silver gelatin 89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 mo.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(History)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
presented by Scammon and Calkins. In summary, it may be said that both crown-heel (CH) and crown-rump (CR) measurements were valid for the purposes of the present study. That monograph substantiated that there is little dimensional change in the CR length of fetal material preserved in formalin, and a change of less than one per cent for any of the measurements employed in the present study. Patten and Philpott found little shrinkage in fetal specimens fixed in formalin, formol-alcohol or bichromates, if infiltration were in celloidin. Shrinkage was demonstrably less in specimens of more than 20 mm (CR) length, due perhaps to the compactness of the developing muscular and connective tissue, and the reduction of the interstitial spaces.

The periodic acid Schiff stain used represented a modification of Bernick's technic. Since the tissues were fixed in formalin the results were not as colorful as those obtained by alcohol fixation, which is recommended. The Krichesky technic gave the best differentiation of tissues. The Hematoxylin and Triosin stains were satisfactory. Bibliographic references concerning the staining methods are indicated in Table I.

Since thick celloidin sections do not readily adhere to glass slides during staining procedures, the sections were individually stained, care being taken to insure that they
were kept oriented as to anatomical right and left, and to the proper anterio-posterior sequence. The most satisfactory method of achieving a proper anatomical orientation and order was to employ a rubber stamp to number the sections in sequence as they lay on the microtome blade immediately after cutting them. The numbers generally withstood all the processes of staining and remained visible beneath the glass coverslips of the finished slide. In the event that a stamped number became illegible, the relative position of the slide in the anterior-posterior sequence was determined by comparing the structures in the section with those seen in adjacent sections. Such a procedure is accurate, but of course, time consuming.

The mounted sections were then projected upon white poster-board at a magnification of 25X. Illustrations of such reconstructions, made without the use of the wax-plate method, are described by Chase and referred to by Fowler. Lateral reconstructions prepared from gross frontal sections of the head will be illuminating to the investigator who consults The Frontal Section Anatomy of Kampmeier, Cooper and Jones. Similarly, in the present work, serial frontal sections of fetal specimens were necessary to plot accurately the graphic reconstructions, (plates 1-3); but they were also needed to determine where nerves end, because a most misleading appearance can be produced by oblique sections of nerve trunks when these alter their plane of direction. It is obvious that,
for the purpose of graphic reconstruction, sections taken in
the sagittal plane would be more confusing than helpful.

The pertinent region of the head of Specimen number 1,
illustrated in figures 1 and 2, was cut into sections 30
microns thick, which were prepared in the following sequence:
the first section was stained with hematoxylin and triosin, the
second with Krichesky’s modification of Mallory’s triple
stain, the third with periodic acid Schiff, the fourth kept in
reservoir (not stained). With the fifth section this order was
repeated again, and so on in succession.

Turning now to the actual work of reconstructions, a
lantern slide, in which the photograph of the right side of
the fetal head had been reduced to one-half actual size, was
projected on the poster-board, and the outline from glabella
to gnathion to gonion was traced. (See fig. 1) A line was then
drawn on this outline to represent the Frankfurt plane, and
from this horizontal line, vertical lines were drawn at inter-
vals of 15 mm to serve as reference points to be explained
presently. When a stained section was projected upon the out-
line the skin on the lower jaw was superimposed upon the pre-
viously drawn profile (glabella – gnathion – gonion). With
this skin line chosen as the common line of reference, the
inferior margin of the mandibular bone was plotted from the
sections. Since the sections were 30 microns thick, and
enlarged 25 times, each projected section represented a thickness
Fig. 1. Fetus of approximately 4 months, (CR 120 mm), after fixation.
Fig. 2. Fetus of approximately 4 months, (CR 120 mm), after fixation.
of 0.75 mm and since, further, every fourth section was plotted, the horizontal distance between the points on the plot was 3 mm. The vertical intervals of 15 mm, drawn on the poster-board, as just mentioned, provided points of reference, for the millimeter rule employed in plotting the 3 mm, 4 section, intervals; the 15 mm interval consequently represented the thickness of 20 sections. When all the plotted points derived from these vertically-oriented sections were connected, a graphic reconstruction of the profile of the mandibular base resulted. The profile thus obtained by plotting, coincided closely with a (pre-decalcification) profile radiograph of the face, when the latter was projected on the poster-board (See fig. 3).

The graphically-reproduced inferior border of the mandible now served as a second, more stable reference line for orienting the projected slides. After aligning such sections in proper vertical relation to the mandibular border, several additional structures were plotted which, when the points were connected, produced a graphic profile reconstruction depicting: 1) Meckel's cartilage, 2) inferior alveolar nerve, 3) mandibular tooth buds, 4) lowest point of bony orbit, 5) infraorbital nerve and branches and, 6) maxillary tooth buds and adjacent stroma.

For specimens 5 and 7, a different method of orientation was employed in order to more easily secure a stable plane of reference for illustrating, in graphic reconstructions, the relation of the infraorbital nerve to the maxillary dental
Fig. 3. Profile radiograph of a fetus of approximately 4 months, (CR 120 mm), enlarged 6 X
structures. Three horizontal lines were notched in the lateral side of the celloidin block containing the fetal face: 1) the Frankfurt line, 2) a line passing through nasion and 3) an inferior line through point "b" the most posterior point of incurvation of the lower jaw, with lines 2 and 3 parallel to 1. On the frontal surface a single vertical line was notched from glabella to gnathion. These several lines served the purpose of orienting the celloidin block in a drill press while a No. 56 (.0465 in. dia.) drill was used to make holes which extended from nasion and point "b" as far posterior as the coronal plane passing through the external auditory meatus. The holes were drilled parallel to the superior and inferior lines on the lateral surface of the block.

When the sections from a celloidin block had been mounted, the image of the tissues was projected upon a poster-board as before and the inferior border of the holes left by the drill at nasion and at point "b" were marked to establish the vertical distance between them. Two horizontal lines, (one passing through each point) were drawn across the entire surface of the poster-board. As the serial sections were plotted, these arbitrarily determined lines of reference provided a stable horizon on which to orient the image of the projected slide. Vertical orientation was maintained by visually aligning projected points (orbitale, zygomaxillare or the superior border of a dental sac), bilaterally on the same horizontal plane so
that a plumb line intersected nasion, nasospinale and gnathion. The nasal septum is at times so deviated that it was not a good plane of vertical reference. The inferior border of the hole drilled at nasion was then superimposed on the previously mentioned arbitrarily drawn horizontal line which passed through nasi

The structures plotted were: 1) lowest point of the bony orbit, 2) infraorbital nerve and dental branches, and 3) maxillary tooth buds and their stroma.

After the graphic reconstructions had been made, it seemed advisable to ascertain how accurately they reproduced the course of the fetal structures. Two fetal heads comparable in age to those specimens depicted in plates 1 and 3, were therefore sectioned in the sagittal plane and examined histologically. Comparison of such a sagittal section, (fig. 14) with the graphic reconstruction illustrated on Plate 3, shows their close correspondence, and hence, the relative accuracy of the reconstruction method.

Gross Dissection of the Infraorbital Nerve In Human Fetuses

The specimens for this second part of the investigation were obtained from the same source, and selected by the same criteria as those used for preparing graphic reconstructions.

Three heads were hemisected, with the sagittal cut running through the nasal septum. Two of the specimens (A, 360 mm
(CR), full term, and B, 280 mm (CR), or 8 lunar months) were partially decalcified in nitric acid-formalin (See Table I). A third full-term specimen (C), was not decalcified. Preliminary dissection was accomplished with the aid of an Optikon* binocular loupe which magnified 3 X. Final dissection of the infraorbital nerve and its superior alveolar branches was done with a Spencer American Optical Binocular dissecting microscope (Cycloptic Microscope series 53 M). Dissection was usually performed under magnifications of 7 to 10 X. Magnifications of 15, 20, and 25 X were employed to determine finer detail of the fibers about the dental sacs.

Local Anesthesia as a Method in Determining the Dental Distribution of the Infraorbital Nerve

The selection of the method, children and teeth. As already stated, the term anesthesia describes the analgesic effect which follows the deposition of local anesthetic solutions about nerve fibers. The technic of injection of the anesthetic solution here employed is known by several names: the Posterior superior alveolar, the Zygomatic, or the Tuberosity. The latter term most accurately reflects the position of the needle and its relationship to the bony and soft tissues. In children it is necessary to use a needle in a bent

*Storz Instrument Co., 4570 Audubon Ave., St. Louis 10, Mo.
hub* to fix precisely the site of deposition of the anesthetic solution. Before being able to secure such hubs, the writer made thirty-two preliminary injections with a 1 5/8 inch straight, tapering needle, in order to aid in establishing the criteria by which the success of the deposition of the anesthetic solutions could be judged. These preliminary trials are not presented in the tabulations because the tip of the straight needle could not be accurately guided to the anatomic position desired.

The deposition of anesthetic solutions in the region of the maxillary tuberosity was accomplished with 1 5/8 inch tapering needles which were bent at an approximate angle of 45° by the special hub. The hub is screwed to the threaded tip of a metal carpule syringe (See fig. 6) commonly employed in dental practice.

The children in this study were seen in a Southern California community with a population of approximately 30,000, over a period of several months. The subjects chosen were those who required local anesthesia in the treatment of pathological lesions involving dental structures in the posterior quadrants of the maxillary dental arch. All the children, about whom results are reported, exhibited a "normal" dento-facial complex;

*The tapering needles and hubs were from the Mizzy, Inc., Clifton Forge, Virginia.
they did not exhibit signs of any gross irregularities in their total development. In other words, children with such abnormalities as a cleft palate, cerebral palsy, or other serious incapacities were excluded. The sixty tuberosity injections reported include several instances of bilateral injections in the same individual. The dentitions ranged from full primary to young permanent.

To ascertain whether the extent of an injection of local anesthetic could be determined, the decayed molar, or the most medial molar if several were involved, was opened with a water-cooled 57 carbide burr revolving in a Midwest Company air-rotor contrangle handpiece. Extractions were an indication for the deposition of anesthetic solution. Pain response was usually verbally expressed, but autonomic reflexes such as the "beading" of perspiration upon the upper lip, or bridge of the nose, were considered to be overt signs of fright and possibly pain. If the subject felt no discomfort, no injection of local anesthetic was made.

The tuberosity injection. The injections were made in accordance with the measurements described by Jorgensen.63 The height of the maxilla was measured by placing a Boley gauge at the gingival margin of the 1st or 2nd primary molar and measuring "up" to the infraorbital margin. To avoid injury to the eye, the Boley gauge was placed on the skin just below the
bony infraorbital margin. The distance in millimeters was recorded (See fig. 4).

The significance of this measuring technic lies in the fact that the maxillary height at the tuberosity is approximately the same as that in the infraorbital region. The posterior superior alveolar nerves enter the foramina of the tuberosity half-way between the gingival margin of the fully-erupted molar teeth and the posterior border of the floor of the orbit. Thus, if the anterior measurement of maxillary height is halved (fig. 5), the resulting number of millimeters represents the distance from the posterior gingival margin to the foramina for the transmission of the posterior alveolar nerves.

After the preparation for the injection was made by ascertaining the maxillary height as just indicated, the recorded number of millimeters was marked on a tapering needle by a piece of rubber band which had been placed on the needle prior to sterilization (See figs. 6-8).

The technic of the injection was to palpate digitally both the tuberosity of the maxilla and the posterior surface of the zygomatic process of the maxilla, and leave the index finger on the zygomatic process. The lip was retracted, and the tissues prepared for the injection. The tip of the needle was inserted in the fornix of the vestibule, just a little distal to the midpoint between the posterior surface of
Fig. 4. Measuring the maxillary height

Fig. 5. Relation of primary molars, maxilla, infraorbital canal and infraorbital margin in a 6 year old.
the tuberosity and the posterior surface of the zygomatic process of the maxilla. The needle was stepped superiorly and distally, while injecting a few minims of solution as the needle was advanced, until the rubber marker lay at the same height as the gingival margin of the primary molars. The bulk of the solution was deposited at the terminal position of the needle tip. Aspiration was practiced with all injections. Not over 1 cc of Mepyrlcaine (Orocaine*) was slowly deposited in the area of injection. No injection was repeated if it was not immediately successful.

For the purpose of evaluating the results of the deposition of anesthetic solution, two categories were recorded: 1) anesthesia of the tooth or teeth, and 2) incomplete, or no anesthesia of the tooth or teeth.

The mesio-buccal root of the first permanent molar may in some instances be anesthetized by infiltrating the solution in the para-apical region of the mesio-buccal root. The principles are those of underlying infiltration anesthesia for any dental structure. A 1-inch tapering needle is employed. Although this injection was made to accomplish restorative work on some of the patients in this series, such teeth are listed in the incomplete or no anesthesia column.

*Mizzy, Inc.*
Fig. 6. Position of the needle on the tuberosity, primary dentition

Fig. 7. Position of the needle on the tuberosity, as the first permanent molar starts to erupt.

Fig. 8. Position of the needle on the tuberosity, mixed dentition.
CHAPTER IV

OBSERVATIONS AND RESULTS

Results From Sections and Graphic Reconstructions

Stained sections. The frontal sections stained by the Krichesky modification\textsuperscript{70} of Mallory's Triple Stain were most arresting, with the red of the bone spicules sharply contrasting with the blue background of collagen and cartilage. In Specimen 1 the toothbuds presented a brilliant reddish-gray appearance, while the nerve bundles exhibited less saturation of the same color. In older specimens the nerves and toothbuds assumed a definite blue cast.

The hematoxylin and triosin sections were characteristic for this stain. The silver stains were of sufficiently good quality to distinguish the course of the nerve fibers. Because of formalin fixation of the tissues, the periodic-acid-Schiff stain revealed all the structures in shades of green and blue, rather than those of pink for myelin and collagen.

The bilateral paths of the superior alveolar nerves in Specimen 1 are here illustrated in two different frontal sections. The fibers of the anterior superior alveolar nerve are seen in figure 9 and those of the posterior superior
Fig. 9. The anterior superior alveolar nerve as observed in a frontal section through the primary canine and lateral incisor of a fetus of approximately 4 months.
(CR 120 mm) 6 X
Fig. 10. The posterior superior alveolar nerves as observed in a frontal section between the primary 2nd and permanent 1st molar in a fetus of approximately 4 months. (120 mm CR) 6 X
Fig. 11. Superior alveolar nerve descending from infraorbital nerve to a molar tooth bud in a fetus of 120 mm (CR) 18X

Fig. 12. Superior alveolar nerve descending from infraorbital nerve to a molar tooth bud in a fetus of 120 mm (CR) 18X

Fig. 13. Pathway of the anterior superior alveolar nerve in a fetus of 120 mm (CR) 18X
alveolar nerve in figure 10. Figures 11, 12, and 13 show them in higher magnifications.

**Graphic reproductions.** Plate 1 illustrates the graphic reconstruction of the pertinent region in Specimen 1, a fetus of approximately 4 lunar months (CR, 12 cm). After the graphic reproduction had been made, a second 4 month (CR 12 cm) specimen (No. 13) was sectioned in the sagittal plane, and stained with the Krichesky modification of Mallory's stain for connective tissue. Microscopic examination of the second, or control, specimen revealed that the technic of graphic reproduction had resulted in an accurate portrayal of the dental structures as seen in a sagittal cut through the maxillary tooth buds. The teeth were in the bell stage of development.

Two posterior superior alveolar nerves left the trunk of the infraorbital nerve. The first was a definite branch to the first permanent molar, and the second branch terminated between the dental sacs of the first permanent and the second primary molars, (See fig. 10), which were almost contiguous, although microscopic examination of the tissue sections revealed that the fibers were in closer relation to the sac of the first permanent molar.

A middle superior alveolar nerve can be traced from the trunk of the infraorbital nerve to the dentinal papilla of the second and first primary molar, although in the case of the
first primary molar, the nerve's origin from the infraorbital nerve could, at best, merely be inferred.

The anterior superior alveolar nerve was traced from the infraorbital nerve as it passed the nasal side of the primary canine and lateral incisor, at which point it was lost to view.

The inferior alveolar nerve was also portrayed in this reproduction, and the three branches described by Sicher were noted, 1) posterior dental, a distinct branch to the first permanent molar, 2) middle dental, a distinct continuous nerve running parallel to the inferior alveolar nerve (which almost obscures the nerve to the first primary molar) supplying the two primary molars. Finally, in the region between the first primary molar and the primary canine, the inferior alveolar nerve divides into many fine fibers. The primary canine lies lateral to and is supplied by the 3) anterior dental nerve, which could not be followed forward of the distal border of the primary lateral incisor.

Meckel's cartilage was traced from the midportion of the mandibular ramus to the area between the first primary molar and the primary canine, where the cartilage disappeared, only to be once again visible in a short stretch on the lingual side of the primary canine and lateral incisor tooth buds. Posteriorly there is a sharp bend in the cartilage, where the lingual nerve passes in its final distribution to the tongue,
and the portrayed cartilage lies lingual to the inferior alveolar nerve.

Plate 2 illustrates the graphic reconstruction of the pertinent region in Specimen 2, a fetus of 6 months as determined from the medical history. The teeth as portrayed were in the late bell stage of development. After leaving the trunk of the infraorbital nerve the posterior superior alveolar nerve bifurcates, one branch entering the dental sac of the first permanent molar, and the other branch approaching the dentinal papilla of the second primary molar. The middle superior alveolar nerve may be traced from the trunk of the infraorbital nerve to the dental sac of the first primary molar. Arising in close proximity to the middle branch, the anterior superior alveolar nerve, after an anterior-inferior course, disappears from view in the mid portion of the primary lateral incisor which lies lateral to the nerve.

Plate 3 illustrates the graphic reconstruction of the pertinent region in Specimen 7, a fetus of approximately 7 lunar months (CR 24.2 cm). As a control, Specimen No. 11 (CR 25 cm) was sectioned and stained as described for the control in the case of Specimen 1. The reliability of the technic of graphic reconstruction was again confirmed. The teeth were in the stage of apposition (fig. 14).

The posterior superior alveolar nerve bifurcates to run to the dental sac of the first permanent molar, and to pass in close proximity to the dentinal papilla of the second primary
molar. Several nerve branches are given off in the region classically ascribed to the middle superior alveolar nerve. Two of these branches pass in close approximation to the dental sac of the first primary molar, while the others end blindly. Several branches are given off the infraorbital nerve. One of these anterior superior alveolar nerves appears to enter the dental sac of the primary canine and a second definite branch is seen to go to the dental sac of the primary central incisor, and then the branch is lost as it approaches the midline.

A neuro-vascular bundle passing from the region of the infraorbital nerve to the primary lateral incisor may be seen in the sagittally sectioned control section for Plate No. 3 (fig. 14). Two higher magnifications are seen in figures 15 and 16.

Observations Made On Gross Dissections

The dissection of the right side of the fetus at term ("C") illustrated in Plate 4 shows a communicating branch of the anterior superior alveolar nerve. The superficial appearance of the branch suggested that it extended from the infraorbital nerve plexus to the bony lamina above the first primary molar. After the illustrator had recorded this relationship, further dissection was accomplished under the dissecting microscope (10X). It was seen that as the infraorbital nerve lay on the posterior border of the orbital floor, just above the
Fig. 14. The infraorbital nerve as observed in a sagittal section of a fetus of approximately 7 months. (250 mm CR). approx. 3 X
Fig. 15. Approximately 12.5X

Fig. 16. Approximately 25X A higher power of Fig. 14, showing the neurovascular bundle descending from the infraorbital nerve to the primary lateral incisor as observed in a sagittal section of a fetus of approximately 7 months. (250 mm CR)
distal margin of the bud of the second primary molar, a relatively prominent nerve fasicle was given off. The nerve fasicle ran anteriorly and inferiorly to enter a bony canal above and to the nasal side of the developing second primary molar. The nerve fasicle (and of course the canal) descended as it ran anteriorly, the first portion of its sagittal course lying directly beneath the main trunk of the infraorbital nerve, its termination being on the lingual side of the bud of the first primary molar. The branch communicating with the infraorbital plexus was seen to follow a short course in the lamina of bone above the first primary molar, to reach the superior surface of the bony shelf from which point its course is outlined in the plate.

The middle superior alveolar nerve left the infraorbital canal 2 mm distal to the anterior superior alveolar nerve, in a bony canal running medially and inferiorly to the course of the anterior superior alveolar nerve. Branches were traced to the second primary molar bud, and the nerve terminated at the bud of the first primary molar in the area where the fasicle depicted in the plate joined the anterior superior alveolar trunk. There may have been fibers of communication between the middle and anterior superior alveolar nerves.

The posterior superior alveolar nerves supplied the first permanent molar bud.
Dissection of left side of fetus "C". The anterior superior alveolar fasicle left the trunk of the infraorbital nerve as on the right side, and followed essentially the same course. There were no middle superior alveolar nerves. The posterior superior alveolar nerve supplied the two primary molars and the first permanent molar. The posterior superior alveolar nerve was given off the maxillary nerve in the pterygopalatine fossa, just immediately anterior to the pterygopalatine ganglion. After an anterior-inferior course of 2 mm it divided; the short, posterior fasicle, supplied at least two branches to the tuberosity. The long, anterior branch passed through the bone of the superior border of the maxillary tuberosity, running through the tissue above the tooth buds. The nerve supplied the second and first primary molars.

Plate No. 5 illustrates the dissection of the right side of Fetus "B", a fetus of approximately 8 lunar months (CR 280 mm). As the maxillary nerve trunk was traced across the pterygopalatine fossa, the comparatively stout fasicle of the posterior superior alveolar nerve arose, and immediately anterior to its origin (0.5 mm) the middle superior alveolar nerve fasicle left the main trunk. The latter fasicle descended through the posterior bony floor of the orbit, and after running 4 mm in a bony canal it divided into a superior division which ran anteriorly (in a bony canal) to supply the first primary molar and an inferior division which sloped
somewhat more abruptly to supply the second primary molar.

From the time that it came to lie on the posterior floor of the bony orbit, until it emerged from the infra-orbital canal, the almost sagittally directed infraorbital nerve traversed an approximate distance of 14 mm. From the mid-portion of the trunk arose the fasicle which supplied the anterior teeth. This anterior superior alveolar nerve, after entering a bony canal ran anteriorly and medially. The nerve almost immediately divided into an inferior and sharply sloping fasicle which supplied the primary canine, and a superior fasicle which descended lingually to the primary lateral and central incisors to provide their innervation.

It was noted that each of the primary teeth was innervated on the superior medial surface of the bud.

Dissection of left side of fetus "B". The left side is not illustrated but dissection revealed the same pattern of distribution of the superior alveolar nerves.

The fasicles of the superior alveolar nerves of fetus "B" were of noticeably smaller diameter than those of the term specimens "A" and "C".

Fetus "A". The innervation of this full term specimen (360 mm CR) was bilaterally similar. The posterior superior alveolar nerve was given off the maxillary nerve about 1 mm distal to the superior border of the maxillary tuberosity.
Only one well defined fasicle apposed itself to the tuberosity, and entered the bone. The middle and anterior superior alveolar nerves emerged in posterior to anterior sequence about 4 mm anterior to the posterior-superior border of the maxillary tuberosity. These nerves then ran down through separate bony canals (the anterior nerve above the middle) to supply the first and second primary molars; and the primary canine, lateral and central incisors respectively.
Results Obtained by the Deposition of Anesthetic Solution

Tuberosity injections in sixty cases produced the following results:

<table>
<thead>
<tr>
<th>TEETH OBSERVED</th>
<th>ANESTHESIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td>1st Permanent Molars</td>
<td>33</td>
</tr>
<tr>
<td>2nd Primary Molars</td>
<td>22</td>
</tr>
<tr>
<td>1st Primary Molars</td>
<td>7</td>
</tr>
</tbody>
</table>

To determine if the above results possessed any biological significance, two $X^2$ tests were employed, the 1st considering the permanent and primary molars as two separate groups:

<table>
<thead>
<tr>
<th>TEETH OBSERVED</th>
<th>ANESTHESIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td>1st Permanent Molars</td>
<td>33</td>
</tr>
<tr>
<td>1st and 2nd Primary Molars</td>
<td>29</td>
</tr>
</tbody>
</table>

Here, $X^2 = 0.77$, indicating the probability of significance as 60%.

In the 2nd test the permanent and 2nd primary molars were considered as one group and the 1st primary molars as another.

<table>
<thead>
<tr>
<th>TEETH OBSERVED</th>
<th>ANESTHESIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td>1st Permanent and 2nd Primary Molars</td>
<td>55</td>
</tr>
<tr>
<td>1st Primary Molars</td>
<td>7</td>
</tr>
</tbody>
</table>

Here $X^2 = 1.37$, indicating the probability of significance at 75%.

*cf. Smith's [108](p. 426) report of 5% success for the 1st permanent molars.
CHAPTER V

DISCUSSION

The concept that the growth and pathways of the nerves to the teeth can best be understood if the concurrent development of the jaws and teeth is considered at the same time will be discussed by correlating reports from the literature with the results obtained during the present investigation. As Hewer stated, it is not possible to understand the development of nerve endings in the various parts of the body without a study of their surrounding tissues, for surroundings influence nerve development.

The first technic in this study, graphic reconstruction, employed serial, stained frontal sections as a means of comparing and recording the pertinent anatomical structures in a tissue section with their contiguous portions in the preceding or the succeeding tissue sections. An investigator working with this method becomes increasingly aware of the mutual interdependence in the growth of the jaws, teeth, and the nerves to the dental structures. For example, the relationship of the infraorbital nerve to the maxilla and the teeth is shown in the tissue sections photographically reproduced in figures 9 and 10, (4 month fetus) and the graphic reconstruction of plates 1-3, (4, 6, 7 month fetus). Such a close relationship of these structures is exhibited early in life, for it is
reported that the centers of ossification of the mandible, maxillae and palatine bone (which bones are well developed by the end of the third fetal month) are situated near the inferior alveolar and infraorbital nerves (Scott). Furthermore, the configuration of these dento-facial structures, as portrayed in the previously mentioned figures and plates, are in harmony with the known anatomy of the face during the period of childhood and later. These findings are in accord with Noback's report that the facial skeleton enjoys a rapid and early development. Therefore, the information conveyed in plates 1-3 (fetal) may be meaningfully applied to patterns of nerve distribution in the primary or mixed dentition stage (infant and child).

A consideration of the actual technic of preparing the accompanying two-dimensional graphic reconstructions from stained frontal sections, makes it obvious that it lacks the detail obtained in a three dimensional wax-plate reconstruction. It also has a distortion that is inherent in any straight line portrayal of a curving object (in this case the maxilla and mandible). The real advantages of the graphic technic, in comparison with other technics, lie in the fact that: 1) there is a saving of time; 2) the nerve endings in the young fetus can be more accurately followed than by other technics; 3) the technic of sectioning more accurately reveals details of
structure at an early age; the essential relationships may be portrayed in bold relief, while those parts that might cause confusion may be omitted. For example, in plate 1 there is no question as to the location of the nerve trunks or the tooth buds. Another representative finding is the apparent upward deflection of Meckel's cartilage as the inferior alveolar nerve approaches it in the area of the mandibular ramus. Low described an inward deflection of Meckel's cartilage at this point, but the illustrations of his wax-plate model show an upward deflection which is consonant with that shown in Plate 1 of the present study. Streeter, also, employed profile reconstructions to study human fetuses. He was able to report that at the third month the elements of the peripheral nervous system have practically reached the condition found in the adult. Galvez furnished corroborative evidence by the wax-plate technic. Thus, it may be concluded, from the reconstructions presented and from the literature cited, that the reconstruction technic is an accurate method of determining the pathway of the nerves to the teeth.

As to the reciprocal influences of the nerves and the jaws, one recalls the statement by Low that the course and shape of Meckel's cartilage seems to be largely modelled by the relatively large inferior alveolar and lingual nerves. The just-cited evidence of Streeter, Galvez and Low leads to
the conjecture that the nerves may partially model the mandible. It is evident from Dixon's thesis material that the osseous tissue of the maxilla of a (26 mm CR) fetus splits as it grows posteriorly, thus enabling the anterior superior alveolar nerve to pass to the incisor teeth. The bone presumably unites behind the nerve, thereby forming a canal. The path of the anterior superior alveolar nerve, as portrayed in Dixon's sixth illustration, bears a resemblance to that in figure 9 of the present thesis. The latter photograph reproduces a cleft in the infraorbital margin, a reminder that the bone envelops the infraorbital nerve. Dixon, starting with the 34 mm (CR) fetus, described this process of enfolding in his text and accompanying figures. He also portrays the significance of the maxillary sinus in its relation to the teeth and their nerve supply. Since the enlargement of the maxillary sinus is associated with an increase in maxillary height, width and depth, there is obviously an increase in the distance between the dental structures and the infraorbital nerve. From the available evidence it appears that the terminal portions of most of the dental nerves have reached the region of the teeth by the fourth fetal month, whereas most of the development of the sinus is postnatal. Therefore, one might presume a modification of the pathways of the nerves as the sinus grows. In summary, the nerves to the teeth develop more rapidly than the osseous tissues of the jaws, on which structures
the nerves have a definite modelling influence.

The influence of the nerves on the teeth is not as clear. One suspects that the growing teeth, whose development lags behind that of the nerve trunks, may influence the location of the nerves. At the time that the permanent incisor, canine and premolar teeth develop they are, of course, situated high in the maxilla. The position of various of these teeth has been observed by the present investigator in serial, stained frontal sections of the maxilla of an infant of eleven months and another of eighteen months. Roberts by means of gross microscopic dissection showed the situation of the second premolar and the permanent molars in the child of four years. At the present time it is impossible to say what influence these permanent teeth may have on the course of the infraorbital nerve and its branches because the chronology of the innervation of the primary and the permanent teeth has not been determined. Such chronology would logically try to correlate the time of innervation with the stage of development of a particular tooth, and to attempt a formulation of the sequence of innervation, i.e., the centrals are innervated first, the molars last. Furthermore, another problem is concerned with the assumption that there is some difference in the process by which nerve fibers reach the permanent molars, as contrasted with the succedaneous, or successional, teeth. Such a premise seems logical if only on the basis that the spatial relationship to contiguous structures is obviously
different in these teeth. Such problems have been mentioned by Bradlaw,\textsuperscript{12} Erausquin,\textsuperscript{33} Galvez,\textsuperscript{43} Hammar,\textsuperscript{49} and James and Hollingshead.\textsuperscript{60} A further reason for presuming that teeth have more influence on the position of the nerves than the converse is the fact that teeth are apparently not dependent on trigeminal innervation for their development.\textsuperscript{60} For example, Glassstone\textsuperscript{44} grew dental papillae, odontoblasts and dentin in vitro, Edwards and Kitchen\textsuperscript{32} reported that unilateral resection of the inferior alveolar nerve of kittens did not significantly affect the development of the permanent tooth germs, and the autogenous transplantation of human third molar tooth buds has been practiced for years, as exemplified by the reports of Clark\textsuperscript{20} and Fleming.\textsuperscript{37} These latter observations lead to one more remark: there is nothing in the present investigation, or in the literature, to tell us specifically what attracts the nerve to the pulp in terms of space and time. We are left with Harrison's\textsuperscript{50} conclusion, that the reaction between nerve and end-organ has not been discovered.

The method of graphic reconstruction seems to be one of the most accurate ways of determining the pathways of the nerves to the teeth. This is especially true for the inexperienced investigator, to whom nerve fibers seemingly appear and disappear in a most disconcerting fashion in the tissue sections. It would be almost impossible for the novice to plot accurately their course from section to section without
resorting to some technic of measurement. For the making of such reconstructions, tissue sections as thick as thirty microns gave the best results without sacrificing staining quality and distinctiveness of all structures. Sections of 60 and 120 microns were easier to plot, the nerves stood out, but many nearby structures were obscured by the thickness of the tissues, or the density of the stain.

It is obvious from looking at the plates (1-3) that the reconstructions reveal more about the innervation of the molars than of the canines and incisors. This, of course, is due to the curvature of the anterior portion of the jaws, and the fact that the anterior superior alveolar nerves are situated to the lingual side of the anterior teeth.

A related finding was the presence of the first permanent molars in the fetus of four months (120 mm CR), as portrayed in the graphic reconstruction of Plate 1. The outline of these teeth were clearly seen at a magnification of 25X, as were the nerves which ran to their pulps. Galvez\textsuperscript{43} found a dark staining area in this region at 120 mm. When his serial stained sections were examined at a higher power (100X) the epithelium of the molar bud was evident. Orban's\textsuperscript{87} text states that these germs arise from the dental lamina at about four months of fetal life (160 mm). One deduces that the latter figure represents a CH measurement, and that of Galvez a CR, although there is no accompanying textual evidence.
The investigator had the impression that the teeth in specimen 1 may have started to calcify somewhat earlier than the time indicated by Schour and Massler. In accord with the report of Krause, mesio-distal calcification was more rapid than was vertical, and the maxillary central incisors calcified at a faster rate than other teeth. No attempt was made to compare the sequence of calcification. The dental sac, as portrayed in figures 9 and 10, does not appear as the definite sac-like structure seen in hemisected specimens of 125 and 135 mm in which the sagittal cut passed thru an incisor tooth bud. Stains such as hematoxylin and triosin, or Krichesky's, make the follicle appear more delicate and less definite than it really is. Scott commented on this peculiarity, and cited evidence to substantiate the conclusion.

One final comment concerns the technic of orienting the outline of the projected tissue sections. The first reconstruction was based essentially on the outline of the base of the mandible. Although the mandibular base is a stable point of reference, (growth in height occurs primarily at the alveolar border, length at the posterior of the ramus) it does present a concavity, therefore some distortion would occur even if it were to be plotted against an outline projected from a predecalcification radiograph of the mandible. Much less distortion is present when the reconstructions are oriented, as were those shown in Plates 2 and 3, and described
under methods.

The technics of microscopic gross dissection are, of course, evident. The clarity with which the nerves may be observed and followed from the parent trunk to the tooth buds recommends this technic; otherwise fibers and even small trunks may be severed while their bony surroundings are being pared away. Decalcification of the maxillae prior to dissection was helpful, but good dissection of fetal specimens is possible without it. The size of the nerves in the two term specimens "A" and "C" were larger than in the eight month fetal specimen "B". No conclusion can be reached as to whether this is a factor of age, or of individual variation, or both. Of more importance was the observation that the anterior superior alveolar nerve was of a relatively large size when compared with the other alveolar nerves, and the parent trunk (see Plate 5). Both Cordier, et al.,25 and Jones62 have commented on the large volume of the nerve. In Plate 4 a nerve fiber is seen extending between the infraorbital plexus and the area of the first primary molar. The possible significance of the observation as well as that of the observed pathways of the nerves will be considered in the discussion of the nerve-block technics.

Before drawing any conclusions from this dissected material, one should consider at least three modifying factors; 1) the maxilla has not expressed its ultimate height, width or depth, 2) the maxillary sinus is very small, and 3) the teeth have
not as yet erupted, indeed their roots have yet to form. That all of these events, which will occur with time, will influence the final location of the nerves to the teeth may be inferred. For example, Cordier, et al., reported that the developing maxillary sinus had an influence in separating the original trunk into its dental nerves. Since the sinus starts as an outpouching of the nasal wall at three months of fetal life (Frazer) and the nerve trunks to this area are well defined at three months (Streeter), the full implication of Cordier's statement is not clear. The report does illustrate the general principle that nerves are influenced by surrounding structures.

Several reasons prompted the inclusion of the results of the nerve block technic as a part of this investigation. The literature is scanty concerning the time of innervation of the teeth, especially in man. Studies of the maxillary innervation by means of serial stained sections were even more scarce, probably because of the great amount of time required to determine the complex pathways of the nerves. Secondly, there is a paucity of reports concerning the innervation of the teeth of embryonic, fetal newborn, infant or child specimens. In summary, a review of the literature revealed that studies of the nerves to the teeth have fallen into four general classifications: 1) dried bones, 2) gross and microscopic dissection of fetal and adult specimens,
62, 86, 78, 116 3) histologic sections and serial sections with or without accompanying reconstructions, 28, 33, 43, 60, 110 and 4) observations made from the anesthetization of certain regions. 6, 21, 91, 97 Many of the reports were parenthetical in nature, and more specific investigations usually did not state two criteria which may be of importance: 1) the age of the specimen, and 2) the condition of the dentition. Finally, the nerve block technics proved to be a method of obtaining a larger amount of pertinent information in a much shorter period of time than is possible by means of dissection or reconstruction. Ultimately the nerve block technics were to be the sine qua non of the applicability of the anatomical information furnished.

Examination of Plates 1-5, and the written description contained in the chapter titled Results, made it possible to state two general observations. First, there were several patterns of innervation of the maxillary teeth. Secondly, even in the same individual, the innervation in the right maxilla may differ from that in the left. For example, in Plates 1 and 5 the first permanent molar is innervated by the posterior superior alveolar nerve, the primary molars by the middle, and the canine and incisors by the anterior superior alveolar nerves. In Plates 2 and 3 both the permanent first molar and second primary molars were innervated by the posterior superior
alveolar nerve, and the first primary molar was presumably supplied by the middle superior alveolar nerve. An examination of fetus "C" revealed a posterior, middle and anterior superior alveolar nerve on the right side, while on the left side there was no middle superior alveolar nerve. The posterior superior alveolar nerve supplied the permanent molar and primary molars. Specimens "A" and "B" were bilaterally similar in innervation and presented posterior, middle and anterior superior alveolar nerves. The posterior and middle superior alveolar nerves may leave the parent trunk at almost the same location. Indeed, the anterior superior alveolar nerve may branch from the posterior extremity of the infraorbital nerve, and it usually leaves the trunk posterior to the midpoint. In this the present investigation agreed with the findings of Jones who also stated that the anterior superior alveolar nerve was apparently constant in its distribution. There have been several reports of the absence of the middle superior alveolar nerves, the function of these nerves being served by the posterior or anterior superior alveolar nerves.  

There has been general acceptance of the premise that the tuberosity injection will anesthetize all the molar teeth, except for the mesial buccal root of the first permanent molar, which is innervated by the middle superior alveolar nerve.  for example, stated (without presenting
statistical substantiation) that the entire first permanent molar would be anesthetized in only five per cent of the cases, because in these few teeth the sole innervation is the posterior superior alveolar nerve. A consideration of the inconstancy of this middle nerve supply, as described in the preceding paragraph, is a cause to question the classic description of nerve supply.

Since clinical experience with nerve block technics had indicated that not only the entire first permanent molars, but also the primary molars might often be anesthetized by the tuberosity injection, a series of injections was made, as outlined in Methods. To check the extent of the anesthesia, some measurable stimulus was necessary. Hardy, Wolff and Goodell in their book, "Pain Sensations and Reactions," 1952 (p. 54) list the criteria for a stimulus. The chosen stimulus was the mechanical one of a dental bur cutting tooth structure prior to anesthetizing the area. If there was evidence of pain a tuberosity injection was given, and the bur reapplied. Anesthesia was determined by the response of the patient. The results were tabulated and subjected to a Chi Square test. The test did not reveal a biologically significant result. However, under the condition of the present study, the possibility of anesthetizing the molar teeth was greater than is generally accepted by authorities who stated their results after observing the deposition of anesthetic solutions on the maxillary
tuberosity. This becomes of importance in clinical practice because it is often impossible to anesthetize the first permanent molar by infiltration anesthesia. An examination of figure 8 will show that the first permanent molar lies directly under the buttress of the zygomatic process of the maxilla, often called the key ridge. The thickness of bone in this area precludes successful infiltration anesthesia. In later life, the molar may be anterior to this ridge (marked with the black pointing to the molars). Indeed, examination of the maxillae of children and adults will reveal that the former may have a much thicker external plate of cortical bone. In children this thickness of bone may almost obscure the outlines of the roots of the teeth, whereas it is not uncommon to see the roots well outlined in the adult, and often the apices are revealed through perforations in the bone.

The reasons that most operators failed in obtaining successful anesthesia of the first permanent molar by means of the tuberosity injection may be two. First, they did not measure the maxillary height to obtain the proper depth of insertion of the needle. Secondly, as pointed out by Smith, they did not employ a needle in a curved hub. Without such an adaptation it was difficult to pass the needle to the foramina on the curved tuberosity. If the needle was not precisely placed, a soft tissue infiltration anesthetic was the probable result.
As McDaniel and others have pointed out, the nerve supply to the first premolar may be from the anterior superior nerve, while that to the first permanent and second premolar may be from the posterior superior alveolar nerve. The present investigation supports such a contention. An examination of the data presented in the tabulation (p. 79) indicates that the number of anesthetized first primary molars is considerably less than for the 2nd primary and first permanent molars.

Plate 4 shows a connection between the dental and cutaneous components of the infraorbital nerve. This may well represent dental nerve fibers which have travelled thru the infraorbital foramen before joining the remainder of the anterior superior alveolar nerve fibers. Obviously, this provided sensory branches to the first primary molars in addition to the middle superior alveolar supply.

In summary, the results of the information gained from graphic reconstructions, dissections, and nerve blocks is in agreement. The nerve supply to the teeth may be similar, or vary in 1) different individuals and 2) in the right and left maxillae of the same subject.
SUMMARY

Three heads of 4, 6, and 7 months were appropriately fixed, decalcified, embedded in celloidin and serial sectioned in the frontal plane at 30, 60, and 120 μ, respectively. Staining was with Hematoxylin and Triosin, Krichesky, periodic acid Schiff and Pearson's silver gelatin. The frontal sections were projected on to poster board at a 25X magnification and the positions of the infraorbital and superior alveolar nerves plotted. In the resulting sagittal graphic reconstructions the nerve fibers are seen to course to the dental sac of the first permanent and two primary molars. The anterior distribution was poorly defined. Two heads of 4 and 7 fetal months were sagittally sectioned and stained as controls. Nerve fibers could not be as accurately traced, but the morphologic pattern of the control and the graphic reproduction were in harmony. Three specimens at term dissected under a microscope displayed superior alveolar nerves extending to all primary teeth and first permanent molars. More than one pattern of innervation of these teeth was observed. The earliest time of innervation has not been established.

To complement the results of the reconstructions and dissections, the nerve supply to the teeth of living children was investigated by means of nerve block technics. The maxillary first permanent and primary molars were opened with a
dental bur under controlled conditions. If the patient expressed pain, the injection was given by means of a precise reproducible technic of depositing anesthetic solution on the maxillary tuberosity. Sixty such injections were made and the number of teeth anesthetized was recorded, and evaluated by the Chi square test. No injections were repeated. Some subjects received bilateral tuberosity injections, and it was confirmed that the innervation of the teeth in the two maxillae might be similar, or dissimilar.

CONCLUSIONS

1. The maxillary first permanent and second primary molar may be innervated by the posterior superior alveolar nerve, while the first primary molar is supplied by the middle superior alveolar nerve. This apparent pattern predominated in the clinical trials with local anesthetics. (Plates 2 and 3)

2. The maxillary first permanent molar may be innervated by the posterior superior alveolar and middle superior alveolar nerve, which latter nerve also serves the primary molars. (Plate 1)
3. The maxillary first permanent molar may be innervated by the posterior superior alveolar nerve, and the primary molars by the middle superior alveolar nerves. (Plate 5)

4. The middle superior alveolar nerves may be absent.

5. The anterior superior alveolar nerves supply the canine and incisors (Plates 1-3, 5). They may also supply fibers to the first primary molar (Plate 4), (Results, p. 79).

6. The anatomic observations were confirmed by deposition of anesthetic solution on the maxillary tuberosity of children. (p. 79)

7. Nerve fibers were seen to be in their relation to the tooth buds, either: a) in the dental sac, or b) contiguous to the dental pulp. Nerve fibers could not be traced into the pulp. (Plates 1-3)
Plate 1. Graphic Reconstruction of the Innervation of the Maxillary Teeth in a 4 Month Human Fetus (approx. 8X)
Plate 2. Graphic Reconstruction of the Innervation of the Maxillary Teeth in a 6 Month Human Fetus (approx. 8X)
Plate 3. Graphic Reconstruction of the Innervation of the Maxillary Teeth in a 7 Month Human Fetus (approx. 8X)
Plate 4. Dissection Showing a Communication Between the Anterior Superior Alveolar Nerve and the Infraorbital Plexus in a Full Term Fetus
Plate 5. Dissection Showing the Innervation of the Maxillary Teeth in an 8 Month Human Fetus


35. _______. Description of a reconstruction of the head of a thirty-millimeter embryo. J. Anat. & Physiol. 44:303-11, July, 1910.


APPENDIX

LOMA LINDA UNIVERSITY

School of Graduate Studies

CONCERNING THE INNERVATION OF

THE UPPER DENTITION IN MAN

by

Jess Hayden, Jr.

An Abstract of a Dissertation

in Partial Fulfillment of the Requirements

for the Degree Doctor of Philosophy

in the Field of Anatomy

June, 1962
Dissertation

The primary objectives of this study were to determine:
1) the pathway of the superior alveolar nerves and their relation to the maxillary molar teeth in the fetal and neonatal specimens and in the child, and 2) whether nerve fibers entered any microscopically-observed tooth buds.

Materials and Methods. Three heads of 4, 6, and 7 months were appropriately fixed, decalcified, embedded in celloidin and serial sectioned in the frontal plane at 30, 60, and 120 μ, respectively. Staining was with Hematoxylin and Triosin, Krichesky, periodic acid Schiff and Pearson's silver gelatin. The frontal sections were projected on to poster board at a 25X magnification and the positions of the infraorbital and superior alveolar nerves plotted. In the resulting sagittal graphic reconstructions the nerve fibers are seen to course to the dental sac of the first permanent and two primary molars. The anterior distribution was poorly defined. Two heads of 4 and 7 fetal months were sagittally sectioned and stained as controls. Nerve fibers could not be as accurately traced, but the morphologic pattern of the control and the graphic reproduction were in harmony. Three specimens at term dissected under a microscope displayed superior alveolar nerves extending to all primary teeth and first permanent molars.
To complement the results of the reconstructions and dissections, the nerve supply to the teeth of living children was investigated by means of nerve block technics. The maxillary first permanent and primary molars were opened with a dental bur under controlled conditions. If the patient expressed pain, the injection was given by means of a precise reproducible technic of depositing anesthetic solution on the maxillary tuberosity. Sixty such injections were made and the number of teeth anesthetized was recorded, and evaluated by the Chi square test. No injections were repeated. Some subjects received bilateral tuberosity injections.

Observations and discussion. The results of these injections substantiated the observations made on the small number of anatomical specimens, and those cited in the literature. More than one pattern of innervation of these teeth is to be observed, and the innervation in the maxillae of an individual may be dissimilar. Furthermore, under the conditions of this investigation, the tuberosity injection is valuable technic for anesthetizing the first permanent molar and the second primary molar. The first primary molar is less frequently anesthetized.

All of the teeth examined in this study had nerve fibers reaching to their dental sac.
Conclusions. 1) The maxillary first permanent and second primary molar may be innervated by the posterior superior alveolar nerve, while the first primary molar is supplied by the middle superior alveolar nerve. This apparent pattern predominated in the clinical trials with local anesthetics. 2) The maxillary first permanent molar may be innervated by the posterior superior alveolar and middle superior alveolar nerve, which latter nerve also serves the primary molars. 3) The maxillary first permanent molar may be innervated by the posterior superior alveolar nerve, and the primary molars by the middle superior alveolar nerves. 4) The middle superior alveolar nerves may be absent. 5) The anterior superior alveolar nerves supply the canine and incisors and may also supply fibers to the first primary molar. 6) The anatomic observations were confirmed by deposition of anesthetic solution on the maxillary tuberosity of children. 7) Nerve fibers were seen to be in their relation to the tooth buds, either: a) in the dental sac, or b) contiguous to the dental pulp. Nerve fibers could not be traced into the pulp.