AN OSTEO-RADIOGRAPHIC STUDY OF THE MANDIBULAR CANAL

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Dedicated to
the Grand Geometrician of the Universe

and

my wife
Tobienne Osna
and my three sons
Reeve, Ilan and Hirsch

for permitting me the time and opportunity
to do this Thesis

Thou knowest the secrets of eternity
And the most hidden mysteries of all living,

Thou searchest the innermost recesses
And triest the reins and the heart,

Nought is concealed from thee
Or hidden from thine eyes.

O favour us with knowledge, understanding
And discernment from thee.

(Liturgical poem
of
unknown origin)

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CONTENTS

LIST OF TABLES

SUMMARY

Even though the mandibular nerve is of great importance to the dentist, very little research on the course of the nerve and the relationship of the mandibular canal to the adjacent anatomical structures has been carried out.

From the literature, it appears that the lateral ramus prominence (L.R.P.), or antilingula, is found to be present in from 50% to 100% of cases and is situated anterior and superior to the mandibular foramen. Most authors are in agreement on the situation of the mandibular foramen. Only one mandibular foramen is described in each ramus. The mandibular canal is described as lying inferior to the teeth. There is no agreement on the possibility of the existence of a second mandibular canal per hemimandible. Concerning the mental foramen, it is accepted that one is found on each side, but a second foramen, as well as accessory foramina, namely, the major and the minor variety, are described. In the horizontal plane, the mental foramen is found at the apex of the second premolar tooth or between the premolar teeth. In the vertical plane, the mental foramen is situated from inferior to the apex of the premolar teeth to half way between the apex and the crown of the premolar teeth. The mylohyoid groove is converted into a canal in 16% of cases but never commences from within the mandibular canal, according to available literature.

The aim of this study was to:

1) determine whether the lateral ramus prominence could be used as a set reference point on the buccal side to determine the situation of the mandibular foramen on the lingual side of the mandible;

2) determine the relationship of the mandibular canal to the teeth in the vertical and horizontal planes; and

3) determine whether the mental foramen could be used as a set reference point in the antero-posterior plane.

Four hundred mandibles were studied with regard to the mandibular and mental foramina but only 79 with regard to the other findings.

Results

This study showed that the lateral ramus prominence is found in 50% of cases and bilaterally in 38% of cases. The situation of the L.R.P. is superior and postero-superior to the mandibular foramen. It is found opposite the mandibular foramen in only 10% of cases and for this reason the word antilingula is not an appropriate descriptive term. For the above reasons, the L.R.P. can not be used as a set reference to indicate the position of the mandibular foramen.

In the horizontal plane, the mandibular foramen is situated posterior to the middle of the ramus on the medial side. Every mandible possesses at least one mandibular foramen on each side, but furthermore, this study showed that a second mandibular foramen was found in 11 cases unilaterally. The mandibular foramen is situated more anteriorly than it appears on the panoramic radiograph, due to the shadow of the mandibular fossa. In the region of the mandibular foramen, many accessory nutrient canals were observed, the most common situation being distal to the inferior cortical margin of the mandibular canal close to the mandibular foramen in 35% of mandibles.

Every mandible studied had at least one mandibular canal on each side, and, in those cases where a second mandibular foramen was observed, a second mandibular canal was seen. However, these canals must not be confused radiographically with accessory canals, mylohyoid grooves or canals commencing from the roof of the mandibular canal.

It is generally accepted that the mandibular canal runs a course inferior to the posterior teeth. In this study it was shown radiographically that, in about 50% of cases, the mandibular canal lies more buccally, than is generally accepted, in the region of the third molar tooth and to a lesser extent in the second molar tooth region; an observation that can be confirmed on a dry mandible by looking down the mandibular canal from the distal aspect. The mandibular canal runs in the form of an "S" from the mandibular foramen to the mental foramen.

The position of the mental foramen, in the horizontal plane, is at the apex of the second premolar tooth in over 60% of cases, and between the premolar teeth in approximately 20% of cases. In the vertical plane, this study did not find the mental foramen to be superior to the apex of the teeth. The pantomogram, as well as the bissecting-the-angle technique, causes the image of the mental foramen to be projected higher than it is in actual fact situated. The oval type of mental foramen possesses no mental canal and presents in a buccal direction only. It is generally accepted that there is only one mental foramen, but, in this study, a double type of mental foramen was found in 19 mandibles.

Besides the above type of double mental foramen, a further type of double mental foramen was found that has not been previously described in the literature. This type often consists of a more posteriorly-situated, anteriorly-directed mental foramen and a smaller anteriorly-situated incisive foramen, pointing in a posterior direction. A groove is seen between these foramina where the incisive nerve, or part of it, has an extra-osseous course. From this study, it was found that, although there is a statistical correlation between the premental and postmental segments of the mandible, the mental foramen cannot be used as a set reference point in the antero-posterior direction.

In the retromolar area, 27 foramina were found with canals coursing in the direction of the apices of the last two molar teeth. This nerve could contain a branch of the mandibular nerve and the possibility exists that the nerve again joins that nerve in the mandibular canal after giving off a small branch to the molar tooth or teeth.

The mylohyoid groove often appears radiologically as a second mandibular canal. It sometimes appears to be coming from a single (mandibular) foramen and, in other cases, from a separate foramen, thus causing the confusion. This study agrees with those authors who find that the mylohyoid groove can be converted into a canal but disagrees with them in their finding that the mylohyoid canal never commences from within the mandibular canal, as 15 of the 21 mylohyoid canals found, commenced from within the mandibular canal.

OPSOMMING

Ondanks die belangrikheid wat die mandibulêre kanaal vir die tandarts inhou, is baie min navorsing op die verloop, en verhouding, van die kanaal tot aangrensende anatomiese strukture gedoen.

Uit die literatuur, blyk dit dat die laterale ramus prominensie (L.R.P.), of antilingula, in 50 - 100% van gevalle aanwesig kan wees en anterior en superior tot die mandibulêre foramen geleë is. Verder stem die meeste outeurs nie ooreen aangaande die anatomiese ligging van die mandibulêre foramen nie, maar is dit eens dat dit in die middel, en op die mediale aspek van die ramus, geleë is. Slegs een foramen word vir elke ramus beskryf. Dit word beweer dat die mandibulêre kanaal inferior tot die tande geleë is, en daar bestaan ook nog 'n groot mate van onsekerheid of daar meer as een mandibulêre kanaal per hemimandibula kan voorkom. Wat die mentale foramen betref, word aanvaar dat een mentale foramen op elke kant waarneembaar is, maar 'n tweede foramen, asook addisionele foramina, naamlik 'n eksterne (major) en 'n interne (minor) tipe, kan voorkom. Die posisie van die mentale foramen word horisontaal waargeneem by die apeks van die tweede premolaartand, of tussen die premolaartande. Wat die vertikale vlak betref, kan die foramen inferior tot die apeks van die premolaartande geleë wees, of superiorwaarts tot ongeveer halfpad tussen die apeks en die kroon van die tand. Die milohioïedgroef kan in ongeveer 16% van gevalle in 'n kanaal omskep word, maar ontstaan nooit vanaf die mandibulêre kanaal nie.

<u>Die doel van hierdie studie was:</u>

1. Om vas te stel of die laterale ramus prominensie (L.R.P.) as 'n verwysingspunt gebruik kan word om sodoende die posisie van die mandibulêre foramen aan te dui;
2. die verwantskap van die mandibulêre kanaal in 'n vertikale en horisontale vlak ten opsigte van die wortels van die posterior tande te bepaal; en

3. of die mentale foramen as 'n verwysingspunt gebruik kan word in 'n antero-posterior vlak.

400 mandibulas is met betrekking tot die mandibulêre en mentale foraminas ondersoek, maar slegs 79 ten opsigte van ander gegewens.

Resultate

Hierdie studie het getoon dat die laterale ramus prominensie in 50% van gevalle waargeneem is en in 38% gevalle bilateraal voorkom. Die posisie van die L.R.P. is superior en postero-superior tot die mandibulêre foramen geleë terwyl 10% die mandibulêre foramen oorvleuel. Dit is waarom die laterale ramus prominensie nie as verwysingspunt gebruik kan word om die posisie van die mandibulêre foramen aan te dui nie.

Die mandibulêre foramen is in die horisontale vlak posterior tot die middelpunt van die ramus aan die mediale kant geleë. Elke mandibula besit minstens een foramen in die linker en een in die regter ramus, maar hierdie studie het getoon dat 'n tweede foramen in 11 van die mandibulas, wat bestudeer is, waargeneem is. In die gebied van die mandibulêre foramen, is 'n hele aantal addisionele foramina geïdentifiseer wat in die meerderheid van gevalle distaal tot die inferior kortikale rand van die mandibulêre kanaal, by die mandibulêre foramen, geleë is. Die foramen is ook verder meer anteriorwaarts geleë as wat op die röntgenfoto die geval is weens die radiodeurskynende voorkoms van die mandibulêre fossa.

Elke mandibula wat bestudeer is het minstens een mandibulêre kanaal aan elke kant gehad, maar, in gevalle waar daar 'n tweede mandibulêre foramen aanwesig is, is 'n tweede mandibulêre kanaal waargeneem wat in sommige gevalle 'n baie kort verloop het. Addisionele kanale, milohioïedgroewe, asook kanale wat vanaf die dak van die mandibulêre kanaal ontstaan, kan op 'n röntgenfoto as 'n addisionele mandibulêre kanaal presenteer. Meer as een mandibulêre kanaal kan dus voorkom.

Dit word algemeen aanvaar dat die mandibulêre kanaal inferior tot die posterior tande verloop. In hierdie studie is met behulp van X-straalopnames gevind dat, veral in die gebied van die derde en tweede molaartande, die kanaal meer bukkaalwaarts geleë is as wat algemeen aanvaar word, 'n waarneming wat op droë mandibulas bevestig kon word. Die waarnemings is gedoen deur die verloop van die mandibulêre kanaal, vanuit 'n distale aspek, te bestudeer. Die mandibulêre kanaal verloop in die vorm van 'n „S" vanaf die mandibulêre foramen tot by die mentale foramen.

Die posisie van die mentale foramen in die horisontale vlak is by die apeks van die tweede premolaartand, of tussen die premolaartande, geleë. Wat die vertikale vlak betref, het hierdie studie getoon dat die mentale foramen nie superior tot die apeks van die tand aanwesig is nie. Die pantomogram, en die hoek-halverings-tegniek, veroorsaak dat die foramen op 'n hoër vlak geprojekteer word as wat die werklike posisie is. Die mentale foramen verloop veral in 'n postero-superior rigting. Die ovaalvormige tipe foramen het geen mentale kanaal nie en presenteer bukkaalwaarts. Dit word algemeen aanvaar dat slegs een mentale foramen aanwesig is, maar, in hierdie studie is 'n dubbele tipe mentale foramen waargeneem in 19 van die mandibulas wat ondersoek is. Bo en behalwe bogenoemde dubbel mentale foramina, is 'n tipe dubbel mentale foramen gevind wat nie in die literatuur beskryf is nie. Hierdie foramina is in werklikheid 'n mentale en 'n insissiewe foramen. In hierdie gevalle, presenteer die groter posterior geleë mentale foramen in 'n anterior rigting en die kleiner anterior geleë insissiewe foramen in 'n posterior rigting. Daar bestaan ook 'n groef tussen die foramina waar die insissiewe senuwee 'n buite-benige verloop het. Uit hierdie studie, is dit duidelik dat die mentale foramen nie as 'n verwysingspunt in 'n antero-posterior vlak gebruik kan word nie.

Distaal tot die derde molaartand, is 27 foramina gevind waarvan die kanale by die apekse van die laaste, en tweede laaste, molaartand eindig. Die moontlikheid bestaan dat die senuwee 'n verbinding het met die inferior alveolêre senuwee.

Ten slotte, word die milohioïedgroef dikwels op 'n röntgenfoto as 'n tweede mandibulêre kanaal beskryf. Soms lyk dit asof die kanaal vanaf een foramen, en, in ander gevalle weer vanaf twee foramina oorsprong neem. Op pasiënte, kan die milohioïedgroef dus baie maklik met 'n tweede mandibulêre kanaal verwar word. Volgens sommige outeurs, kan die milohioïedgroef in 'n kanaal omskep word maar hierdie kanaal ontstaan nie vanaf die mandibulêre kanaal nie. In dié studie het 15 van die 21 milohioïedkanale vanaf die mandibulêre kanaal ontstaan.

2. AIMS AND OBJECTS

The purpose of this investigation was to do a radiographic study of the mandibular canal in dry mandibles.

Relative to its importance in dentistry, very little research has been done on this canal and its related structures.

This study was undertaken to:

1. review the related literature;

2. investigate the relationship of the mandibular canal to the teeth in the body of the human mandible in both the horizontal and vertical planes;

3. determine whether the lateral ramus prominence (antilingula) can be used as a reference point by the surgeon to indicate the position of the mandibular foramen;

4. investigate whether the mental foramen can be used as a reference point in an antero-posterior direction.

1. INTRODUCTION AND REVIEW OF THE LITERATURE

Embryological development of the mandible

Embryologically, the mandible is formed in the lower, or deeper, part of the first mandibular arch. It is preceded by Meckel's cartilage, which, at six weeks intra-uterine development, has a close relationship to the mandibular nerve, the nerve of the first pharyngeal arch, and its branches, acting as their skeletal support. The lingual branch of the mandibular nerve courses forward on the medial side of the cartilage, whereas the inferior alveolar (dental) branch lies lateral to its upper margin, and runs forward parallel to it to terminate by dividing into the mental and incisive branches. The incisive branch continues its course parallel to the cartilage.

Ossification first occurs in the band of dense fibrocellular tissue in the angle formed by the incisive and mental nerves during the seventh week in the embryo, that is, in the region of the future mental foramen, and, from this centre, the formation of bone spreads rapidly backward below the mental nerve, which then lies in a notch in the bone. The bone in front of this notch grows medially below the incisive nerve and, soon afterwards, spreads upward between the nerve and Meckel's cartilage; in this way the incisive nerve is contained in a trough of bone formed by lateral and medial plates which are united beneath the nerve. At the same time, the notch containing the mental nerve is converted into the mental foramen by extension of bone over the nerve from the anterior to the posterior edge of the notch. The bone grows rapidly forward towards the midline where it comes into close relationship with similar bone-formation of the opposite side but from which it is separated by connective tissue. Growth of bone over the incisive nerve from the lateral and medial plates, converts the trough of bone into the canal(s) for the incisive nerve (Scott and Symons, 1977).

A similar spread of ossification backward produces, firstly a plate of bone in relation to the whole of the lateral aspect of the inferior alveolar nerve, then a bony trough in which the nerve lies and, very much later, a canal for it. By these processes of growth, the original primary centre of ossification produces the body of the mandible as far back as the mandibular foramen and as far forward as the symphysis, therefore that part of the mandible which surrounds the inferior alveolar and incisive nerves.

The lateral ramus prominence (L.R.P.) (antilingula)

A prominence, located on the lateral surface of the ramus of the mandible, may be used to determine the position of the mandibular foramen on the medial surface. Identification of this landmark is very important in mandibular ramus osteotomy procedures in which the medial surface of the ramus is not visible. This prominence has been given a number of names which are popular in various geographical areas of the United States of America, namely, Behrman's Bump, antilingula in the North-east, Jaffe's Bump in the Midwest, Bump's Bump, epilingula and ectacondylar ridge in the South and South-west. It should be noted, however, that the conclusions are pertinent only to the group of specimens studied (50 adult, dentulous dry mandible specimens of mixed groups from India).

According to Langston and Tebo (1977), who performed the above study, generalisation of the findings to other populations may be invalid, even though the Indian population encompasses several ethnic groups.

In the study of Yates, Olson and Guralnick (1976), the lateral ramus prominence (L.R.P.), as determined by inspection and palpation, was identified on both the right and the left rami in 50% of cases. The lateral ramus prominence varied from 4,7 mm anterior, to the same distance posterior to the foramen and from 0,7 mm to 16,2 mm superior to the foramen. It was located anterior to the foramen in 66% of specimens. Langston and Tebo (1977) suggest that the name, "lateral ramus prominence", be adopted in order to provide uniformity of nomenclature and clarity of descriptive expression.

The lateral ramus prominence is present in less than half of the mandibles examined (70 dried mandibles of 19th Century Islandic, New Mexican and unknown origin) according to Yates et al (1976). The definite presence or absence of this anatomical structure was recorded only when all three the investigators agreed. They found that the inferior dental foramen lies in a position which is predominantly posterior and inferior to the lateral ramus prominence. Their conclusion is that the lateral ramus prominence is a highly variable anatomical landmark and, in most instances, is situated considerably anterior and superior to the inferior dental foramen. A surgical cut made between 5 mm and 10 mm distal to the lateral ramus prominence is within a statistically safe area in over 72% of cases, bearing in mind the position of the mandibular foramen.

The mandibular foramen

Almost exactly in the centre of the medial surface of the mandibular ramus, the mandibular canal starts with a wide opening, the mandibular foramen (Sicher and DuBrul, 1975; Warwick and Williams, 1973; and Scott and Dixon, 1978). This opening leads into the mandibular canal which curves downward and forward into the body of the bone to open on the lateral surface at the mental foramen. The mandibular foramen is partly obscured in front and on the medial side by a thin triangular bony process termed the lingula. This tongue-like projection of bone gives attachment to the sphenomandibular ligament.

Hayward, Richardson and Malhotras (1977) disagree with Sicher and DuBrul (1975), Warwick and Williams (1973) and Scott and Dixon (1978), stating that if one divides the ramus of the mandible into four equal vertical sections, the mandibular foramen is generally located distal to the middle of the ramus in the third section.

Worth (1975) notes that the mandibular foramen varies greatly in its radiographic manifestations. Usually it appears as a funnel-shaped area of increased radiolucency with wide variations in width, length and depth of funnel. Often the margins are corticated anteriorly and posteriorly; in some cases there is no cortex, while in others only the anterior cortex is present. The darkness of the shadow varies according to the depth of the depression in the medial aspect of the bone and is greatest where the foramen is more deeply excavated. Some foramina present a striking picture, while others are barely visible in radiographs. The anatomical position of the mandibular foramen varies also. In rare cases, the foramen is situated a short distance above the midpoint of the ramus (Worth, 1975).

Hollinshead (1958) describes the mandibular foramen only in relationship to the height of the mandibular notch. No mention of antero-posterior position is made. He emphasises that the inferior alveolar nerve lies in contact with the mandible for 4,5 mm before it enters the mandibular foramen which lies approximately 1,5 cm to 2 cm below the mandibular notch. The distance from the bottom of the mandibular notch to the lingula varies from about 10,5 mm to 15 mm, according to Hensel (1937) who points out that, if the distance through which the nerve is in contact with the mandible above the lingula is subtracted from this, there is relatively little leeway in which a cut can be made across the ramus without involving either the mandibular notch or the inferior alveolar nerve.

In his study of the Neanderthals from Krapina in Yugoslavia, Smith (1978) states that the mandibular foramen was somewhat different from that as classically described by the anatomists. In these specimens, the medial border extends horizontally, uninterrupted across from the anterior to the posterior aspect of the foramen, creating the impression that the lingula is absent. A more accurate assessment of this situation is that the lingula is continuous with the elevated medial border of the foramen. Thus, in these cases, the lingula is not functionally absent but is indistinct as a separate structure from the elevated medial border of the mandibular foramen.

Neural branches springing from the attached muscles of mastication can penetrate into the mandible and join the branches or the main trunk of the inferior alveolar nerve. In a very few cases, neural branches springing from the outer part of the mandible, penetrate into the teeth roots, especially in the molar area. In the above cases, even after anaesthesia of the main trunk has been performed, the sensitivity still persists and a local supplementary anaesthetic is required in the area of the attachment of the muscle of mastication (Michalopulos, et al, 1974).

Accessory foramina

Barker and Locket (1972) report a case of five foramina of varying size on the medial surface of the right ramus and four on the left side in the mandible of an eight-year-old Caucasian child. On the medial surface of each ramus, approximately 17 mm above the main mandibular foramen and at the base of the coronoid process, a further canal was found. The ramus of this mandible had not reached adult dimensions and, with further growth and remodelling, the location of those more superior canals may not have remained at the base of the coronoid process. However, it is unlikely that these existing distances of 17 mm above the mandibular foramen would have been reduced. In the examination of a further 122 cadaver mandibles, accessory foramina were similarly located in approximately 40% of specimens. It is quite possible, according to these authors, that these foramina receive branches of the inferior alveolar nerve.

The effect of growth processes on the position of the mandibular foramen

Because the mandible grows in an antero-posterior direction by apposition on the posterior border and by remodelling on the anterior border, it would seem that the foramen would become relatively more anterior with age and eventually be lost past the anterior border of the ramus. In the same way, with the condylar growth the position of the mandibular foramen in the vertical plane should come to lie in a more inferior position. Because the height in a vertical position remains statistically constant with age, it holds that the same apposition and remodelling around the foramen in a horizontal and vertical component must take place (Benham, 1976).

In only 11 of the 47 cases (25%) of the children in the study of Benham (1976), was the mandibular foramen found below the occlusal plane. In general, he found that the position of the mandibular foramen becomes progressively higher with age, from near the occlusal plane in the primary dentition to an average of nearly 7 mm (and approximately 15 mm at the upper range) above the occlusal plane in adults.

The foramen and fossa in the young child are located more posteriorly and slightly lower on the medial border of the ramus (Olsen, 1956). As the general growth of the mandible is forward and downward, it appears that the foramen moves upward and forward as the child develops. The changing relationship of the foramen is due to growth at centres located at the posterior border, the angle of the ramus and the alveolar process (Shiere, 1950).

Moss (1960) discusses how the changing position of the mental foramen and canal comes about. With growth, the sliding periosteum causes displacement of the nutrient canal and consequent migration of the point of entry of the nutrient canal around the nerve. Although there is no muscle involvement producing additional pressure, there is every reason to believe that the same occurrence takes place around the mandibular foramen with growth of the ramus. No direct reference to this growth could be found in the literature, except indirectly by Benham (1976).

It does appear that differentiation between the mandibular foramen and the mandibular fossa is not made radiologically by investigators when discussing the position of the mandibular foramen.

The general consensus of opinion is that there is usually one mandibular foramen on each side. However, there is no agreement regarding its exact location on the medial aspect of the ramus of the mandible. The comparison of the position on the left and the right side is not undertaken in detail by any author. Very little discrimination is made between the mandibular foramen and the mandibular fossa radiologically. There is agreement that, with age, the position of the mandibular foramen does change in relationship to the occlusal plane due to growth of the mandible until adulthood.

The mandibular fossa, the depression wherein the inferior alveolar nerve enters the mandible through the mandibular foramen, is usually located about two thirds the distance from the anterior to the posterior border of the ramus on the lingual side. A line drawn perpendicular to the anterior border of the ramus of the mandible, from the deepest point in the coronoid notch, will generally pass through the mandibular sulcus above the lingula. In children, the width is much less than in adults. The younger the child, the narrower the ramus (Phillips, 1943).

The mandibular canal (inferior dental or alveolar canal)

At birth, according to Warwick and Williams (1973), the mandibular canal is of a large size and runs near the lower border of the bone. After the secondary dentition has erupted, the mandibular canal is situated above the level of the mylohyoid line. In this study, no mention is made as to whether the canal changes its relative or actual position in the body of the mandible. However, Shiere (1950) notes that it must be kept in mind that the mandibular foramen and fossa of the child are not in the same relationship as those of the adult mandible. The foramen and fossa in the young child are located more posteriorly and slightly lower on the medial surface of the ramus. As the general growth of the mandible is forward and downward, it appears that the foramen moves upward and forward as the child develops. The changing relationship of the foramen is due to growth at centres located at the posterior border, the angle of the ramus and the alveolar process.

The mandibular canal, which houses the inferior alveolar nerve and blood vessels, is usually single, bilaterally symmetrical, and its position varies with respect to the inferior border of the mandible and the apices of the teeth. The canal may run its course with a gentle curve or with a curve approaching 90^{0} in the region of the third molar tooth. In the region posterior to the mental foramen, the canal may portray a noticeable loop. Whilst the position of the mandibular canal varies with respect to the apices of the roots of the teeth and the lower border of the mandible, the majority can be classed as either of the high or low varieties and these occur in approximately equal proportions (Nortje, Farman and Grotepass, 1977b).

It is generally accepted that the mandibular canal commences at the mandibular foramen on the medial surface of the ramus, midway between its anterior and posterior borders and at the point of junction of the lower one-third with the upper two-thirds of a line drawn between the tip of the coronoid process and the angle of the mandible, and on a level with the upper surfaces of the molar teeth by a funnel shaped aperture. However, for some little distance behind the real commencement of the canal, a groove exists on the inner wall of the ramus which, caused by the inferior dental nerve and vessels, runs downward and forward into the canal (Fawcett, 1895). It runs a course inferior to the teeth which are innervated by the mandibular nerve. Radiologically, the mandibular canal ends at the mental foramen in the greater majority of cases. Anatomically, however, the mandibular nerve divides in the region of the mental canal into mental and incisive branches. The incisive branch continues anteriorly to the region of the mandibular symphysis.

The first person to write a detailed account of the course and position of the mandibular canal was Fawcett in 1895. He took a mandible and made cross-sections through it at 4 mm to 6 mm intervals along the entire length of the mandible, starting posterior to the mandibular foramen and ending almost at the symphysis. Although he only examined one mandible in this manner, it still appears to be the most detailed examination of the mandible to date.

The inferior alveolar branch of the trigeminal nerve (cranial nerve V) and the associated blood vessels enter the mandibular canal through the mandibular foramen. Branches of this nerve innervate all the mandibular teeth on that side of the mandible and, via the mental branch, sensation is supplied to the lower lip on that side of the face. The inferior dental nerve is usually described as entering the mandibular foramen in the form of a single trunk which lies anterior and superior to the inferior alveolar artery. It then gives off dental branches which may form a plexus from which the actual fibres to the teeth arise. The main trunk ends by dividing into the mental and incisive branches (Fawcett, 1895).

Nortje et al (1977b) classify the mandibular canal in the region of the first and second permanent molar teeth only, or their approximate position by extrapolation with existing apices where these teeth have been extracted. These authors classify a low single mandibular canal as one either touching or situated within 2 mm of the lower border of the mandible. Had the classification been along the further length of the mandibular canal, this would have presented many additional complications, as the relative position of the canal varies in the body of the mandible, depending on the straightness or the size of the loop of the canal. The single high mandibular canal was classified as either touching the apices, or within 2 mm of the apices of the third and second permanent molar teeth; 48,9% of subjects were found to have bilateral single low mandibular canals and 46,7% of subjects were found to have bilateral single high mandibular canals. Of all the subjects examined with bilaterally symmetrical single mandibular canals, only 3,3% could not be fitted into the high or low categories.

Of the 3612 subjects, 690 were males (48,9%) and 995 females

(45,7%). The difference in frequency between the male and the female was not statistically significant. (x^2 with Yates' modification = 1,701, dof = 1, $P > 0,2$). The age range of persons with this configuration was significantly different from that for subjects without this type of canal. Only 121 (3,3% of all subjects examined with bilaterally symmetrical single mandibular canals could not be fitted into the high or the low canal categories. Bilateral single low mandibular canal variety was found in 1767 (48,9%) cases including 668 males (46,5%) and 1099 females (50,5%). The higher frequency in the female than the male was statistically significant.

Fawcett (1895) showed that a vertical section made through the beginning of the canal shows it to be pyriform, with the large end downward and slightly outward, the small end upward and inward, and its long axis being about 7 mm, its width being 3 mm. Three millimetres in front of this point, the long axis has diminished to 3,5 mm, the traverse to 2,5 mm. The canal here is seen to be half embedded in the inner wall of the mandible, and more so at its upper end than its lower end, on account of the obliquity of its long axis. The outer wall of the canal consists of a thin shell of compact tissue connected by trabeculae with the outer wall of the mandible. The direction of the canal at this point is forward, downward and slightly outward. As the canal runs forward in the ramus of the mandible, the canal becomes more outward in position so that its outer wall blends with the outer wall of the mandible, and whilst its inner wall is blended with the inner wall of the mandible, the latter is not grooved by the canal as it was grooved a few millimetres posteriorly. The lumen becomes somewhat bluntly pyriform in shape with the small end directed upward and inward, and the general direction of the canal is downward, forward and outward. Further forward, the lumen of the canal becomes almost circular. Here its upper and lower walls are thick. At the level of the last molar tooth, the lumen of the canal is oval, with the long diameter now vertical and the canal, though lying nearer the outer wall of the mandible, no longer grooves it and is directed at its anterior end forward and a little downward with no inclination outward. The upper and lower walls are somewhat thinner than in the previous segment. Inferior to the second molar tooth the canal, still nearly circular in form, is seen against the inner wall of the mandible - the outer wall of the canal is now quite separate from the outer wall of the mandible. Its lower wall is now 6 mm from the lower border of the mandible. Inferior to the first molar tooth, the canal, vertically oval, grooves the inner wall; its very thin outer wall is 2 mm from the outer wall of the mandible, its direction is absolutely forward. The lower wall is 7 mm from the lower border of the mandible, inferior to the socket for the second premolar tooth (Fawcett, 1895).

Lockhart, Hamilton and Fyfe (1959) mention a fact which is presumably universally accepted but very rarely stated, namely that the mandibular canal lies obliquely to the bone in the horizontal plane. Worth (1975) is of the opinion that the inferior dental canal commences at the mandibular foramen in the ramus and passes downward, rather steeply at first with a slightly anterior concavity between the first molar region and the premolar. In some cases, the canal is, however, almost straight. There is a downward, as well as a forward, inclination in other cases. At the mental foramen, the shadow of the canal sometimes turns sharply upward, ending in this orifice. This rising portion of the canal, which exists between the horizontal portion of the canal and the foramen, is variable in length, the length depending on the distance of the canal from the alveolar border, as well as on the precise site of the foramen itself (Worth, 1975).

According to Carter and Keen (1971), the pattern of distribution of the inferior alveolar nerve is classified into three types. One must bear in mind that they base this classification on the dissection of only eight mandibles.

Type 1: In this arrangement, the inferior alveolar nerve is a single structure lying in a bony canal. In two of the mandibles, the tips of the molar roots projected, or appear to project, into the canal so that the branches of the nerve supplying these roots were very short and direct. A slightly different arrangement was found in a further two mandibles. The undivided nerve was situated a little more inferiorly and its branches to the teeth were arranged in a plexus between the nerve and the roots, instead of being direct offshoots to the roots. Six of the eight mandibles were classified in this section.

Type 2: Here the nerve was situated substantially lower down in the mandible, some distance from the roots of the molars. The dental branches were given off more posteriorly and were consequently longer and more oblique in position than in Type 1. One mandible was classified in this section.

Type 3: In this type, the inferior alveolar nerve gives off two large branches posteriorly which, together, could be regarded as equivalent to the alveolar branch, while the main continuation of the nerve occupied a more inferior position and continued, as in the other types, towards the mental foramen and the supply of the canine and incisor teeth. One mandible was classified in this section.

Starkie and Stewart (1930) in their study of the intramandibular course of the canal, reported that the distribution of the inferior alveolar nerve to the teeth is as follows: soon after it enters the foramen, the nerve gives off an alveolar branch which runs parallel to the main stem to supply the teeth posterior to the incisors - possibly Type 2 or Type 3 in Carter and Keen's (1971) classification. The main stem continues to the mental foramen.

Resorption of the alveolar bone in the edentulous mandible may progress to the elimination of part of the mandibular canal and of the mental foramen. Correlations of measurement indicate that the more upright the ramus of the mandible, the higher will be the mandibular foramen; the greater will be the distance of this foramen forward from the posterior border and the broader will be the ramus of the mandible. Gabriel (1958) presents two mandibles which show the disappearance of the mental foramen and part of the mandibular canal. The inferior alveolar nerve was covered by a thin lamina of bone but, more anteriorly, the mandibular canal was transformed into a groove. This groove became shallow and indistinct in the premolar region. Branches of the nerve passed into the bone, one large branch was seen entering the bone in the canine region but the main trunk of the nerve lay along the surface of the bone. The bone of these mandibles shows fairly uniform resorption throughout the body. In the adult dentulous mandible, the mandibular canal, as it passes forward in the body of the bone, lies several millimetres below the level of the mental foramen which it eventually reaches by bending acutely below it and then passing upward. Hence, a considerable amount of bone must be resorbed from the mandible below the level of the mental foramen before the main part of the mandibular canal is exposed (Gabriel, 1958).

A large number of anomalies of the mandibular canal can occur. Among the more interesting, seven were recorded in which the mandibular canal resembled a fistula and a divided mandibular canal ended in two separate foramina, one at the apex of each premolar tooth (Sweet, 1959).

Kiersch (1973) presents a case of a twenty-year-old Caucasian man with a unilateral double mandibular canal. Although he mentions the possibility of a mylohyoid groove being responsible for the appearance of a second canal, the accompanying pantomographic photograph produced as evidence does appear to support his claim.

In the dissections of Starkie and Stewart (1930), the inferior alveolar nerve, immediately after entering the mandibular canal, divides into several branches, one of which, the alveolar branch, is separate from the rest. This branch runs forward to the first premolar tooth in a plexiform manner (the "alveolar" plexus) from which are given off the filaments to the molar, premolar and,possibly,the canine teeth. At the level of the second premolar tooth,it divides into internal and external branches. The internal rejoins the main nerve trunk, whilst the external runs forward to supply fibres to the incisor plexus. The rest of the branches, three or four in number, run forward for a short distance and then re-unite. This process is repeated and results in an increase in the number of branches, so that by the time the mental foramen is reached,there are fifteen or more branches. These have a large amount of connective tissue between them.

At the level of the canine tooth the majority of the fibres, according to Starkie and Stewart (1930), become enclosed in a common sheath and emerge from the mental foramen as the mental nerve. In the posterior two-thirds of their intramandibular course,the inferior dental nerve and vessels are surrounded by a sheath of compact bone, and a tough, thick layer of connective tissue. The bony sheath disappears more anteriorly but the fibrous layer can still be traced along the larger branches of the nerve. No communicating branches between the right and left nerves were seen.

Von Reich (1980) dissected 24 mandible halves and noted that the mandibular canal runs in a double S-shaped curve from the mandibular foramen to the mental foramen. It lies on the lingual side of the mandible in the region of the mandibular foramen. The cortical substances, on the whole, are thicker on the buccal side than on the lingual side, the greatest thickness being measured on the sectioned plane between the first and second molar teeth.

Fawcett (1895) and Casey (1978) note that the large variations in position of the canal are striking. With the growth in width of the face, the mandible widens correspondingly. This overall growth of the mandible takes place by a process of moulding which results from the harmonious deposition of new bone and resorption of old bone where required. Should this be the case, then there should be a relative change in position of the mandibular foramen, particularly during the rapid growth phase of puberty. The mandibular canal in the mandible remains constant, or relatively constant, with regard to the antero-posterior position and, therefore, the same resorption and deposition process must be presumed to occur along the edges of the mandibular foramen (Last, 1963).

Stafne and Gibilisco (1969) observe that, because of its large size, the mandibular canal is seen radiologically in a high proportion of cases, particularly that portion of it which extends from the mandibular foramen to the mental foramen. It often loosely proximates and may come in contact with the roots of the third molar tooth and, sometimes, it follows a course that is also in proximity to the roots of the premolar teeth and the first and second molar teeth. Grant (1965) relates the position of the mandibular foramen to the teeth and finds that the entrance of the foramen is at a height above the level of the crowns of the molar teeth.

Carter and Keen (1971) quote Olivier (1927), who gave a much fuller account and described two types in the arrangement of the main trunk of the inferior dental nerve. In Type I, seen in 66% of his dissections, the nerve forms a single bundle until it divides into its terminal branches at the mental foramen. The filaments to the teeth come off from the undivided trunk, a little posteriorly to the roots that they supply. In Type II, seen in 34% of his dissections, the nerve divides into a larger mental branch which passes out at the mental foramen, and a smaller dental branch which forms a plexus and supplies the teeth. The incisive nerve does not form a separate branch but is an extension of the dental plexus. The incisive nerve lies free in the spongy bone and has neither a fibrous nor a bony sheath. This nerve takes one of three directions:

(a) it passes forward and upward, by a direct route, to the alveoli of the central incisors; or

(b) it first runs horizontally, then turn sharply upward into the alveoli of the central incisors; or

(c) it passes forward and downward towards the lower border of the mandible, where a branch is sometimes given off to the bone, and then turn upward towards the central incisors.

Within the substance of the ramus, the mandibular canal runs obliquely downward and forward, and then horizontally forward in the body, where it is placed under the alveoli and communicates with them by small openings. In the posterior two thirds of the mandible, the canal is situated nearer the internal surface of the mandible, and in the anterior one third, nearer the external surface. At the premolar teeth, it has an opening to the exterior, the mental foramen, but continues towards the symphysis, giving off two small branches to the incisor teeth. Thus the mandibular canal must be considered as commencing at the mandibular foramen and ending close to the symphysis (Warwick and Williams, 1973).

On the other hand, Wedgewood (1966) is of the opinion that the remaining fibres of the inferior dental nerve, anterior to the mental canal, form a bundle of incisive nerves within the bone. This incisive plexus supplies a separate incisive nerve to the canine and incisor teeth and their related structures on that side. Nerve fibres reach almost as far as the ossifying suture, but never enter it. Only in a small mucocutaneous area, overlying the roots of the central incisors, does innervation across the midline occur. No fibres of the inferior dental nerve were found supplying teeth on the opposite side of the mandible.

Carter and Keen (1971) took radiographs of 80 dried mandibles to demonstrate the bony structure between the mandibular foramen and molar teeth. In 49 of the 80 radiographs, a single bony canal, either near the molar roots, or so close that the root tips appeared to penetrate the canal, was seen. Fawcett (1895) agrees with this finding in his dissection. However, in all of these, the margin of the bony canal was complete and unbroken. It appears that these mandibles represent Type I in the classification of Carter and Keen (1971). In 11 of the 80 radiographs, a bony canal was seen fairly close to the molar roots, but with a broken upper border. It is difficult to decide whether this arrangement should be regarded as representing Type I or Type 2. The remaining 20 radiographs showed bony patterns lacking definite mandibular canals and must be considered as representing Type 2 or Type 3. Thus Carter and Keen (1971) claim that the radiographic survey broadly confirms the proportions of the findings in their eight dissections of the mandible. However, it does not appear that these authors examined the dried mandibles radiographically in the vertical plane to determine the relationship of the mandibular nerve to the teeth in this plane.

Anatomically, the inferior dental canal divides in the region of the premolar teeth. One portion passes upward along the mental canal to end in the mental foramen. The other portion of the canal proceeds forward, deep to the premolar teeth and incisors, to terminate almost imperceptibly near the midline of the mandible.

The general consensus of opinion is that the mandibular canal lies inferior to the teeth. Worth (1975) however, feels that the canal also lies slightly buccally. The canals are usually, but not invariably, single and bilaterally symmetrical. The position of the canal varies between infancy and adulthood, with age, with loss of teeth and due to pathology. The different positions of the mandibular canal in different races is not discussed.

It is of interest and importance that the course anterior to the mental foramen of the mandibular canal is very rarely demonstrated in radiographs. When the anterior portion of the canal is visible, it proceeds forward with a gentle downward inclination and with a slight upward concavity. Rarely is it seen beneath the lateral incisors and, even more rarely, is it seen deep to the central incisors. Unlike the posterior portion of the canal, the anterior portion tends to narrow sharply as it passes forward. A rare variation of the anterior portion of the canal is the division into many branches, which spread out in a most disorganised fashion. This appearance has been mistaken for a stellate fracture of the mandible but it should be noted that the canal reveals a thin white cortical margin, while a fracture does not. Another variation is for the anterior portion of the canal to take origin from the main trunk a few millimetres above an upward curve in the trunk, so that it appears to be an indentation in the inferior aspect of the canal (Worth, 1975).

Wedgewood (1966) disagrees with the other authors, as he is of the opinion that the incisive nerve does cross the mid-line to supply a small mucocutaneous area overlying the roots of the teeth but agrees with the general consensus of opinion that the inferior alveolar nerves do not supply teeth on the opposite side of the mandible.

Durst and Snow (1980) reviewed 1024 panoramic radiographs and found 85 (8,3%) patients exhibiting multiple mandibular canals, whereas Nortje et al (1977b) in their review of 3612 panoramic radiographs found only 33 (0,9%) multiple mandibular canals. Durst and Snow (1980) do not mention the mylohyoid groove and it is thus reasonable to agree with Arensburg and Nathan (1979), who query whether some of the "canals" of Nortje et al (1977b) and, later, of Durst and Snow (1980), are not in fact deep mylohyoid grooves. There appear to be no reported cases of multiple mandibular canals, or multiple mandibular foramina, of the size seen on radiographs but described as seen in dried mandibles.

Nortje, Farman and Joubert (1977c) classify double mandibular canals as follows:

Type 1: two canals of equal length originating from one mandibular foramen; whilst in some cases the two canals were of a similar width, the lower canal generally is slightly narrower;

Type 2: two canals as in Type 1, but the shorter upper canal extends to the second and third molar teeth;

Type 3: this is the least common type; here there are two mandibular canals of equal dimensions apparently arising from separate foramina in the mandibular ramus and joining together to form one canal in the molar region of the body of the mandible.

Nortje et al (1977b) mention partial obliteration of the mandibular canal, thus excluding classification. During their investigation they found one case in which no definite canal could be seen at all. This conflicts with the much higher incidence of absence of a mandibular canal as found during dissection by Olivier (1927), quoted by Nortje et al (1977b), and during dissection by Carter and Keen (1971).

The mental canal

From Warwick's (1950) explanation of the growth and development of the mental canal, it does not appear to be present at birth, or if so, it is proportionally much shorter than in the adult. The human mandible grows in this area by deposition of bone on the buccal side around the issuing mental nerve. A bony canal is built up and, in its changing direction, it conforms to the habitual position of the mental nerve at successive ages. Thus Warwick (1950) does not mention the mental canal by name but only as a bony canal, and, from the above description, it appears that he feels that both the canal and the mental foramen actually change direction.

Last (1963) explains the manner of growth and development of the mental canal again, without referring to that structure by name. He states that, with growth in width of the face, the mandible, and consequently the canal, widens accordingly. This overall growth in width of the mandible takes place, as in all bones of the body, by a process of moulding, which results from the harmonious deposition of new bone and the resorption of old bone, where required.

In the adult, the mental canal runs forward, outward and upward in its first third; upward and outward, in its middle third; and backward, upward and outward, in its last third, ending in the mental foramen, vertically below the groove separating the second from the first premolar tooth (Fawcett, 1895) and midway between the alveolar and the lower borders of the mandible, this depending on the age and the presence of teeth. The whole canal is about 5 mm in length (Fawcett, 1895).

In general, very little appears to be written on the mental canal as such. The majority of authors mention the mental nerve and artery, explaining their origins and that they emerge from the mental foramen, without mentioning that they first pass through the mental canal.

A good example of this, is the article by Sweet (1943) in which he states that the chief nutrient supply of the mandible is made available through the inferior alveolar (mandibular) artery. It enters the mandibular foramen and passes forward in the mandibular canal through the body of the mandible. At the second premolar tooth, the artery divides into the mental branch, which emerges from the mandibular canal through the mental foramen. The same author in 1959, in his article about the various positions and radiographic appearances of the mental foramen, does not mention the mental canal by name but diagrammatically represents a long mental canal very distinctly.

The mental canal may be orientated in the following three axes (De Freitas et al, 1976).

1. postero-latero-superiorly (PO)
2. antero-latero-superiorly (AD)
3. both postero-latero-superiorly (PO) and antero-latero-superiorly (AD) simultaneously.

There is a predominance of the PO direction in both sexes and sides. A higher incidence of the AD direction was observed in females, in comparison with males, in a ratio 2:1. De Freitas et al (1976) agree with Warwick (1950 and Montague (1954) who claim that the forward direction of the mental canal is common in apes and newborn children. The canal gradually changes direction in children and, at the age of six years, it is directed upward.

Worth (1975), like Sweet (1959), discusses the mental canal, without referring to it by name. Worth (1975) states that at the mental foramen, the shadow on a radiograph of the canal sometimes turns sharply upward, ending in this orifice. This rising portion of the canal which exists between the horizontal portion of the canal and the foramen is variable in length, depending on the depth of the canal from the alveolar border, as well as on the precise site of the foramen itself. The canal, as it approaches the surface to end in the mental foramen, is directed upward, outward and often a little backward. Because of this inclination to the beam of rays during radiography, nowhere is any length of the canal in the axis of the beam. Consequently there is no projection of the canal margin sufficient to produce a cortical shadow in the radiographs (Worth, 1975).

Sicher and DuBrul (1975) feel that the relationship of the first premolar tooth to the mental canal and foramen deserves special attention. Ordinarily, the mental canal arises from the mandibular canal in the plane of the first premolar tooth, sometimes slightly distal to this plane. From its origin inside the mandible, the short mental canal runs outward, upward and backward to open in the mental foramen, situated between the two premolar teeth or, in the plane of the second premolar tooth. The oblique course of the mental canal makes it understandable that its outer end is at a higher and more posterior plane than its inner end. This explains the fact that in radiographs, the mental foramen often is projected upon the apex of the second and rarely upon the apex of the first premolar tooth. At this point, the mandibular canal is seldom in the immediate neighbourhood of the apices of these teeth and therefore the mental foramen appears to have no connection with the mandibular canal and often is diagnosed wrongly as a pathologic lesion of the bone at the apex of a tooth. However, the lamina dura and the periodontal ligament space around the apex of that tooth will not be affected in that instance.

The mental foramen

The mental foramen, through which the mental nerve and blood vessels emerge, is located inferior to and between the mandibular first and second premolar teeth, sometimes below the second premolar tooth but, in rare cases, below the first premolar tooth. In a vertical plane, the foramen is situated halfway between the lower border of the mandible and the alveolar crest. Frequently, especially in younger individuals, it is situated somewhat closer to the lower border of the mandible. The canal, which opens at the mental foramen, is directed outward, upward and backward and therefore opens at an angle to the outer surface of the mandible. Consequently, the rim of the foramen is sharp only at the antero-inferior circumference (Sicher and DuBrul, 1975). These authors do not quote figures to explain how often the mental foramen appears in the various positions.

Between the roots of the first and second premolar teeth, or below the root of the second premolar tooth, the mandibular canal divides into the mental and incisive canals. In man, the mental foramen is usually single but it may be multiple. With multiple foramina, the usual number is two. Accessory foramina may be of the major or the minor variety (De Villiers, 1968). The mental foramen is situated in the body of the mandible, about halfway between its lower border and the alveolar margin. Its relationship to the teeth varies from the level of the apex of the first premolar to that of the posterior root of the first molar. In about 50% of cases, it lies below the apex of the second premolar tooth (Scott and Dixon, 1978).

Hollinshead (1958), in attempting to anaesthetise the mental nerve of the more anterior lower teeth, finds that the foramen may usually be found on the vertical line drawn downward from the palpable supra-orbital notch. In about 50% of cases, it lies at the level of the apex of the mandibular second premolar tooth, between the apices of the two premolar teeth in about 20% to 25% of cases and posterior to the second premolar tooth in about 24% of cases. In 1% to 2% of cases, it lies at the apex of the mandibular first molar tooth.

The vertical position of the mental foramen varies in the young person (Hollinshead, 1958). As the primary teeth erupt, the secondary teeth are developing within the bone of the jaws and, for a time, both sets are represented in the dentition. As the primary teeth are shed, they are replaced by the secondary teeth. Up to this stage, the mental foramen lies near the lower border of the mandible on each side. The bone gradually lengthens, particularly behind the mental foramen, to provide space for the additional secondary teeth which develop in that area while there is also an increase in vertical height of the mandible to accommodate the secondary teeth and the lower part of the bone becomes thickened to provide additional support. In consequence, the mental foramen gradually moves upward and the process of remodelling continues throughout the period of growth and development. The mental foramen in the adult lies midway between the upper and lower borders of the mandible. With advancing age, the teeth are often lost and less bony support is needed. The alveolar process consequently resorbs and the mental foramen comes to lie nearer the upper border of the bone, a finding supported by Reed and Sheppard (1976).

The position of the mental foramen is variable, the commonest sites being at or below the apex of the second premolar tooth or a little medial to and below the apex of that tooth. The foramen is, however, radiographically observed in different positions, for example: medial to the root of the mandibular second premolar tooth, even as high as halfway up the root of that tooth; or well below the apex of the second premolar tooth or distal to it; or close to the first premolar tooth.

The shadow foramen may be well defined or may fade imperceptibly into the adjacent bone. It may be oval, round, oblong; of an irregular shape; or no shadow may be visible at all on the radiograph. It is rarely corticated, although some portion of the margin may be so, while the rest shows varying degrees of sharpness. Where visible radiographically, it appears as a radiolucent shadow of widely differing darkness (Worth, 1975).

The mental foramen is a particularly important landmark in radiographic interpretations. It appears as a radiolucent area similar in size and shape to a small apical granuloma at the roots of infected teeth. Differentiation may be accomplished by establishing the relation to the mandibular canal. In his study of 500 complete periapical examinations in the mandibular premolar tooth area, Sweet (1943) found that the mental foramen was observed in about 50% of cases.

In the greatest percentage of human mandibles, the mental foramen is seen radiographically between the mandibular premolar teeth. However its position may vary from a position anterior to the first mandibular premolar tooth to one that is posterior to the second premolar tooth (Kerr, Ash and Milard, 1978). Thus they do not mention any cases where the foramen is inferior to the medial root of the first mandibular molar tooth. They agree that multiple mental foramina do occur. The mandibular canal continues to the symphysis menti, but it communicates with the outer surface of the body at the mental foramen situated 1,25 inches (3,18 cm) from the symphysis, in line between the premolar teeth and midway between the upper and lower borders (Grant, 1965, and Wheeler, 1965). These authors do not relate the position of the foramen to the apices of the teeth but to the bone.

Sweet (1959) states, that according to his study of a number of dry mandibles, convincing proof is presented to show that, because of gross variations in size and shape, there was not a single point on the body of the mandible (including the lower border) that could be constantly used as a reliable point for measurements to show the exact location of the mental foramen.

Gabriel (1958) measured the level or height of the mental foramen relative to the lower border of the mandible in an attempt to discover whether the position of the mental foramen alters with age. He took measurements of the perpendicular distance from the mental foramen to the lower border of the mandible on 21 dentate, 21 partially edentulous and 21 edentulous mandibles. By the usual variance ratio tests, the difference between the means was not significant. (The variance ration being 1,80 for $n_1 = 2$ and $n_2 = 60$ in the usual notation). In other words, the presence or absence of teeth does not affect the position of the mental foramen with regard to the relationship to its inferior border of the mandible.

Moss (1960) notes the constancy of the relative position of the mental foramen in the body of the mandible. If the mandibular body is divided into premental and postmental foraminal segments and these segments are measured at all ages, it is found that the length of these segments remains relatively proportional throughout life. Therefore, increase in body length of the mandible cannot be due solely to condylar growth, since this would only serve to constantly increase the relative size of the postmental segment. While the position of the mental foramen remains relatively constant, the relationship of the mandibular dentition to it does not. This medial migration, which is quite apart from medial drift, is both a generalized primate pattern and a generalized mammalian pattern. Moss (1960) further explains the change in direction of the mental foramen and of the foramen of any long bone.

There is a slight variation according to tribal and racial groups with regard to the number of mental foramina as seen from Table I below (Riesenfeld, 1956).

Table I Multiple mental foramina

	Sides examined	Cases with multiple mental foramina	%	Average number of mental foramina	
				LEFT	RIGHT
Polynesians	40	5	12,50	1,02	1,05
Melanesians	484	47	9,71	1,09	1,11
Negroes	512	41	8,01	1,10	1,09
Bolivian Indians	92	7	7,61	1,04	1,05
Utah Indians	293	15	5,12	1,04	1,05
Egyptians	830	30	3,61	1,02	1,05
N.W. Coast Indians	607	20	3,29	1,03	1,03
Hungarians	989	29	2,93	1,02	1,04
Washington Indians	140	3	2,14	1,03	1,03

The sample of only 40 Polynesians (Table I) is probably not sufficient and is thus not very reliable. In all his cases, Riesenfeld found 16 cases with three foramina, ten of these being found in Negroes. He further points out that the racial distribution of the mental foramen differs greatly from that of the infraorbital and ethmoidal foramina. Thus, the African Negroids, who have the lowest frequency of multiple infraorbital and ethmoidal foramina, show a very high frequency of mental foramina, a characteristic parallelled by the Oceanic Negroids. Indians of the North-West Coast on the other hand, who figured so prominently in their high frequency of infraorbital and ethmoidal foramina, appear very low on the list of multiple mental foramina. There is a great deal of regional variability among the Mongoloids and Caucasoids listed without, however, indicating any particular trend that could be interpreted on environmental grounds. Riesenfeld (1956) agrees with previous studies that multiple mental foramina are slightly more frequent on the right than on the left side, with the exception of the Washington and North West samples, in which the values are identical on both sides, and the African Negroids in which the average number of mental foramina on the left side is higher than on the right side, a difference which is, however, statistically not significant. It must be noted that in Table I Riesenfeld (1956) classifies all Negroes together but discusses the difference between Oceanic and African Negroes.

Although not overtly stated, the direction of the mental foramen is usually described with the body of the mandible in the horizontal position. Warwick (1950) does not quite agree with the direction of the foramen as described by Gabriel (1958) and noted that in 20 mandibles from the newborn, the direction was always upward and backward. Further dissection of the mental nerve in ten foetuses shows that the direction corresponds with the direction of the foramen in the neonatal mandible. It was found that the majority of foramina after the age of five years generally points upward, and usually backward as well. Warwick (1950) also took radiographs with the mouth in the closed and open position. Comparison of the oral angle to mental foramen axis in these two positions showed the following:

(1) the axis becomes more vertical upon opening the mouth but still does not incline backward relative to the alveolar plane;

(2) the angle of the mouth moves considerably upward and backward relative to the foramen in the open position, an average of eight cases showing a 40% increase.

It appears that two factors may be involved in the change of direction of the mental foramen: firstly, a functional variation in the distance from the foramen of exit to the soft tissue supplied by the nerve; and secondly, a relative difference between the growth of the body and alveolar parts of the bone, and therefore, between the foramen and the same soft tissue. The latter relationship is involved in the development of the chin, the backward inclination of the foramen occurring approximately at the time of the development of the human chin (Warwick, 1950). This author then made reference to records of fossil man, and the modern condition of the foramen was found to exist in those forms which presented a prominent chin. In those hominids possessing little or no chin, the foramen is usually double or multiple, and so not directly comparable to the direction of the foramen in modern man.

In these cases, most of the foramina pointed forward and upward, but a posterior one was often directed upward and backward, perhaps serving to transmit the posterior branch of the nerve to the skin in that area in the fossil man. In apes, and chinless fossil man, a single, forwardly directed foramen, sometimes duplicated, is seen. But the gorilla, alone of chinless forms, presents a single, usually backward directed, foramen (Warwick, 1950).

In the light of the above findings it may be said that when single, and so comparable to the recent human condition, the foramen is directed upward and forward, a fact which may be related to chinlessness or alveolar prognathism. The phylogenetic evidence is thus in agreement with the ontogeny of the human mental foramen, but the growth changes which produced a chin do not seem to provide a complete explanation for the change in direction of the foramen and it is concluded that the functional factor of jaw movements is also involved.

Condylar growth of the mandible would appear to alter the relationship between the mental foramen and the area supplied by the mental nerve, thus altering the angle at which the nerve emerges at successive ages; but the observations reported here suggest that mandibular growth alone does not adequately explain these changes (Warwick, 1950).

The location of the mental foramen has clinical significance in the differential diagnosis of periapical lesions in the premolar area and for surgical intervention in this region (Fishel, Buchner and Hershkowith, 1976). It is important to find the exact location of the mental foramen by radiographs and to be familiar with the variations in its location. In the survey by Sicher and DuBrul (1975), many cases were not considered for reasons as stated below. For standardisation, all radiographs were taken by the same experienced radiographer using a short cone and the "bisecting the angle technique".

The radiographs were chosen according to the following criteria:

1. high quality with respect to angulation and contrast;
2. mixed dentitions were eliminated because of the possibility that buds of permanent teeth might obscure the mental foramen;
3. radiographs in which the lower premolar teeth were missing or had deep caries, root canal treatment, or various restorations, were eliminated because of a possible associated pathologic process causing a periapical radiolucency;

4. radiographs in which the lower canine was missing were eliminated because of the possibility of a mesial drift of the premolar teeth;

5. radiographs in which the upper premolar teeth were missing were eliminated because of the possibility of overeruption of the lower premolar teeth.

With the use of a calibrated grid, the location of the mental foramen was measured in relation to the first and second premolar teeth. In the horizontal plane, the mental foramen was registered as medial, distal, or overlapping on the apex of the examined tooth. In the vertical plane, it was registered as superior, inferior, or overlapping the apex of the premolar tooth (Sicher and DuBrul, 1975).

The above findings suggest that the mental foramen can be seen in periapical radiographs in 46,8% of the cases. This is in agreement with the report by Sweet (1943), who identified the mental foramen in about 50% of his cases. The study also indicated that the location of the mental foramen is far from being constant, in both the horizontal and the vertical planes. One of the important clinical implications of this is that periapical radiolucencies, even mesial to the first premolar tooth and distal to the second premolar tooth, may represent the image of the mental foramen and not a pathologic condition (Sicher and DuBrul, 1975).

Measurements in the vertical plane showed a larger number of mental foramina located under the level of the first premolar tooth than under the second premolar tooth. This is probably because the root of the first premolar tooth is shorter than that of the second premolar tooth (Sicher and DuBrul, 1975).

In the horizontal plane, most of the mental foramina were found between the two premolar teeth. This is in agreement with the radiographic findings of Sweet (1943) and with the anatomic location described in several textbooks of anatomy. However, comparison of the radiographic studies with two detailed anatomic studies of skulls reveals some differences in regard to the location of the mental foramen. The main difference is that, while in the anatomical studies, the highest percentage of mental foramina is found in the apical area of the second premolar tooth, in the radiographic studies the mental foramen is most commonly found between the premolar teeth.

According to Sicher and DuBrul (1975), several textbooks of Radiology refer to the mental foramen as a constant feature which appears as a radiolucent area below and or between the lower premolar teeth. They suggest, accordingly, that only faulty angulation causes the mental foramen to be seen at the apex of one of the premolar teeth. The results of this study, coupled with the anatomical studies, clearly indicate that the location of the mental foramen is variable in both the horizontal and vertical planes. In 300 cases, (30%), the mental foramen was found bilaterally. It was found unilaterally in 336 cases (33,6%); 182 mental foramina were on the left side and 154 on the right side. In 364 cases (36,4%) the mental foramen could not be identified clearly.

In the above study, the location of the mental foramen in the horizontal plane is illustrated as follows:

in about 70% of the cases, it was located between the premolar teeth;

and in about 22% of cases, it was in the apical area of the premolar teeth;

in 7,5% of cases, the mental foramen was located medial or distal to the premolar area.

The location of the mental foramen in the vertical plane is as follows: in the highest percentage of cases the mental foramen was found located superior to the apices of the premolar teeth

in 36,0%, above the level of the apex of the first premolar tooth;

and in 61,6% above the level of the apex of the second premolar tooth

(Sicher and DuBrul, 1975).

Sweet (1959) reports similar findings with 63,3% between the premolar teeth and 22,9% at the apical area of the second premolar tooth. Fishel, Buchner and Hershkowith (1976) cite Mastuda (1927) who found that in 329 mandibles, the mental foramen was found at the apex of the second premolar tooth in 69,9% on the left side and 67,2% on the right side. Apparently no radiographs were taken.

Bearing basic radiographic principles in mind, the position of the mental foramen in the radiograph appears as a radiolucent area, but as to where it will appear on the radiograph, depends on the angulation of the tube of the Xray machine (Ennis, Berry and Phillips, 1967). Thus these authors feel that the foramen can be made to change its position depending on the angle at which the radiograph is taken.

Sweet (1942) finds that the mental foramen is in evidence more often in the edentulous mandible. A consecutive periapical full mandibular radiographic examination was done by Sweet (1959) on 585 patients and divided into groups according to sex and age but with no reference to race.

The study of Sweet (1942) produced the following results:

1. the mental foramen could be observed on both sides of the mandible in 43,7% of cases, and on only one side in an additional 24,2% of all cases examined, it being radiographically absent in 32,1% of cases;

2. in males, the mental foramen was disclosed more often until the age of 35 years but after this age, the foramen becomes increasingly difficult to observe;

3. in females the mental foramen became increasingly difficult to observe from the earliest age.

The right mental foramen was disclosed in 49,2% of examinations while the left mental foramen was seen in 54% of 500 periapical full-mouth radiological examinations (Sweet, 1942). In a later study, Sweet (1959) selected periapical radiographs in spite of the fact that they do not show the inferior border of the mandible and he gives the following two reasons that influenced his choice:

1. the periapical examination is a technique which has been standardized, whereas standardization is difficult when making lateral mandible radiographs,

2. the periapical technique reproduces the tissue with greater accuracy and better definition.

Sweet (1959) admits that the survey was complicated by the absence of teeth and the factor of parallax. In radiographing the lower premolar area, the standard angle of projection is minus 10^{0}.

There is thus a tendency to cast the image of the mental foramen higher on the film than it actually is. This will account for some of the instances where the foramen is recorded at or above the apex of the nearest tooth. Of the 646 foramina recorded in the horizontal position, only 148 (23%) were located at the apex of the second premolar tooth, considered by anatomists as the normal position of that foramen. The other 498 (77%) were recorded over a wide area. In the vertical position, of 464 foramina recorded and corrected for parallax, Sweet (1959) found that 350 (82%) were located below the apex of the nearest tooth, but not in as precise a position as the anatomists maintain. There were 132 (11,28%) that could have been misinterpreted. He found that the foramina were at the level of the apex of the teeth in the greater majority of cases, 51 at the apex of the first premolar tooth; 409 distal to the apex of the first premolar tooth but medial to the apex of the second premolar tooth.

De Villiers (1968), while discussing the number of mental foramina in the South African Negro, notes that,in man,the mental foramen is usually single but that it may be multiple. With multiple foramina,the usual number is two. De Villiers (1968) quotes Murphy (1957) who says that the accessory foramina are of two types and suggests that the accessory foramina be called major and minor. The minor foramen commonly lies on,or just within,the rim of the main foramen and is separated from it by a tongue of bone, which is usually distinct, but may be poorly developed so that the division of the foramen is not always easily discernible. The major type of foramen is always larger than the minor type of foramen, is well separated from the main foramen and is situated either antero-superiorly, postero-superiorly, posteriorly or inferiorly to the main foramen. De Villiers (1968) notes that the major variety of multiple mental foramina is slightly more common in the South African Negro than the minor variety. Thus, the former variety is recorded in 20,7% of the male and 20,5% of the female mandibles(on one or both sides), whereas the latter variety is present in 15,2% and 12,1% of males and females respectively. Bilaterally,the major variety occurs in 7,4% of males and 9,2% of females, while the minor variety is found in 9,0% and 7,9% of males and females, respectively.

A combination of both major and minor types of foramina occurs in 3,2% of males and 0,7% of female mandibles. Disregarding sex, the major variety of multiple mental foramina is thus present in 182 (14,1%) of the 1292 sides examined and the minor variety in 151 (11,7%) sides examined. No greater number than four foramina was seen on any one side, (that is, three accessory foramina). A slightly greater dextral incidence for the major variety (97 against 85) and a slightly sinistral incidence for the minor (79 against 72) variety was found insignificant by the Chi-square test (De Villiers, 1968).

The frequency distribution of the four tribal groups shows that major accessory foramina occur most commonly in Sotho in males (32,6%) and in females (26,1%) and the Cape Nguni female (25,0%), whereas the minor variety occurs with almost equal frequency amongst the Cape Nguni male (28,3%), the Shangana-Tonga male (23,5%) and the Natal Nguni male (20,0%). Chi-square tests are less than in the corresponding expected values at the one per cent level of significance, indicating that there is no significant difference in the tribal distributions for the females or the sexual distribution, but the intergroup differences observed in the male were significant.

In a sample of 37 infant and juvenile South African Negro mandibles, major accessory foramina occur bilaterally in one specimen and on the left side in two specimens; while minor accessory foramina are present in five specimens; in one of these bilaterally and in the remainder on the left side (De Villiers, 1968).

The occurrence of two accessory foramina on the same side is extremely rare. The minor accessory foramina are formed by a small osseous bar separating the nerve from the blood vessels within the main foramen. De Villiers (1968) notes that Le Double (1906) and Murphy (1957) suggested that this osseous bar represents an ossified fibrous septum but states that the South African Negro mandible provides no evidence to suggest that the division between the mental and the minor foramina is fibrous at any time after birth.

The present data of De Villiers (1968) shows that the African, American and Oceanic Negroids share, with the Australian Aborigine, the highest incidence of multiple mental foramina in man. The Caucasoid groups show the lowest incidence, while most of the Mongoloid series have frequencies which are intermediate between the Negroid and the Caucasoid extremes. The complete absence of multiple foramina in Simonton's Egyptian series may be due to his small sample, since Riesenfeld's (1956) larger series of Egyptian mandibles gave a frequency of 3,6%, which lies near the lower limit of the Mongoloid range (De Villiers, 1968).

The mental foramen in the South African Negro of both sexes is commonly directed superiorly and posteriorly (46,5% of males and 47,5% of females). Superiorly directed foramina occur in 26,7% and 28,4% of males and females respectively; posteriorly directed foramina in 15,3% and 11,4% respectively thus in a total of 88,5% in the male and 87,4% in the female mandible the mental foramen is directed upward and/or backward (De Villiers, 1968).

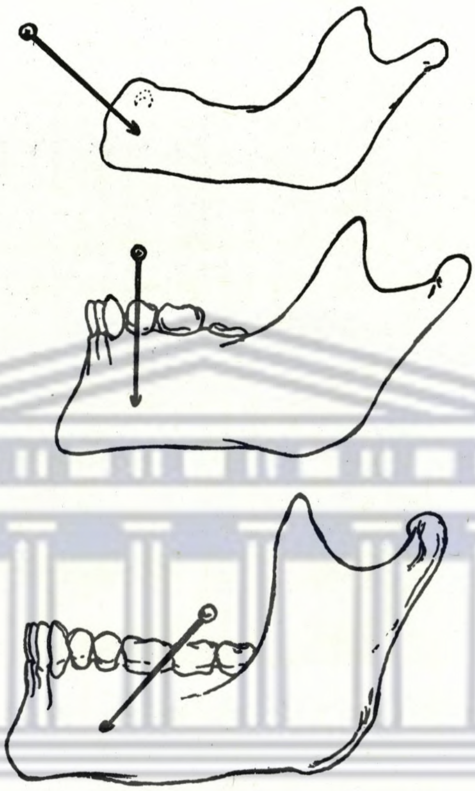
According to De Villiers (1968), in the youngest South African Negro age group, the mental foramen is, in all cases, directed anteriorly and/or superiorly. The direction changes with the eruption of the second deciduous molar tooth to postero-superior and superior. This trend continues into adulthood. De Villiers (1968) finds that the change in the direction of the mental foramen occurs at a younger age than is claimed by Warwick (1950), who did his research on Caucasians.

The mental foramen may be properly likened to the nutrient foramen of any long bone. When a pin is placed in such a foramen, the anatomist according to Moss (1960), is of the opinion that the protruding head of the pin "points to the more rapidly growing end". Figs. 1 and 2 below show that in the newborn, such a pin in the mental foramen points forward, while its direction is upward at six years and relatively backward in the adult. It is claimed that the periosteum of a growing bone is under tension and that the tensile forces at a given point are proportional to the growth rates of the two ends of the bone (Moss, 1960).

When the growth rate of one end predominates, the periosteal tension in that direction will be greater. The effect of such an unequal tension is "slipping" of the periosteum and consequent migration of the point of entry of the nutrient vessels. This, together with the surface apposition of new bone which accompanies growth in width, causes the foramen to face the direction of the most rapid growth.

In the newborn, the formation of the chin is the most rapid mandibular growth process, and accordingly, the foramen faces forward. With the eruption of the secondary teeth, the increase in body height produced by alveolar growth provides the tension and the foramen faces upward. Subsequent additions to body length and the posterior shift of the ramus, occurring with the eruption of the second and third deciduous molar teeth, direct the foramen

Fig. 1



Newborn, five-year-old and adult mandibles.
A pin is placed in the mental foramen. Note the shift of the relative position of the teeth to the foramen and the change in direction of the head of the pin.

The pin points in the direction of the greatest bone growth. At birth, the chin is being formed; at five years, the alveolar height is increasing; in the adult there is the increase in body length to accommodate the molar series.

(After Schuricht, H.: Uber Verandering am Unterkeifer wahrend der ontogenetischen und phylogenetischen Entwicklung, Halle, 1952, Max Niemeyer).

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Fig. 2

Sliding of the periosteum, indicated by the arrow, causes displacement of the nutrient canal (mental foramen).

The continuous lines show the canal in its present form.

Dotted lines indicate the site at which the most rapid bone growth is occurring.

(After LaCroix, P.: The Organization of Bones, Philadelphia, 1951, Blakiston Company).

(Reprinted with permission from A. Jerome Freeland, Vice President and Journal Publisher, the C.V. Mosby Company. Taken from the Journal of Prosthetic Dentistry, 10 (6) 1149-1159 Nov./Dec. 1960 - Functional Analysis of Human Mandibular Growth. M.L. Moss).

backward. These additional phases of mandibular growth thus produce a more dynamic concept. The mandible is not simply growing. It is not just adding to its length and height and so passively carrying the teeth downward and forward. Certain other events occur simultaneously. The area of most rapid growth rate is shifting, the entire dentition is migrating medially, but the mental foramen is retaining a relatively constant position while it alters its direction of opening. None of these later events are in any way dependent on growth in the mandibular condylar process (Moss, 1960).

Relationship of the third molar tooth to the inferior dental canal

The position of the mandibular canal varies in relation to the third molar tooth. Most commonly, the canal lies immediately below the roots of this tooth. It may be well below the roots of the tooth, thus closely related to the inferior margin of the mandible, or it may be situated above the level of the molar tooth apices. On the other hand, the apices of the molar tooth may appear to be superimposed over the canal, or the molar apices may appear to be below the canal.

Rarely do the apices enter the canal. Distinction should be made between a root that invaginates the superior wall of the inferior dental canal, causing the lumen of the canal to be narrowed locally, and actual entrance of a root into the lumen. In the former case, thin bone, probably only the lamina dura, separates the root from the lumen of the canal. In the latter instance, there is no bone between the root and the contents of the canal. Except in the presence of disease, the latter condition is a rare finding, while the former is found rather commonly.

Sometimes a groove can be seen radiographically and anatomically on a dry mandible in the root of a third molar tooth at the same site as the inferior dental canal, so that it seems permissible to conclude that the root and canal come into very close contact. But it is not possible to state whether or not bone exists between the root and the contents of the canal (Worth, 1975).

The whole subject of the exact relationship of the canal and the teeth is controversial. Experiments with dried mandibles, in which wire is inserted into the canal, have led to the conclusion that, even under the most favourable circumstances, it is difficult to determine the precise relationship by means of radiography, for it is impossible to escape from the limitations of dealing with shadows of solids on a flat surface. Stereoscopic radiographs do not serve as reliable guides (Worth, 1975).

Despite the limitations inherent in the interpretation of shadows projected onto a flat surface, a great deal can be learnt concerning the relationship of the canal to the third molar tooth. In many cases it is possible to identify grooving of the apex by the canal and, in some instances, obvious separation of the apices by the canal. Should the canal lie to one side, a difference in the density of the shadow will proclaim the presence of a groove in the root and this assumption may be supported by the recognition of a small concavity on the medial or distal aspect of the buccal surface of the roots. In some instances in which the root is grooved by the canal, there is some diminution in the lumen of the canal where the latter is closely related to the root (Worth, 1975).

The arrangement of the apices of some third molar teeth suggests that the normal development of the tooth has been interfered with, since the inferior dental canal appears to be immediately adjacent to the deformed root; it is assumed that there is a causal relationship, and subsequent removal and study of such teeth may confirm the suspicion.

In cases where the root apex of a third molar tooth appears to, or does, project into the lumen of the inferior dental canal from above, the walls of the inferior alveolar canal appear to approximate each other, or to be in actual contact. The superior margin is the affected cortex and a convexity in it brings the two walls together. This appearance is often interpreted as an indication that the canal is squeezed by the developing molar roots. It is apparent, however, that the lumen is not so completely obliterated as the radiographs may suggest for this might interfere with the blood supply anterior to the molar. Worth (1975) was unable to conclude that there was any interference with the normal blood flow in cases of constricted canals. The apparent gross narrowing of the canal is more of a projection effect than fact, although this does not invalidate the conclusion that some part of the walls of the canal are in close apposition or apparently in contact.

A very interesting projection effect is sometimes seen in radiographs taken of the lower third molar tooth, and less often of the second molar tooth, when the apices of the roots of the teeth and the inferior alveolar canal are superimposed. There is an apparent increase in the width of the periodontal ligament shadow, limited to the region of the apex or apices superimposed on the superior border of the canal. The lamina dura appears to be situated further away from the root than normally in this area, the abrupt difference in the shadow of the ligament, as contrasted with the same structure above the canal being very striking. The precise limitation of this change indicates that the appearance is due to projection.

The physical explanation of the phenomenon is unknown. The appearance is sharply limited to the region of the superimposition. Great care is necessary in such cases, not to mistake the appearance for disease or to regard disease as being a projection effect. With the projection effect, the lamina dura is intact despite its apparent displacement from the root. This development may be slight or marked; when marked, the greater is the likelihood that the appearance might be mistaken for disease. In apical disease, the lamina dura is affected but the change is not usually confined to the margins overlying the foramen or canal (Worth, 1975).

In cases that require extraction of the third molar tooth, an exact knowledge of the relationship of the canal to the molar roots is important and this is one of the most logical reasons for routine radiography of the area prior to surgical procedures (Sweet, 1943).

In rare instances, the roots of an impacted third molar tooth grow straight toward the mandibular canal, eventually surrounding its contents. The tooth then has a root which is, to a variable extent, divided into buccal and lingual parts. The mandibular canal may lie in this abnormal bifurcation, or, if the apices of the roots fuse below the canal, the alveolar nerve and blood vessels may be completely enveloped. The main complication, caused by this rare anomaly during removal of the tooth, is damage to the inferior alveolar neurovascular bundle. In view of these complications, the routine radiographs should be supplemented by one taken in a vertical projection, the film being in the occlusal plane (Sicher and DuBrul, 1975).

If a root apex is in contact with the superior border of the mandibular canal, no relative displacement between the two structures can be detected on the localization radiographs. The closer the two structures are located linguo-buccally, the smaller will be their relative displacement on localisation radiographs.

The relative position of the root apices and the mandibular canal can be determined by application of the principle that the radiographic image of a buccal image can be shifted in any direction, relative to an image of a lingual object, by projection of the radiographic beam in that desired direction. This is the usual application of Clark's localisation technique (Richards, 1952).

The mylohyoid groove

A narrow groove, known as the mylohyoid groove, commences in the region of the inferior margin of the mandibular foramen, runs downward and forward and fades away in the submandibular fossa. The groove in which the mylohyoid nerve and vessels lie, usually starts infero-posterior to the mandibular foramen, below the lingula.

The mylohyoid nerve is a motor branch of the mandibular nerve. It originates close to or at the mandibular foramen and initially runs in this groove on the medial aspect of the mandibular ramus. The groove follows a course parallel to the mandibular canal, running medial to it for approximately 20 mm and terminating below the posterior extremity of the mylohyoid ridge. A prolongation of the sphenomandibular ligament is attached to the lingula inferiorly, continues and expands over the mylohyoid groove as a fibrous membrane, fusing with the periosteum at the lips of the groove and transforming it into an osteofibrotic canal.

Arensburg and Nathan (1979) found that, in approximately 16% of cases, the mylohyoid groove is partially, or totally, converted into a bony canal by the ossification of the covering membrane. Where the ossification is only partial, it is sometimes present proximal to the lingula or at the distal part of the groove. In some cases, incomplete ossification is manifested by a deep groove with sharp edges that come close to one another without fusing. Where the mylohyoid groove is converted into a full canal, and in the entire length of that canal, the covering bony surface of the mandibular ramus appears smooth, without traces of a mylohyoid groove, the opening to the canal being seen proximal to the mandibular foramen while a second opening is present at the distal end of the canal. Careful dissection shows that, in practically all these cases, the mylohyoid nerve runs in its own canal parallel to the inferior alveolar nerve and is separated from it by bony tissue. In their study of 390 mylohyoid grooves in dry mandibles, there were no examples of the mylohyoid nerve running in the same canal as the inferior alveolar nerve (Arensburg and Nathan, (1979).

Variations in the anatomy of the inferior alveolar canal were recently reported by Nortje et al (1977b) who describe various types of double canals. As these authors do not mention instances related to ossified grooves of the mylohyoid nerves and vessels, Arensburg and Nathan (1979) feel that some of these may be partially ossified mylohyoid grooves.

Sutton (1974) from his dissections, noted a clear relationship in many instances between an accessory nutrient foramen and the mylohyoid groove. The accessory canal was seen running in an anterior direction.

The mylohyoid groove is of considerable importance, in as much as it indicates, with reasonable accuracy, the downward course taken by the posterior half of the inferior dental canal (Fawcett, 1895).

Other nutrient canals of the mandible

According to Sagne, Olsson and Hollender (1977), Lofgren (1957) appears to be the first to have described the foramina in the retromolar area of the mandible in man. In three different mediaeval Scandinavian groups of material, Sagne et al (1977) found retromolar foramina in about 12% of cases. Without giving a reference, they state that the results of later investigators have indicated that they originate from the mandibular nerve. They investigated 183 retromolar regions in skull material from 99 individuals,dating from four different periods during the Middle Ages. In the whole sample, foramina occurred in about 20% of the retromolar areas. There were only minor differences in frequency between the right and left halves of the mandible, between men and women and between the young adult and the mature group. In most cases,the course of the retromolar canal could be followed for a distance of between 10 mm and 20 mm. As a rule, the course of the canal in the upper part was directed anteriorly towards the apex of the third molar tooth. In some cases the canal could be observed without using a wire indicator. Although the investigation was done on mediaeval material, Sagne et al (1977) feel it appropriate to apply the same conclusions drawn from it to modern material since there is a strong similarity between mediaeval material and present-day material from Scandinavia. A frequency of accessory foramina and canals of about 20% may be expected in the retromolar region (Sagne et al, 1977).

Blood vessels of the mandible traverse the cancellated structure of the bone through canals that appear in radiographs of the mandibular teeth as radiolucent lines passing vertically through the body of the mandible and varying in different individuals in length, width and degree of radiolucency. They have been inaccurately interpreted as evidence of periodontal infection. It is important to know that, excluding the mandibular canal and mental foramen, the canals, and corresponding foramina that transmit branches of the mandibular artery,may be seen in periapical mandibular radiographs in about 15% of individuals. The great majority of these nutrient canals are observed in the incisor region, although occasionally they may be revealed in the posterior areas. (Sweet, 1942).

Of great importance,is the discovery that nutrient foramina are nearly as prevalent in the mandibular incisor area as are nutrient canals, for 15% were disclosed on the right side and 13,4% on the left side (Sweet, 1942). Nutrient canals and foramina must, however, exist in all individuals, whether or not they are disclosed in radiographic examinations.

Sweet (1943) found that, according to age, the older the individual the more likely one is to discover nutrient canals and foramina. In four out of six age groups,the average number of findings was slightly larger in females than in males.

In 62 mandibles from a dissecting room collection, observations were made on the smaller foramina to be found on the surface of the posterior part of the mandible. Counting only foramina with an internal diameter of 0,1 mm or greater, such foramina were almost invariably seen near the condyle of the mandible, near the mandibular foramen and in the retromolar fossa. The largest of these foramina were most commonly seen in the retromolar fossa (one-third of the mandibles) and near the condyle (one-fifth of the mandibles). The foramina were common in,or near,the areas of insertion of muscles of mastication and probably transmitted the neurovascular bundles found on dissection (Carter and Keen, 1971). Pattersen (1977), studying a panoramic radiograph, reports an aberrant canal arising from the inferior alveolar canal, coursing towards the distal aspect of the third molar tooth and exiting from the mandible just posterior to the third molar tooth. The canal was approximately 75 mm in length and about 3 mm in diameter.

The nutrient canals arising from the mandibular canal mainly follow two courses, viz. those that extend upward into the interdental space,and those that run directly to the apical foramen of the teeth. The latter canals are very small and rarely observed on the radiograph. Those that lead to the foramina of the posterior teeth may be seen in instances in which the bone trabeculae are sparse, and they are indicated by fine radiopaque lines which represent the walls of the canal. The interdental canals are more often seen in the anterior region of the mandible and also posteriorly in cases in which the alveolar process is very thin. In rare instances,the canals that lead to the apical foramina are also faintly visible in this region. In the edentulous mandible,the interdental canals become increasingly prominent (Stafne and Gibilisco, 1969).

Casey (1978) discusses a case of a dried mandible of an adult Caucasian of approximately 30 years of age which has bilateral accessory foramina posterior to the right third molar tooth and slightly anterior to the position on the left side. Both canals join the mandibular canals below the third molar tooth on the right side and the second molar tooth on the left side. Casey (1978) feels that it is possible that they contained sensory nerve fibres which innervate teeth other than, or in addition to, the third molar teeth.

According to Michalopulos et al (1974) the following variations in the nerve supply can occur:

1. the formation of an incisor canal which remains incomplete is traced in a great number of mandibles;

2. neural branches springing from the attached muscles of mastication penetrate into the mandible and join the branches or the main trunk of the inferior alveolar nerve;

3. in a very few cases, neural branches springing from outside of the mandible penetrate into the teeth roots especially in the molar teeth.

From their dissections, a clear relationship is seen in many instances between an accessory foramen and the mylohyoid groove. There is sometimes a portal of entry to these openings angled in a distal to medial direction.

The role of nutrient canals in the spread of infection in the mandible should be obvious (Carrol and Hirschmann, 1980).

The shape of the mandibular canal and thickness of the cortical bone of that canal

Fawcett (1895) sectioned an entire mandible vertically and bucco-lingually every 3 mm to 4 mm. In many of the sections, the variations in thickness of the cortical bone surrounding the mandibular canal are noted. A section made through the beginning of the canal shows it to be pyriform in shape with the long axis downward and slightly outward, the small end upward and inward (lingually). The canal is here seen to be partially embedded in the inner wall of the mandible, more so at its upper end than at its lower, on account of the obliquity of its long axis. The outer wall of the mandibular canal consists of a thin shell of compact tissue connected by trabeculae with the outer wall of the mandible.

In the segment of the coronoid process and ramus, immediately anterior to the segment described above, the canal courses outward (buccally), its outer wall blending with the outer wall of the jaw while its inner wall blends with the inner wall of the jaw. The latter wall is, however, not grooved by the mandibular canal as it was in the previous segment.

The segment immediately anterior to the last still passes through the coronoid process and ramus, and shows the mandibular canal still tending outward so that it lies at its anterior end slightly grooved at the inner surface of the outer wall of the mandible, but its inner wall is still blended with the inner wall of the mandible. Thus the width of the mandibular canal here is the width of the jawbone,less the thickness of the two cortical plates of bone.

In the next segment of the coronoid process and ramus, the mandibular canal still grooves the outer wall of the mandible and reaches the inner wall and is now oval in shape. The upper and lower walls of the canal are very thick here.

The segment of the root of the coronoid process just behind (distal to) the last molar tooth shows the lumen of the canal now almost circular. The canal itself still grooves the inner surface of the outer plate of the mandible. Both its upper and lower walls are thick.

The segment of the posterior part of the obliterated socket of the last molar tooth shows the lumen of the mandibular canal as oval with its long diameter now vertical and the canal, though lying nearer the outer plate of the mandible, no longer grooves it. The upper and lower walls of the canal are somewhat thinner than in the previous segment.

The segment of the middle of the obliterated socket of the last molar tooth shows the lumen of the canal almost circular and lying midway between the outer and inner wall of the mandible. Here no mention is made of the thickness of the cortical plate of bone surrounding the mandibular canal. The lower wall of the mandibular canal is 7 mm from the inferior border of the mandible.

The segment of the posterior half of the socket of the second molar tooth shows the lumen of the mandibular canal still nearly circular in form and situated against the inner wall of the mandible. The outer wall of the mandibular canal is now seen quite separate from the outer wall of the mandible, though connected to it by bony trabeculae. The inferior wall of the mandibular canal is now 6 mm from the inferior border of the mandible.

The segment of the anterior part of the socket for the second molar tooth shows the canal again oval, with its long diameter vertical. It slightly grooves the inner wall of the mandible; the outer wall of the canal is very thin and separated by an interval of 7 mm from the inferior border of the mandible.

The segment of the posterior half of the socket of the first molar tooth shows the canal, vertically oval, grooving the inner wall; its very thin outer wall is 2 mm from the outer (buccal) wall of the mandible. The lower wall is 7 mm from the inferior border of the mandible.

The next segment includes the middle of the socket of the first molar tooth. The canal, still vertically oval, has a very thin outer (buccal) wall, separated by a distance of nearly 3 mm from the outer wall of the mandible. The distance of its lower wall from that of the inferior border of the mandible is 7 mm.

The following segment includes the anterior half of the first molar tooth. It shows the mandibular canal, vertically oval, now separated very slightly from the inner wall of the mandible by cancellous tissue. Its lower wall is 8 mm from the lower border of the mandible.

The section of the posterior half of the socket of the second premolar tooth shows the canal, once more circular in diameter, with very thin walls which are free - the inner one 1 mm from the inner wall of the mandible, the outer 1,5 mm from the outer wall of the mandible and its lower wall nearly 9 mm from the inferior border of the mandible.

The next section includes the anterior half of the second premolar tooth, and the posterior two-thirds of the canal of the mental nerve and vessels. The mandibular canal terminates here by bifurcating into the mental and incisive canals and, at the point of bifurcation, which takes place some little distance behind the point where the mental canal pierces the outer wall of the mandible, the canal lies against the outer alveolar plate of the mandible.

In the section which includes a little of the anterior part of the mental canal and a good part of the socket of the first premolar tooth, the incisive canal is observed commencing. This canal, in the posterior part of the segment, lies against the outer plate of the mandible, but after a course of 4 mm is separated from that plate by about 1 mm of cancellous tissue. Its direction is therefore forward and inward. The lumen is circular, much less in size than that of the mandibular canal and the walls are very thin.

The following section includes the posterior part of the socket of the canine tooth. Here the incisive canal is 1,5 mm in diameter, lies almost midway between the outer and the inner wall of the mandible and has very thin walls. The lumen is circular and the canal is directed forward, slightly inward and upward.

The section of the apex of the socket of the canine tooth, as well as a little of the upper posterior part of the lateral incisor tooth, shows the incisive canal in the anterior half of this segment bifurcating, being divided into two parts by a vertical septum. Both canals lie midway between the anterior (labial) and posterior (lingual) walls.

The next and last section pertinent to this study, includes the greater part of the lateral incisor tooth and the lower and posterior part of the central incisor. Here no trace of an incisive canal can be distinguished (Fawcett, 1895).

3. MATERIALS AND METHODS

The dried mandibles on loan from the Department of Anatomy, University of Stellenbosch, were initially examined. There was a total in excess of 400 mandibles, the majority bisected close to the symphysis. The mandibles used were selected according to the following criteria:

1. a total of at least three molar teeth had to be present, preferably with at least one on each side;

   there were a few exceptions which will be discussed subsequently when the individual cases are discussed;

2. the two halves of each mandible had to have belonged to the same person;

   there were cases where both hemi-mandibles had belonged either to the left or the right side, or had not belonged to the same person,

3. the two halves of the mandible had to be able to be approximated as they had been in life, allowing for the thickness of the saw blade used.

The above criteria reduced the number of mandibles radiographed in the survey to 79. In excess of 400 mandibles were studied with regard to the mandibular and mental foramina.

Technical aspects

The 79 mandibles were radiographed with a Siemens Heliophos 4E Xray machine. The tube of the machine was raised, so that the anode-film distance was maintained at a constant distance of 152 cm. The light beam diaphragms on the Xray machine were used to cone down the Xray beam to the exact size of the film cassette to avoid undue scatter. The film cassette used was of the type routinely used in the panoramic type of Xray machine in the Department of Dento-Maxillo-Facial Radiology, Faculty of Dentistry. The milliampere-seconds (mAs) was kept constant throughout the survey at 10 mAs.

For lateral views, the Xray machine was set at 46 kilovoltspeak (kVp) and for the vertical views at 57 kVp. This Xray machine has a rotating anode. The aluminium filter was 2 mm Aluminium equivalent filter.

Du Pont Cronex 4 Xray film was used in the study.

The intensifying screens used in the cassette were of the type that are normally placed in the panoramic dental Xray system cassette, namely Kodak X-Omatic Regular intensifying screen.

Initially, a brass wire of 0,5 mm diameter was passed down the mandibular canal from the mandibular foramen on the dried hemimandibles as far forward as possible, without undue force, and keeping the brass wire within the canal.

Ideally, it was attempted to push the brass wire forward down the canal until it could be seen through the mental foramen. This was not often achieved.

Applying the same principle, a brass wire of the same thickness was then pushed via the mental foramen down the incisive canal as far as possible in the direction of the symphysis menti. In those cases where the thicker wire could not be used, a brass wire of 0,35 mm diameter was used.

The position and direction of accessory nutrient canals and nerve canals was indicated where possible by pushing soft ligature wire of 0,25 mm diameter down those canals.

The mandibles were radiographed in a horizontal and vertical plane with the wires in position. In the vertical plane, the mandibles were radiographed in a similar position to the standard horizontal plane. According to van Rensburg (1980) the standard horizontal plane of the mandible is defined as that plane with which contact is made at three or more points when vertical pressure is applied to the second left molar tooth or its socket. This applies to mandibles that have not been bisected. In this position it was found that the inferior border of the mandible is horizontal and the most vertical part of the mandible is on the buccal side of the ascending ramus, usually in the region of the deepest part of the mandibular notch.

A platform was constructed in order to take radiographs in the vertical and standardised horizontal position (Figs. 3 and 4). The platform was made from perspex, 6 mm in thickness, with four vertical uprights, each to accommodate one hemimandible (Fig. 5). The size of the platform was limited by the size of a cassett of a panoramic radiograph. Perspex was used as it is not generally seen on the radiograph and it thus does not interfere with the beam of the Xray. The uprights consisted of round metal wire 75 mm in length and of 3 mm diameter.

An attempt was made to confirm whether the lateral ramus prominence on the buccal side could be used as a reference point to find the position of the mandibular foramen on the medial surface of the ramus. When found to be present, brass wire of 0,5 mm diameter was bent into small circles with a diameter of approximately 2 mm and pasted on the lateral ramus prominence on its maximum convexity. The relationship of the lateral ramus prominence to the mandibular foramen, as indicated by the end of the brass wire in the mandibular canal, could then be determined radiologically by means of a lateral radiograph.

The mandibles acquired for research purposes, had been sectioned close to the symphysis during dissection of cadavers. The dried hemimandibles were placed in the same relationship to the standard horizontal plane as described above. In most cases, contact against the vertical upright was made on the buccal side of the ramus of the mandible close to the region where the lateral ramus prominence is sited. The rare exceptions are those cases where the bone is very prominent buccally,close to the inferior border of the mandible and close to the angle in the region of attachment of the masseter muscle. The same relationship can, however, still be maintained by placing the mandible where the bone is prominent against the vertical upright. The ascending ramus will then not touch the vertical upright but the mandible can be placed in a position with the ascending ramus almost parallel to it so that the standard horizontal plane of the mandible can be simulated. The dried hemimandibles were then radiographed in the vertical plane. The mandibles were then placed horizontally on their buccal surfaces and radiographed. Soft prosthetic blue wax was used to support the hemimandible in a horizontal position where necessary. Because the mandibles had been cut in half it was easier to ensure standardisation when radiographs were taken of the hemimandibles in the horizontal position.

To localise the position of the mylohyoid groove radiologically in those cases where it cannot be seen on the Xray photograph, a brass wire of 0,5 mm diameter, with a length of approximately 5 mm was glued in the mylohyoid groove approximately 5 mm anterior to the mandibular foramen. Where the mylohyoid groove was converted into a canal, it was often not possible to maintain this position.

The number of mylohyoid canals was noted as well as the site of commencement, that is, from within or from without the mandibular canal.

Using dividers, the length of the premental and postmental segments of the body of the mandible were measured from the midpoint of the mental foramen with the mandible in the standard horizontal plane. Where there was more than one mental foramen, the measurement was made from the middle of the larger one. All measurements of the premental segment were made from the symphysis to the midpoint of the mental foramen at the height of that foramen. The postmental segments were measured from the midpoint of the mental foramen in a horizontal plane, to the posterior border of the mandible at that level. In some cases, the midpoint of the symphysis was located with difficulty and in others that point of measurement was distinct. The blade of the saw used to cut the mandible was 1 mm thick and this thickness was taken into consideration during measurements.

Nutrient foramina were recorded. Only nutrient canals, into which a 0,25 mm brass wire could be passed (without undue force) over a distance of at least 3 mm to 4 mm, were considered as nutrient canals for the purpose of this study. Many smaller foramina were observed.

Nutrient foramina, within a circumference of approximately 1 cm of the mental foramen, were recorded. Accessory nutrient canals were searched for in the roof of the mandibular canal by looking down the canal from the distal aspect of the mandibular canal through the mandibular foramen.

Foramina on the lingual side of the mandible, approximately opposite the mental foramen, were recorded. Again, where possible, soft ligature wire of 0,25 mm diameter was inserted as far as possible using light pressure.

The mandibles were then examined visually and radiologically. The positions of the mandibular and mental foramina were radiologically determined, since the brass wire had been cut off at the level of the foramina.

The distance from the mandibular foramen, as shown by the end of the brass wire within the mandibular canal, to the deepest part of the sigmoid (mandibular) notch, was measured on the radiographs.

The distance, in a horizontal plane, from the anterior cortical margin of the mandibular foramen, as indicated by the end of the brass wire within the mandibular canal, to the anterior border of the ascending ramus, was measured on the radiographs. The distance, in the same horizontal plane from the posterior cortical margin of the mandibular canal, at the height of the mandibular canal, to the posterior border of the ascending ramus of the mandible, was measured on the radiographs.

From the radiographs, the position of the mandibular canal was determined in both the horizontal and the vertical planes. The position of the mandibular canal in the body of the mandible was determined relative to the apices of the molar teeth.

The relationship of the distal root of the molar teeth, individually, to the mandibular canal was recorded. In the horizontal plane the distance between the apex of each molar tooth and the superior cortical margin of the mandibular canal was measured.

An attempt was made to find the position of the mandibular foramen in relation to the total height of the mandible. A measurement was made along the posterior border of the mandible in a straight line from the apex of the condyle to Gonion. Gonion is described as the most inferior, posterior and outward projecting point of the angle of the mandible. A further measurement was made from Gonion along the posterior border of the mandible in a straight line to a line drawn perpendicular, to a line that passes through the most inferior part of the mandibular foramen as indicated by the brass wire within the mandibular canal. Thus the height of the mandibular foramen, above the angle of the mandible, and also the total length of the mandible along the posterior border, was measured to determine if any relationship of the height of the mandibular foramen above Gonion to the total length of the mandible exists.

In the vertical view, the mandibular canal was considered to lie buccally to the molar teeth where the lingual cortical margin of the canal was separated from the tooth by bone. Where the cortical margin either touched the tooth or lay on the peripheral third of the tooth, the canal was considered as lying infero-buccally to the tooth concerned. Where the canal lay more lingually to this point, but did not contact the lingual margin of the tooth, it was considered to lie inferior to the tooth. In a more lingual position to the above, the canal was classified as lying linguo-inferiorly to that tooth.

Canals leading off the mandibular canal were noted, both on radiographs and by looking down the mandibular canal from the distal aspect.

Definitions

1. Median : The sample median of a set of n measurements $X_1 \ldots X_n$, is the middle value when the measurements are arranged from the smallest to largest.

   Roughly speaking, the median is the value that divides the data into two equal halves.

2. Mode : The mode is that value in the data set with the highest frequency, that is, the one that occurs most frequently.

3. Mean : The sample mean or average of a set of measurements $X_1 \; X_2 \ldots X_n$ is the sum of these measurements divided by n. According to the concept of average the mean represents the centre of a data set (Bhattacharyya and Johnson, 1977).

4. FINDINGS

Race and sex ratio

Unfortunately incomplete records of sex, race or age were kept of the original cadavers presented to the University of Stellenbosch by other medical schools at the time of inception of the Faculty of Medicine at the University of Stellenbosch.

The mandibles can be divided (Table II) according to race and sex as follows:

Table II

	Negroid	Coloured	White	Unknown
Male	18	27	2	0
Female	0	9	3	0
Unknown	0	0	0	20
	18	36	5	20
Total: 79				

Age distribution

For the reasons given above, there were 23 mandibles of which the age is unknown. In addition, there were four cases where it was only known that the cadavers had been adult. The rest were divided as follows:

Under 20	Under 30	Under 40	Under 50	Under 60	Under 70	Under 80
3	4	7	5	15	11	7

The mean age was 56 years and the mode age group was in the under-60 age group; the under-70 age group being the next most populous.

The lateral ramus prominence (L.R.P.)

The lateral ramus prominence, when present, is not always a clearly defined prominence but often an obscure, almost vertical ridge of thickened bone, extending from just distal to the deepest part of the mandibular notch and approximately 1 cm inferior to it. Alternatively, it may extend from the region just anterior to the neck of the condyle to about 1 cm superior to the inferior border of the mandible, just anterior to the angle of the mandible. In other cases, the L.R.P. is slanted more obliquely and runs from the postero-superior aspect of the lateral surface of the neck of the condyle, downward and forward at an angle of approximately 45^{o} to the horizontal plane.

The author doubts whether this type of indistinct thickening should be considered as a lateral ramus prominence. Three of these cases showed an abnormal amount of tooth attrition and this may support the author's contention that these are not anatomical structures as such, but a thickening of bone in response to stress. However, in the survey, these bony thickenings were included as lateral ramus prominences. In other cases, the L.R.P. was seen as an oval thickening that could clearly be accepted as that structure. The localisation of its midpoint relative to the lumen of the mandibular foramen is problematical.

The L.R.P. was not present on the left side in 37 mandibles (46,8%) and on the right side in 38 mandibles (48,1%). Thus the L.R.P. was present in 42 mandibles on the left side and on the right side in 41 mandibles. In 30 mandibles (38%) the L.R.P. was present on both sides. The mandibles in this study were therefore not uniformly bilaterally symmetrical in this respect.

Where the L.R.P. was found to be present it,could be further divided into those cases where the L.R.P. was within a radius of 5 mm of the mandibular foramen as determined on radiographs,where the third dimension is eliminated. The position of the mandibular foramen was determined by the end of the brass indicating wire that had been inserted down the mandibular canal. The position of the L.R.P. was determined by the brass wire bent into a small circle with a diameter of about 2 mm and pasted on to the L.R.P. (Fig. 16)

Whereas there was some similarity in numbers between the absence of the L.R.P. on the left and right sides, there was no similarity on the two sides of the position of the L.R.P. when bilaterally present.

On the left side there were 25 (31,6%) L.R.Ps. within a radius of 5 mm and 17 L.R. Ps. further than 5 mm from the mandibular foramen with one case 10 mm and one case 13 mm away.

On the right side there were 21 (26,5%) L.R.Ps. within a radius of 5 mm and 20 (25,3%) further than 5 mm from the mandibular foramen with one case being 11 mm, one 12 mm and one 14 mm away.

The lateral ramus prominence could be further divided according to sex, as follows: (Table III)

Table III The presence or absence of the L.R.P., according to sex

Left side:

	Present	Absent	Total
Male	23	24	47
Female	6	6	12
Unknown	13	7	20
Total:	42	37	79

Right side:

	Present	Absent	Total
Male	27	20	47
Female	4	8	12
Unknown	10	10	20
Total:	41	38	79

On the right side in the female mandibles, the difference between the presence and absence of the L.R.P. was noted.

On the right side the L.R.P. is present in four mandibles (33,3%) and absent in eight mandibles (66,6%).

The position of the lateral ramus prominence when present in relationship to the mandibular foramen can be given (Table IV).

Table IV The position of the L.R.P. in relationship to the mandibular foramen

Left side:

	Anterior	Antero-Superior	Superior	Postero-Superior	Posterior	Inferior	Opposite	Total
Male	1	2	8	4	0	2	6	23
Female	0	0	5	0	0	0	1	6
Unknown	0	2	7	0	1	0	3	13
Total:	1	4	20	4	1	2	10	42

Right side:

	Anterior	Antero-Superior	Superior	Postero-Superior	Posterior	Inferior	Opposite	Total
Male	0	3	15	4	1	0	5	28
Female	0	0	3	0	0	0	1	4
Unknown	0	0	5	2	1	0	2	10
Total:	0	3	23	6	2	0	8	42

The findings on the L.R.P. are that they are present in just over 50% of cases of which 38% had L.R.P. symmetrically.

When present, they were found, in over 50% of cases, to lie in the superior or postero-superior position, the next most common position being opposite the mandibular foramen.

The mandibular foramen

It is generally accepted that there is only one mandibular foramen on each side of the mandible. All the mandibles originally inspected had at least one mandibular foramen. There were several mandibles with accessory canals in the region of the mandibular foramen of a size that raised doubts about classification into single or double foramina. However, in others, no doubt existed that they should be classified as double mandibular foramina (Figs. 6 to 8, and 49).

Double mandibular foramina were present on the left side in five cases (6,5%) and on the right side in two cases (2,6%). No cases were found where more than two mandibular foramina were present. Where there is more than one mandibular foramen on one side there must be, if only for a short distance, more than one mandibular canal.

The position of the mandibular foramen on radiographs is often misleading because of the mandibular fossa situated posterior, and sometimes slightly postero-superior, to the mandibular foramen. One must bear in mind that the lumen of the mandibular canal lies obliquely to the bone and thus, on the radiograph from the lateral view, virtually no lumen can be observed. Thus most of the dark shadow observed on a radiograph, is caused by the mandibular fossa. The foramen is therefore situated more anteriorly than it appears to be on the radiograph.

The mandibular canal usually has a clearly demarcated superior and inferior sclerotic margin. It was thought that where these end posteriorly, a fine line drawn from the superior to the inferior margin will often indicate where the end of the canal is situated. However, this is not the case.

To test this position radiologically, a brass wire was glued over the lumen of the mandibular foramen, ignoring the shape of the lingula, and radiographs were taken. In most cases, the sclerotic margin does tend to go past the brass wire for a distance of up to 2 mm to 4 mm, along the superior border. The inferior border, in the majority of cases, ends 1 mm to 2 mm distal to the brass wire. Thus the ends of the sclerotic margins of the mandibular canal do not indicate the position of the mandibular foramen. Distal to the mandibular foramen, the sclerotic margins form part of the mandibular fossa.

In an attempt to localise the medial rim of the obliquely placed mandibular foramen radiographically, a brass wire of 0,5 mm thickness was placed on the medial lip of the mandibular foramen of twenty mandibles in such a position that it could just not be seen when looking at the bone from the medial aspect. Its position, and relationship to the mandibular foramen and fossa on the radiograph, was then determined. Because there is no constant size or shape of the lingula, there was no constant position of the brass wire. The brass wire varied in position from lying almost at right angles to being almost parallel to the mandibular canal. Because the mandibular fossa radiologically makes the mandibular canal appear to end further distally than it in actual fact does, the brass wire did not appear radiologically to be at the opening of the canal. There appeared to be no relationship between the brass wire and the cortical margins of the mandibular canal. The distance varied distally and was not constant. Anteriorly, the cortical ridges form part of the mandibular fossa. On no radiograph could an indication of the position of the lip of the mandibular foramen be found.

An attempt was made to determine the antero-posterior position of the mandibular foramen radiologically. Ignoring the size of the lumen of the mandibular foramen, measurements were taken horizontally at the height of the mandibular foramen (as indicated by the end of the brass wire inserted into the mandibular canal) from the anterior cortical margin of the mandibular canal to the anterior border of the ramus of the mandible and also from the posterior cortical margin of the mandibular canal to the posterior border of the ascending ramus of the mandible.

On the left side,(Table V) the distance anterior to the mandibular foramen had a mean of 14,9 mm with the mode of 13 mm; while on the right side the mean was 15,4 mm,with the mode a distance of 17 mm.

Table V The position of the mandibular foramen

	Left		Right	
	Anterior	Posterior	Anterior	Posterior
Mean	14,9	11,6	15,4	12,6
Median	15,0	12,0	15,0	12,0
Mode	13,0	12,0	17,0	12,0

Thus, accepting that the size of the lumen of the mandibular foramen is approximately the same on both sides (or ignoring the size of the foramen),the antero-posterior length of the ascending ramus of the mandible is larger on the right side. On both sides the anterior portion is larger than the posterior portion. Thus the mandibular foramen is not situated in the middle of the ramus.

There is a significant correlation between the horizontal distance both anterior and posterior to the mandibular foramen and the total antero-posterior distance of the mandible at this height. The correlation is not very strong on either side. Pearson Correlation coefficient $\gamma = 0{,}27$. Statistically this indicates that as either the anterior or posterior distance (to the mandibular foramen) increases - so does the overall total length.

From the measurements anterior and posterior to the mandibular foramen, it can be seen that, if the mandible at this height is divided vertically into four equal segments, the mandibular foramen will most commonly lie in the third segment from the anterior border of the ramus. The mean distance of the mandible posterior to the mandibular foramen is 43% of the total antero-posterior distance of the mandible (less the size of the mandibular foramen) at the height of the mandibular foramen.

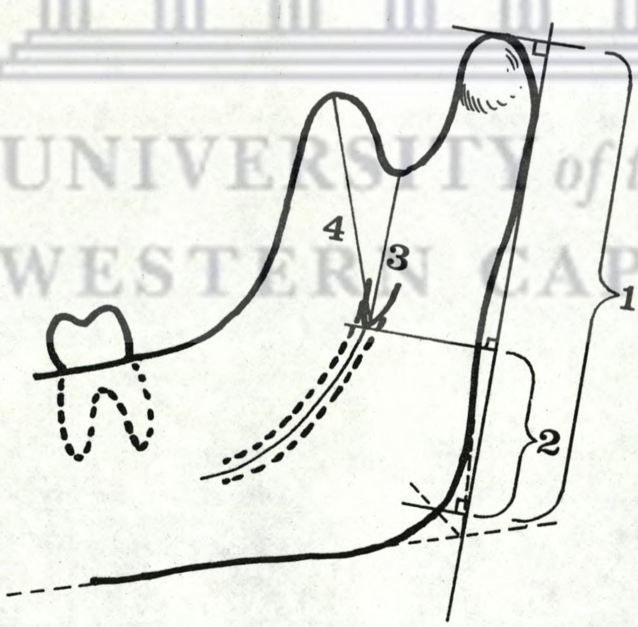


Fig. 9 Diagram of the mandible explaining points of measurement.

No indications could be found in the literature regarding points of measurement to determine the site of the mandibular foramen. The following measurements were taken from the radiographs (Fig. 9):

initially, a line was drawn along the posterior border of the mandible from the angle of the mandible to a line perpendicular to the most superior point of the head of the condyle (1);

another measurement was made along the posterior border of the mandible from the angle of the mandible to a line drawn perpendicularly through the mandibular foramen (2);

also from the mandibular foramen to the deepest part of the mandibular notch (3);

and finally, from the mandibular foramen to the most superior point of the coronoid process (4).

The distance inferior to the mandibular foramen was measured from only one position, that is, the angle of the mandible.

Comparisons and correlation coefficients calculated were then made between these distances.

From the aforegoing diagram, it should be clear how the position of the mandibular foramen in a vertical dimension was determined. Depending from where measurements are made, the relative position of the mandibular foramen in the ramus of the mandible does change.

There is a strong positive correlation between points (3) and (4). Statistically, as the distance from the mandibular foramen to the notch increases in length, so does the distance from the mandibular foramen to the tip of the coronoid process; or conversely, the larger the distance to the coronoid process, the larger the distance to the notch from the mandibular foramen. The Pearson Correlation coefficient is positive (γ = 0,69).

If it is accepted that the ascending ramus of the jaw ends at the height of the mandibular notch, (the coronoid process and the condyle not being part of the ascending ramus), then the position of the mandibular foramen is determined by comparing points (3) and (2); that is, the heights above and below the mandibular foramen. The two lines are so close to being parallel that the discrepancies here in length can be excluded. The mean average of the left and right sides indicate that the mandibular foramen is in the middle of the ramus on both sides in a vertical plane. On the left side, the mean is 0,497 and the median 0,50, and on the right side, 0,491 and 0,518 respectively.

However, if it is accepted that the condylar process is part of the ascending ramus of the mandible, then points (1) and (2) must be compared, in which case, the mandibular foramen will be found to lie in the lower half of the ramus. It is found to lie 33,7% of the distance from the angle of the mandible to the condyle, that is, almost exactly where the inferior and middle third meet along the posterior border of the mandible, the mean being 0,3374 and the median 0,342.

When looking at a cephalometric radiograph, the two angles of the mandibles often do not overlap. At the same time, it is presumed that the patient had not been positioned quite correctly, making allowances for the object-film length magnification of the two sides of the mandible.

However, when comparing the length of the posterior borders of the mandible, one often finds that they are not quite the same length. As it is generally accepted that the two sides of the face are almost symmetrical, a correlation closer to unity will be expected. There is a strong positive correlation (γ = 0,8245) yet the author would not have been surprised had it been higher.

It may be mentioned here that, when looking at a panoramic radiograph or at a dry mandible itself, it is noticed that the one coronoid process is often shorter than the other. Thus it is not surprising to find that statistically, there is no correlation in length between the two sides.

<u>The mandibular canal</u>

With the exception of one shortened mandible (due to a healed fracture) the mandibular canal was clearly seen for most of its course, but at least as far anteriorly as the medial root of the first molar tooth, in all the radiographs with the mandible in the horizontal position. The brass indicating wire, in some cases, did not penetrate as far anteriorly as the mandibular canal appeared on the lateral view of the radiograph, although the calibre of the lumen appeared radiologically large enough to accommodate the brass indicating wire. The fact that the brass wire could not be passed more anteriorly, was possibly due to the fact that the curvature of the brass indicating wire and the curvature of the mandibular canal could not be made to coincide. As already noted, Fawcett (1895) notes that along its course the thickness of the cortical bone of the mandibular canal varies as it passes anteriorly. This may have assisted in allowing the wire to become obstructed and in doing so not being able to be passed more anteriorly.

With the mandibles placed in the standard horizontal plane, it was noticed that the long axes of the teeth were not orientated in a vertical position. The molar teeth tended to slant slightly lingually and also distally. During life, when the individual is in the upright position, the position of the mandible is usually not in the standard horizontal plane and thus the inferior border of the mandible is not parallel to the horizontal. In that position, the molar teeth are, as is universally recognised, upright or slightly medially inclined besides their lingual inclination.

On a radiograph, with the mandible in the horizontal position, a straight line drawn through the head of the condyle obliquely downward and forward can be drawn through the mandibular foramen and will be seen to overlap the mandibular canal for a distance of 3 cm to 4 cm. For these 3 cm to 4 cm, the straight line will be seen to be parallel, but inferior to the external oblique ridge. This relationship is not affected by the extraction of teeth as neither structure is affected by that procedure.

The relationship of the mandibular canal to the molar teeth

In the horizontal plane

In the horizontal plane, the mandibular canal was seen to lie inferior to the existing molar teeth, the position, measured in millimetres, from the apex of the distal root, being as follows:

Table VI The horizontal plane relationship of the mandibular canal to the molar teeth

	1st Molar		2nd Molar		3rd Molar	
	L	R	L	R	L	R
Mean	5,7	8,6	3,7	3,8	2,0	2,1
Median	5,0	6,0	3,0	4,0	2,0	2,0

In the vertical plane

When comparing the relationship of the mandibular canal to the molar teeth in the vertical plane, one must be very careful to note the relationship of the mandibular canal to the apices of the teeth, as the greater majority of molars are tilted lingually to varying degrees. The mandibular canal was considered to lie buccally to the molar teeth only in those cases where bone could distinctly be seen between the cortical margin of the mandibular canal (Fig. 10) and those teeth when viewing the radiographs in the vertical plane. The mandibular canal was considered to lie infero-buccally to the teeth when the cortical margin of the mandibular canal lay somewhere between the lateral margin and the outer third of those teeth using the brass indicator wire as an indication). The mandibular canal was considered to lie inferior to the teeth when it was in a position more lingually than explained above. It was considered to lie infero-medially when it lay on the lingual third or more lingually than this in the same view.

In the vertical plane, the canal was classified (Table VII) as lying either buccally, infero-buccally, inferiorly or infero-medially to the existing molar teeth as follows:

Table VII The vertical plane relationship of the mandibular canal to the molar teeth

	1st Molar		2nd Molar		3rd Molar	
	L	R	L	R	L	R
Buccal	1	3	6	5	24	26
Infero-buccal	17	11	30	32	20	21
Inferior	23	27	12	12	3	3
Infero-medial	3	2	-	-	-	-

Thus the canal lies buccally to the third molar tooth in 51,1% of cases on the left side and in 52,2% of cases on the right side, and infero-buccally in approximately 42% of cases on both sides.

In the case of the first molar tooth, the canal lies directly beneath the molar teeth in 52,3% of cases on the left and in 62,8% of cases on the right; infero-buccally in 38,6% of cases on the left and 25,6% on the right side. Here there were three cases (6,8%) on the left and two cases (4,6%) on the right where the canal lay in an infero-medial position.

Verification of the buccal relationship of the mandibular canal to the mandibular third molar tooth is possible, to an extent, by visual inspection. If one views a mandible from the posterior aspect, with the third molar tooth in its normal position, one is able to observe that the mandibular foramen is situated buccal to the third molar tooth, and by following the course of the mandibular canal, one can observe that, although it courses towards the apex of the third molar tooth, it is still in a position buccal to it. In a vertical plane the mandibular canal runs a straight course to the mental foramen, that is, it veers only slightly, if at all, to the medial or buccal cortical bony plate.

Nowhere in the available literature is the change during life, in the height of the bone, inferior to the mandibular canal discussed in detail. By examining a large number of mandibles one becomes aware that there is a definite reduction in the height of the body of the mandible both above and below the mandibular canal due to the loss of bone when teeth are extracted. In some relatively young people, there is a considerable amount of bone loss of the mandible in general that cannot be explained by the loss of alveolar bone due to the loss of teeth or that can be explained as a normal ageing process. Thus, although it cannot be explained, in these cases there must be a loss of bone superior and inferior to the mandibular canal.

Once teeth have erupted into the mouth, the increased masticatory forces stimulate additional bone to be deposited in the basal bone of the mandible to strengthen it. Thus when all the teeth have been lost, there is every reason to believe that the lack of physiological stimulus, because of reduced masticatory forces, will permit the resorption, to varying degrees, of bone inferior to the mandibular canal. Thus the position of the mandibular canal in the mandible must change with the extraction of teeth and with age.

Canals leading to the mandibular canal

It is generally accepted that no recognisable canals lead into the mandibular canal.

In the region of the mandibular foramen, accessory nutrient canals are found fairly frequently. In most instances these canals are of such a calibre that there is no doubt that they are merely accessory nutrient canals. Doubt exists whether either blood vessels alone or blood vessels and nerves occupy these canals during life. However, in some instances the foramina of these canals are of a much larger size. It is difficult to decide at which size of canal diameter to classify the canal and foramen as an accessory nutrient canal or an additional mandibular canal and foramen. The uncertainty is further complicated by the fact that the mandibular canal itself is considered as the nutrient canal of the mandible.

Many accessory nutrient foramina were seen on the medial aspect of the ascending ramus of the mandible mainly in the region of the mandibular foramen. The commonest site for these foramina to be found was distal to the inferior edge of the mandibular fossa.

Retromolar canals

Foramina with canals leading to the region of the apex of the distal root of the third molar tooth were observed in the area of the retromolar pad area (Figs. 12 and 16). In many of these instances the indicating wire could reach the apex of the tooth. On the left side, 19 canals (24,4%) were observed. In one case no second or third molar tooth was present on that side. On the right, eight canals (10,3%) were observed. This may possibly be considered as an accessory extra-osseous nerve supply from the mandibular nerve to the molar tooth or teeth. There is no proof that the nerve continues on to join the mandibular canal.

The lingual canal

On the medial (lingual) surface of the body of the mandible close to the inferior border and approximately opposite the first premolar tooth, a foramen is often seen running in a postero-anterior direction (Fig. 12). Soft ligature wire was placed in these canals, when these were found, before radiographs of the mandible were taken. Table VIII, below, illustrates the configuration of the canals found:

Table VIII The lingual canal

	Left side		Right side	
	No.	No. joining incisive canal	No.	No. joining incisive canal
Male	21	13	21	9
Female	8	2	6	0
Unknown	6	1	9	3
Total:	35	16	36	12

Thus, on both sides, the lingual canal was seen in a greater percentage of males and more of these canals were found to join the incisive canal in the male than in the female. In almost 40% of cases, a canal on the medial side of the mandible, as described, (Table VIII) was seen joining the anterior continuation of the mandibular canal.

Table IX Accessory foramina around the mandibular foramen

	Accessory Foramina					Canals joining mandibular canal			
	Number	Left		Right		Left		Right	
Inferior	single	32	40,5%	23	29,1%	3	3,8%	1	1,3%
	multiple	6	7,6%	5	6,3%	0	-	0	-
Superior	single	9	13,6%	5	6,3%	0	-	2	2,5%
	multiple	1	1,3%	1	1,3%	0	-	0	-
Additional	single	15	19%	10	12,7%	0	-	0	-

1. Inferior = foramina distal to the inferior cortical margin of the mandibular foramen along the inferior border of the mandibular fossa (Figs. 11 and 12).
2. Superior = foramina distal to the superior cortical margin of the mandibular foramen along the superior border of the mandibular fossa.
3. Additional = additional foramina on the medial surface of the ramus of the mandible in the region of the mandibular foramen (Fig. 18).

The majority of additional foramina were found inferior to the mandibular notch on the medial side of the ascending ramus of the mandible (Figs. 48 and 49).

On the left side, 3,8% of the canals commencing distal to the inferior cortical margin of the mandibular foramen joined the mandibular canal. On the right side, an aggregate of 3,8% of all the canals joined the mandibular canal. As these canals have a very small lumen, not permitting wire to pass along the course of the canal, and because the size of the canal does not make it easily noticeable radiologically, there is, in all probability, a much greater number of canals joining the mandibular canal than is apparent.

In one mandible, on one side only, a nutrient canal was seen commencing 4,5 mm inferior to the deepest part of the mandibular notch on the medial aspect of the mandible and, after running in an antero-inferior direction, it was seen to end 2,3 cm later within the mandibular canal.

Unilaterally, on the buccal aspect of one mandible, there were three distinct, separate foramina opening in an arc of a parabola with the mental foramen (Fig. 28). All three these foramina were directed posteriorly, indicating that the neurovascular bundle came off the mandibular nerve and passed in a posterior direction or, alternatively, an additional neurovascular supply joined the mandibular nerve in three different places. Indicating wires, passed through the more anterior two canals, could be seen through the mental foramen as they were pushed forward along the mandibular canal.

Nutrient canals also entered the bone along the top of the alveolar margin, distal to the last molar tooth (Figs. 12 and 13). In one case (Fig. 47), these canals were found bilaterally and were of an unusually large size. The majority of these canals did appear to end in the region of the apex of the distal root of the third molar tooth. It is, however, possible as explained above, that the canal may continue and join up with the mandibular canal on that side. There were 19 (24,4%) such canals on the left side, and eight (10,3%) on the right side.

It must be pointed out that there were small foramina all over the mandible, including all locations already described. These foramina and their canals were not considered in this survey as they would not permit the passage of the thinnest soft indicating ligature wire and were not radiologically noticeable.

In another mandible, (Figs. 15 and 16), an additional nutrient canal was observed bilaterally and distal to the inferior surface of the fossa of the mandibular canal. The shorter one was 1,9 cm in length, and the longer one 3,2 cm in length. The indicating wire permitted one to observe radiologically that both canals were inferior but parallel to the mandibular canal. On the radiograph of the right side, the mylohyoid groove gave the appearance of being an additional canal.

The mental foramen

The number of mental foramina

There was at least one mental foramen found on each side of all the mandibles studied. As previously stated, in excess of 400 mandibles were originally inspected and this was found to be the case in all the mandibles. Of the 79 mandibles in the survey, one could not be included here as the bone was fractured in the region of the mental foramen, and the foramen could not be seen. Thus of the 78 mandibles the following additional mental (Figs. 21 to 23 and 36) and accessory nutrient foramina were noted:

Table X The number of mental and accessory mental foramina

	No. of Mental foramina		No. of Accessory foramina	
	2	3	1	2
Left	10 (13%)	0	10 (13%)	1 (1,3%)
Right	8 (10,4%)	1 (1,3%)	7 (9,3%)	1 (1,3%)

Direction of the mental foramen

When describing the direction that the mental canal or foramen faces, the mandible was initially orientated in the standard horizontal plane so that the mental canal or foramen could be observed from the lateral aspect. Depending upon the position of the eye of the observer in order to look straight into the canal, the inclination of the canal was classified as facing upward, upward and backward, backward or forward.

For the sake of clarification, it must be explained that the foramen was never described as facing outward as, in addition to any other direction, it does so in every case to a greater or lesser extent. (Table XI)

Table XI Direction of the mental foramen

	backward	upward and backward	upward	forward	oval
Left	12	28	13	1	22
Right	4	36	19	1	16

Thus the canal faces either upward and backward or upward in 72,4% of cases on the left side and 53,9% on the right.

An additional type of mental foramen, the oval type, presented in 21% of cases on the left and 28,9% of cases on the right, was observed (Table XI) which has not been recorded in the literature. The foramen is oval in shape (as is mentioned in the literature) but very superficial, in that there is no mental canal and the foramen faces directly buccally (Figs. 34 and 35).

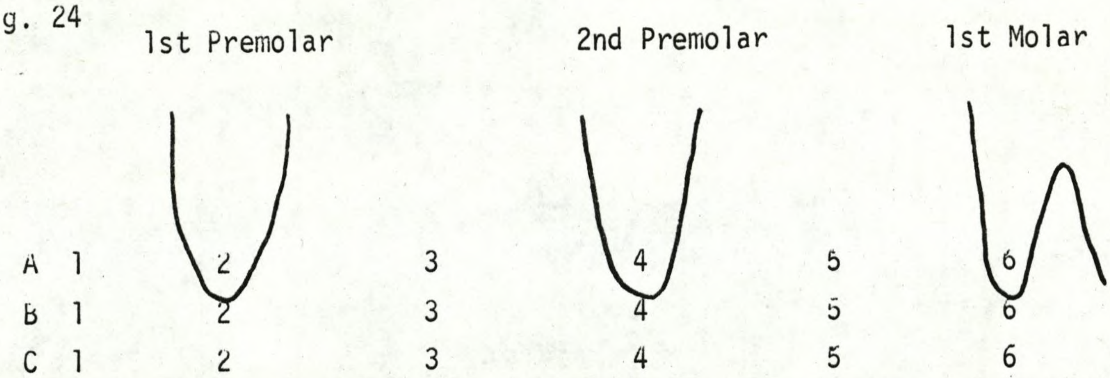
On looking towards the posterior angle of the mental foramen, the end of the mandibular canal can be observed and, in the anterior corner of that foramen, the beginning of the incisive canal can be seen. The mandibular and incisive canals were seen to lie in a plane only just deeper than the mental foramen. The shape of these foramina was not always the same bilaterally. One such foramen was found to have a length of 7 mm. The longer and more oval the mental foramina appear to be in shape, the more superficial the mandibular and incisive canals appear to be in position, that is, there appears to be a complete absence of the mental canal. If all the mandibles found with this type of canal were edentulous in that area, it could be postulated that this is possibly part of a resorption process, but this was not the case.

Relationship of the mental foramen to the teeth

The distance from the superior rim of the mental foramen to the apex of the nearest tooth, or to a line drawn through the apices of the nearest teeth on either side of the foramen, was measured. No counts were made where there were no teeth in that area. The positions were classified as follows (Fig. 24):

A the foramen appears above the apices of the teeth
B the foramen appears touching the apices of the teeth
C the foramen appears inferior to the apices of the teeth

Fig. 24



From the aforegoing diagram,the mental foramen was found to lie in the following positions:

TABLE XII The relationship of the mental foramen to the apices of the teeth

Left side			Right side		
Site	No.	%	Site	No.	%
B3	4	6,5	B2	1	1,7
B4	10	16,1	B3	2	3,4
B5	5	8,1	B4	12	20,3
C3	11	17,7	C3	8	13,6
C4	25	40,3	C4	29	49,2
C5	7	11,3	C5	5	8,5
			C6	2	3,4

Thus, on the left side, the mental foramen was seen to lie most commonly at, or inferior, to the apex of the second premolar tooth, that is in 35 cases (59,4%); between the premolar teeth in 15 cases (24,2%) (Table XII). On the right side, the position where the mental foramen was seen to lie most commonly, was at, or inferior to, the apex of the second premolar tooth, that is, in 41 cases (69,4%) and between the premolar teeth in ten cases (16,9%). Only two cases were found where the foramen lay inferior to the medial root of the first molar tooth. In both these cases, it was difficult to decide whether to classify them as lying in position C6 or C5 (Fig. 13).

It must be noted that in position A, the mental foramen would lie above the apices of the teeth. In many cases the inferior rim of the canal actually lies opposite,or only just above,the apices of the teeth. In no case was the mental foramen found to be above this position. Thus, the mental foramen is never found superior to the region of the apices of these teeth.

The position of the mental foramen varies in relationship to the apices of the teeth when examining the relationship visually and on radiographs.

To give an example: the mental foramen may appear visually to lie between the apex of the second premolar tooth and the mesial root of the first molar tooth; on the radiograph it may, however, be seen to lie at the apex of the second premolar tooth; therefore, the canal lies more anteriorly, radiologically, than it would appear to be when inspecting the mandible visually.

The crowns of the teeth are normally slightly anteriorly tilted, and this may account for the optical illusion. As the Xray beam was constantly vertical to the horizontally lying mandible, the error of parallex is not considered in this instance, as the cause of the movement in position of the mental foramen. On visual examination it is also difficult to decide on the exact position in the vertical dimension in the relationship of the mental foramen and the apices of the teeth.

However, on the radiographs the vertical position of the mental foramen was never found to be superior to the apices of the teeth. On the contrary, however, the mode radiological position of the mental foramen was just inferior or up to 8 mm inferior to the apices of the teeth.

Where the mental foramen lay inferior to the apices of the teeth, that distance varied between 1 mm and 8 mm. On the left, the mean was 2,7 mm and the median 2 mm, while on the right the mean was 3,2 mm and the median 3 mm. Thus the possibility does exist that the mental foramen may lie slightly more inferiorly on the right side.

In one mandible, (Fig 29) where severe periodontal bone involvement extended to the apex of the teeth in the premolar area, the superior rim of the mental foramen was damaged. However, from only one case, one cannot postulate that severe periodontal bone destruction will normally lead to damage of an adjacent foramen.

During the search at the Department of Anatomy for suitable mandibles that would lie within the framework of this study, an edentulous mandible was found (Fig. 30), similar to the one described by Gabriel (1958). It shows exposure of the mandibular canal on the left side, in the region of the second molar tooth. The mandibular canal is converted to a groove with approximately the same depth as the normal mandibular canal. As the 'canal' or groove runs forward it becomes shallower. In the region of the mental foramen, the groove once again becomes intra-osseous for a distance of 6 mm to 7 mm and then the canal once again converts to a shallow groove which runs virtually to the symphysis. On this hemimandible, there is a second canal commencing in the retromolar pad area, running a superficial intrabony course for a distance of 1 cm and then joining the mandibular canal. On the right hand side of the same mandible, the mandibular canal becomes superficial for a distance of 8 mm in the region of the first molar tooth. In its course anteriorly, the groove again acquires a bony covering which extends to the region of the mental foramen. In addition, also on the right hand side, a canal is again seen to commence in the retromolar pad area, running a superficial intrabony course for a distance of 1,3 cm, and then converting into a groove which continues into the mandibular canal in the region of the first molar tooth. Thus, this does indicate that the two nerves on each side join in the region of the first molar tooth.

The mandibular nerve, except for part of its mental branch, is generally accepted as running an intra-osseous course, from its entrance into the bone at the mandibular foramen to the region of the symphysis. In the photographs (Figs.25 and 31 to 33) there appear to be two mental foramina (in addition to the accessory nutrient canals). There is a depression in the bone between the two foramina, suggesting that part of the nerve here runs an extra-osseous course for approximately 5 mm to 6 mm. Here the nerve runs a course, initially anteriorly, and then also antero-medially as it enters the incisive canal at what must be described as the incisive foramen, and not at what was previously considered as the more anteriorly situated second mental foramen. It continues anteriorly as the incisive nerve, or possibly joins up with the rest of the intra-osseous incisive nerve which then runs forward along its accepted course. The size of the lumen of the mental foramen is much larger than the calibre of the lumen of the incisive foramen. A possible explanation for this is that the mandibular nerve consists of the mental and part, or all, of the incisive nerve before they divide. The mental nerve has mainly an extra-osseous path (except for the mental canal) whereas the incisive nerve alone continues forward on its intra-osseous path. This type of double mental foramen may appear bilaterally.

The two foramina lie in the same horizontal plane and there is a definite groove between these foramina where the incisive nerve winds its extra-osseous way anteriorly and then antero-medially. The direction of the posteriorly-situated mental foramen is also an exception to the generally accepted rule in that it opens to the exterior in an anterior direction. It is clear that, since the incisive nerve runs forward and then medially into the bone, the more anteriorly-situated foramen will appear to be opening in a posterior direction to allow entry to it. Thus the more posterior foramen can be considered as the true mental foramen and the more anterior one as the incisive foramen of the mandible.

If the above is not considered to be the case, then it must be considered as a further example of two mental foramina where,in each case, a part of the continuing mental nerve exists separately. However, this would not explain the directions of the foramina, the fossa between the foramina or the lack of continuity between the more anterior foramen and the more distally-placed mandibular nerve. This then can also be considered as a further variation of the mental and mandibular canals.

Statistically,there is no correlation, on either side, in the distance between the postmental segment and the distance on the mandible horizontally, (distal to the mandibular foramen) which could indicate that the increase in growth of the former is not associated with growth in the latter.

There is a strong positive correlation between the postmental distance and the total length of the mandible on both sides, which could indicate that growth of the former affects the length of the latter.

There is no correlation between the premental and the postmental segments on either side. This could indicate that the increase in the total length does not indicate an increase in the postmental segment. This could suggest that the growth in the postmental segment area does not correlate with growth in the total length of the mandible. Alternatively, this could suggest that there is more growth in the premental segment than is generally realised. For if this were so, the increase in length of the body of the mandible would occur mainly in the postmental segment due to condylar growth. The findings are thus in agreement with Moss (1960) who noted that the length of the premental and postmental lengths of the body of the mandible remain proportional throughout life.

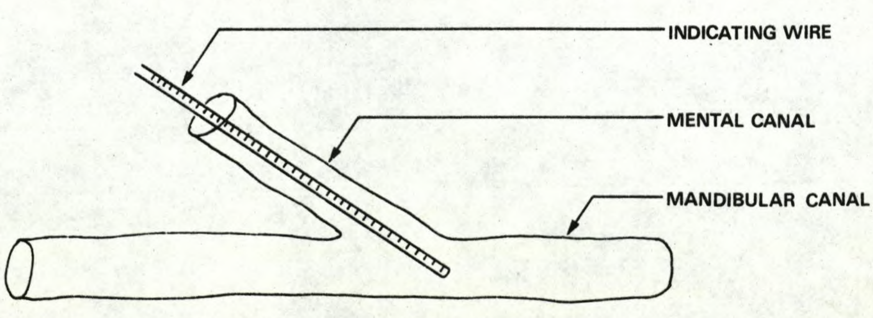
There is no correlation between the premental distance and the total width of the ascending ramus on either side which could possibly indicate that the growth pattern of the former has no relationship with the growth pattern in the latter.

As there is no statistical correlation between the premental and the postmental distances of the mandible, the mental foramen can not be used in an antero-posterior direction as a reference for measurements. This is in agreement with Sweet (1959), whose study on dry mandibles provided sufficient proof that there was not a single point along the body of the mandible, including the lower border, that could constantly be used as a set reference point for measurements in the horizontal or the vertical plane.

The mental canal

No attempt was made to measure the length of the mental canal in those mandibles where that canal was present as there was no way of ascertaining where the canal ended. From the diagram (Fig. 40), it can be seen that the mental canal enters the incisive canal at an angle that varies from subject to subject depending on the direction of the canal; there is no way of telling when the brass measuring wire has passed from the mental into the mandibular canal. Thus it could not be determined with certainty what the average length of the mental canal in any age group was.

Fig. 40



With the growth in width of the face, the mandible widens correspondingly (Last, 1963). This overall growth in width of the mandible takes place, as with all bones of the body, by a process of moulding which results from a harmonious deposition of new bone and the resorption of old bone where required - thus allowing for a canal. This may explain why the mental canal forms. At the same time it may be a rational explanation, in the case of the oval mental foramen, why there is no mental canal formed as it must have resorbed during the process of remoulding.

The relationship of the mylohyoid groove to the mandibular canal

The relationship of the mylohyoid groove to the mandibular canal was noted on radiographs. In some cases where the canal was very shallow,only the brass wire,pasted with Scotch tape in the groove, delineated the position of the mylohyoid groove. Had the wire not been so placed, the position of the groove could,in many cases, not have been localised. Where the mylohyoid groove lies lingually to the mandibular canal there was often overlapping of the indicating wires, creating the impression that the groove lies in the mandibular canal.

Just anterior to the mandibular foramen,the commencement of the mylohyoid groove has a close relationship to the mandibular canal. As the mandibular canal proceeds anteriorly, this relationship does not remain constant. The mandibular canal runs firstly downward and forward and then mainly forward, whereas the mylohyoid groove continues to run downward. Thus,the further anteriorly on the mandible the structures are compared, the further apart they lie, with the mylohyoid groove taking up the more inferior position. The relationship of the mandibular canal to the mylohyoid groove was observed for a distance of 5 mm after the commencement of the mandibular canal. From a technical point of view the 5 mm indicating wire could, however, not always be placed in a constant position. This position was chosen as this is the site where the mandibular canal and mylohyoid groove have the closest and most constant relationship.

It was noted further that fairly deep and/or wide mylohyoid grooves were often not observed radiologically, while, at other times, relatively shallow mylohyoid grooves were observed radiologically. Thus, the presence radiologically of the mylohyoid groove is no indication of the size or depth of that groove.

A random sample was carried out on 25 mandibles to compare the mylohyoid groove with the rim of the foramen of the mandibular canal to determine whether the mylohyoid groove affected the shape of the mandibular foramen. On only ten out of the 25 mandibles, was the anatomy on the left and right sides the same. An attempt was made to find out whether the anatomy of the foramen is affected by the position and relationship of the mylohyoid groove. The following findings were made.

The mylohyoid groove commences on the rim of the mandibular foramen but does not notch the rim.	(8 sides 16%)
The mylohyoid groove commences on the rim of the mandibular foramen and there is a notch on the rim.	(18 sides 36%)
The mylohyoid groove commences inferior to the rim of the mandibular foramen and does not notch the rim.	(8 sides 16%)
The mylohyoid groove commences inferior to the rim of the mandibular foramen and there is a notch in the rim.	(12 sides 24%)
The mylohyoid groove commences inferior and distal to the rim of the mandibular foramen and does not notch it.	(2 sides 4%)

On the twenty-fifth mandible, the mylohyoid groove commenced as a canal from within the mandibular canal. Thus there was no contact or association with the rim of the mandibular foramen. On the left side, the rim was notched while on the right side the rim was smooth with no sign of a notch.

The aforegoing findings indicate that the position of the mylohyoid groove does not affect the shape of the mandibular foramen.

Where the brass wire was placed in the mylohyoid groove, the relationship with the mandibular canal was the following:

Table XIII The mylohyoid groove

	No groove	Inferior	Lingual	Superior
Left side:	1	56 (70,9%)	21 (27,3%)	1
Right side:	1	58 (74,4%)	19 (24,4%)	-

Thus, 5 mm anterior to the mandibular canal, the mylohyoid groove lies inferior to the mandibular canal in over 70% of cases and lingual (medial) to it in approximately 25% of cases (Table XIII). One case was found where the groove lay superior to the canal on the left side. Slightly more anteriorly, it dropped into the position where one would expect it to be found. On one mandible no mylohyoid groove could be seen on either side. This would be a normal finding in that part of the mandible where the mylohyoid groove is converted into a canal, but no canal was seen on either side.

The mylohyoid canals

There were eleven mandibles (14,3%) where the mylohyoid groove was converted into a canal on the left side and ten mandibles

(13%) with a mylohyoid canal on the right side (Figs. 41 to 46). Of these, eight canals (10,1%) on the left side, and seven canals (8,8%) on the right side, commenced from within the mandibular canals. Thus the majority of mylohyoid canals commenced from within the mandibular canal, that is, 15 of the 21 cases.

Where the mylohyoid groove is converted into a canal, the bone covering that canal on the lingual side of the mandible is completely smooth with not the slightest indication of a groove along the entire length of that canal.

There was no correlation between those mandibles with mylohyoid canals and those mandibles having either canals in the roof of the mandibular canal or those with canals leading to the apical area of the last molar tooth.

There was also no correlation found between the above mandibles and those with accessory mental foramina. Thus it cannot be said that where multiple canals are found, they tend to occur on one mandible.

Accessory canals around the mental foramen

Because of the small number of accessory nutrient canals found around the mental foramen (Figs. 37 to 39), no attempt was made to distinguish or classify them into the major or the minor types of foramina.

On the left side, 11 mandibles (14,1%) had at least one accessory canal and one mandible had two accessory canals; while on the right side, 21 mandibles (26,6%) had accessory canals with 11 mandibles (14,1%) with one, seven mandibles (8,9%) with two canals, and one each with three, four and five accessory canals.

Many nutrient canals of a small calibre were observed on the anterior surface of the mandible up to 1 cm from the symphysis. None of these canals were considered as additional mental foramina, due both to their size and location.

Additional canals leading off the mandibular canal

In some cases, on looking down the mandibular canal through the mandibular foramen from the distal aspect of the mandible, one could observe a canal opening in the roof of the mandibular canal.

In two instances (Figs. 18 and 19), a wire could be pushed down this canal and it surfaced in an opening at the junction of the body and the anterior portion of the ascending ramus of the mandible.

In another case (Fig. 17), the wire showed that the canal had a convexity upward but then ended close to the mandibular canal. In all probability the canal continued further anteriorly than the wire indicated and, judging by the direction of that canal, it rejoined the mandibular canal.

In those cases where an existing wire could be inserted into that canal (Figs. 14 and 15), it was noted in the vertical radiographic view that the canal lay as far buccally to the teeth as did the mandibular canal. In the vertical view, they actually appear to overlap each other, whereas the horizontal views show them to diverge and converge again.

There were nine canals (11,4%) on the left and five canals (6,5%) on the right side leading off the mandibular canal.

5. DISCUSSION AND CONCLUSIONS

Lateral ramus prominence

Lateral ramus prominence and antilingula are the terms most commonly used to describe the protuberance of bone on the buccal side of the ascending ramus. The findings of this study show that this structure is present in slightly more than 50% of mandibles and, where found, is situated opposite the lingula in approximately 20% of cases (that is, 10% of all mandibles). The author thus feels that the term antilingula is not an appropriate one whereas lateral ramus prominence, is a more fitting and descriptive term which should be used for the sake of uniformity. Hence, the author concurs with Langston and Tebo (1977) who suggest that the term lateral ramus prominence be adopted in order to provide uniformity of nomenclature and clarity of descriptive expression.

The findings of this survey agree with those of Yates et al (1976) who found the lateral ramus prominence to be present on palpation and inspection in less than half of 70 mandibles inspected. The author disagrees with the above authors regarding its situation as, of the 83 lateral ramus prominences found, only one lay anterior and seven antero-superior to the lingula. Where one groups the lateral ramus prominences that lie anterior, antero-superior and superior together then 51 (61,4%) of the 83 lateral ramus prominences lie in this group. Those that lie superior to the lingula constitute 43 of the 83 (51,8%). There are ten lateral ramus prominences (12,2%) lying postero-superiorly as opposed to seven (8,4%)

lying antero-superiorly. These findings thus disagree with those of Langston and Tebo (1977) who found the L.R.P. to be present in all the mandibles examined.

The findings in this survey show that proportionately the lateral ramus prominence occurs as frequently in the male as the female. Yates et al (1976) are correct in stating that this structure is a highly variable anatomical landmark.

The mandibular foramen

As stated previously, seven mandibles were observed with two distinct mandibular foramina on one side but none could be observed radiographically. No mandible had two mandibular foramina on both sides. The mandibular fossa, postero-superior to the mandibular foramen, does make that foramen appear radiologically more posterior than it is situated. The present findings on the position of the mandibular foramen are the same as those of Hayward, Richardson and Malhotras (1977), when measuring the position of the mandibular foramen radiologically, namely that, if one divides the ramus of the mandible vertically into segments from anterior to posterior, the mandibular foramen is located distal to the middle of the ramus in the third segment.

The findings in the survey on the position of the mandibular canal are not in agreement with Sicher and DuBrul (1975), Warwick and Williams (1973), or Scott and Dixon (1978).

The position of the mandibular foramen cannot be localised radiographically by following the cortical margins of the mandibular canal. Due to the small sample in each age group, no conclusions have been suggested regarding the change in position of this foramen with age.

The distance superiorly, from the anatomical position of the mandibular foramen, to either the mandibular notch or to the apex of the head of the condyle, was measured. As the condyle is part of the mandible, the measurement should be from the apex of the condyle. The mandibular foramen is then situated where the lower third and the middle third of the mandible meet.

Should one measure the distance from the mandibular foramen to the mandibular notch superiorly, then the foramen lies in the middle of the mandible on the medial side, but then it is necessary to mention that the length of the condyle was not included in the measurement.

Langston and Tebo (1977) measured the distance on the mandible from the lateral ramus prominence to the mandibular notch. In the horizontal plane these authors measure through the most inferior part of the mandibular foramen, at this level, from anterior to posterior.

The mandibular canal

At least one mandibular canal was found on every hemimandible examined in the survey. None of the seven mandibles, with two mandibular foramina (and thus two mandibular canals for at least a short distance), showed a second mandibular canal radiographically. There is no reason to believe that a second mandibular canal can not be seen radiographically. According to the classification of Nortje et al (1977b) the possible existence of the canals can be explained as follows:

Type 1: Here there are two canals of equal length originating from a single mandibular canal. As the second mandibular foramen (and therefor the canal) found in the survey was much smaller than the main canal, this possibly could have been a mylohyoid groove that appeared radiographically as the second mandibular canal. (Fig. 20).

However, the commonest type of accessory canal found in the region of the mandibular foramen is that type commencing distally to the mandibular foramen along the inferior cortical border of the mandibular fossa and there is no reason why this could not have been seen by the above authors as this type of double mandibular canal. (Figs. 11 and 16).

Type 2: Canals were found commencing in the roof of the mandibular canal and these could have appeared as the shorter upper canal. (Figs. 14, 15 and 17).

Type 3: This type is problematic but very possibly could be a case of the genuine double mandibular canal and, for that reason, Nortje et al (1977b) found it to be the least common type of double mandibular canal.

Arensburg and Nathan (1979) had reason in some cases to suspect that certain of the double mandibular canals in some cases reported by Nortje et al (1977b) were mylohyoid grooves or canals but, on the other hand, some of them appear to have been genuine cases of double mandibular canals. (Figs. 6, 7 and 8).

From the description of Fawcett (1895), the mandibular canal runs in an S-shaped curve, vertically and horizontally, a fact which was first mentioned by von Reich (1980).

According to the classification of Carter and Keen (1971), the possible existence of the mandibular canal can be explained as follows:

Type 1: The mandibular canal here is in the position classically recognised by the anatomists.

Type 2: This could be the low type of mandibular canal according to Nortje et al (1977b) but, additionally, it appears to have a nerve commencing in the roof of that canal.

Type 3: Similar to Type 2 of Nortje et al (1977b), viz caused by the canal leading off the roof of the mandibular canal.

There exists a strong possibility that there are many more nerves commencing in the roof of the mandibular canan than were seen in the survey, but, because of lack of visibility, were not observed.

The position of the mandibular canal in the peripheral part of the body of the mandible must change with age. As the mental foramen becomes more superficial, so must the canal in that region. In extreme cases, the canal can be converted into a groove, (Fig. 30), as was also recorded by Gabriel (1958).

In the vertical relationship, the canal lies inferior to the first molar tooth in 57,4% of cases but slightly more buccally in the second molar tooth in 65,7% of cases. In relationship to the third molar tooth the canal lies along the buccal outline of that tooth in 53,7% of cases.

The mental foramen

The findings of the survey agree with those of Riesenfeld (1956), Kerr et al (1978), Scott and Dixon (1978) and De Villiers (1968) that there can be more than one mental foramen. The survey shows that there were ten (13%) double foramina on the left and nine (10,7%) on the right side. Riesenfeld (1956) found that there was a slightly higher frequency on the right side and, as his survey covers several thousand cases, the author feels it unwise to compare these findings statistically.

The direction of the foramen is posterior, superior or postero-superior in the great majority of cases in the adult mandible.

In the vertical relationship, this foramen is found in the region of the apices of the teeth, or more inferiorly particularly in the region of the premolar teeth. Here the author disagrees with Worth (1975), who states that it can be found even half-way up the root of the tooth. Sicher and DuBrul (1970), and Sweet (1943), state that the position is variable in the vertical plane but do not elaborate further. There is no doubt that in the bisecting-the-angle technique, the angle, at which the radiograph is taken varies from film to film and in different situations in the mouth and this will affect the position of the mental foramen as seen on the film. As the panoramic radiograph is also taken at an angle, this must also transpose the mental foramen to a higher level. This did not happen in the survey, as the same standardised lateral view was constantly used.

As one mental foramen was found on each side of all the dry mandibles examined, the findings do not agree with Sweet (1943) who found radiographically that the mental foramen was present in 50% of cases. Some reasons can be postulated for the difference in the findings as follows:

1) the mental foramen was inferior to the radiographic beam;
2) the mental foramen being situated buccally, can be hidden by the thickness of bone on an intra-oral film;
3) the increased film-object distance,due to the buccally situated foramen and the intra-oral film,may play an important role in the lack of clarity of outline of the foramen on the radiograph.

Although the film-object distance is not smaller in the panoramic radiograph, there is little between the mental foramen and the film that can absorb the rays, and thus, had Sweet (1943) done his survey on the panoramic radiograph, he would probably have found a much larger incidence or mental foramina present.

The commonest site for the mental foramen is at, or inferior to, the apex of the second premolar tooth in 65% to 70% of cases, between the premolar teeth in 17% to 20% of cases, allowing for the difference on the left and right sides. This is in agreement with Sicher and DuBrul (1970), De Villiers (1968), Hollinshead (1958), Scott and Dixon (1978) and Worth (1975). Kerr, Ash and Milard (1978) found that the mental foramen lies more commonly between the premolar teeth. As previously explained, this could be due to the medial tilt of the teeth, or an optical illusion.

The mental foramen can not be used as a set reference point for measurement, in either the vertical or the horizontal plane, because of the variation in shape, size and position of the foramen, the movement of teeth in the area of the foramen, and, finally, the age changes of the surrounding bone.

Accessory nutrient canals

Little importance can be attached to the nutrient canals since they occur in a haphazard position.

The mylohyoid groove

The survey broadly agrees with Arensburg and Nathan (1979) regarding the percentage of mylohyoid canals found, but disagrees with them regarding the separation of this canal from the mandibular canal. As the mylohyoid nerve is a branch of the mandibular nerve, there is no reason to believe that the two nerves should not, sometimes, run in a canal common to both of them for a short distance.

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THE PERSPEX PLATFORM

Fig. 3 Lateral view

Fig. 4 Frontal view

Fig. 5 The platform with two mandibles in position

Fig. 3

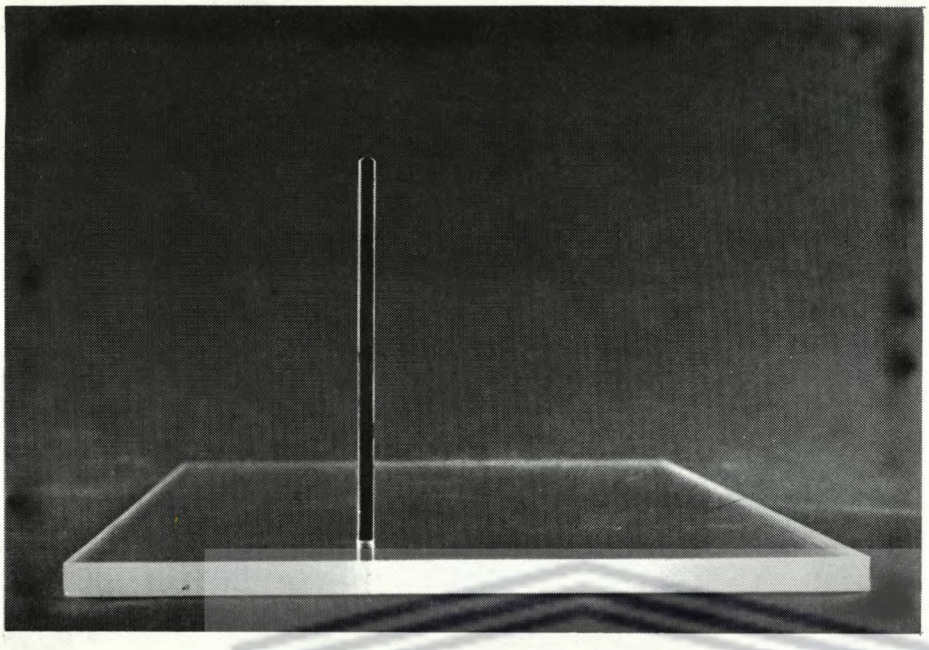


Fig. 4

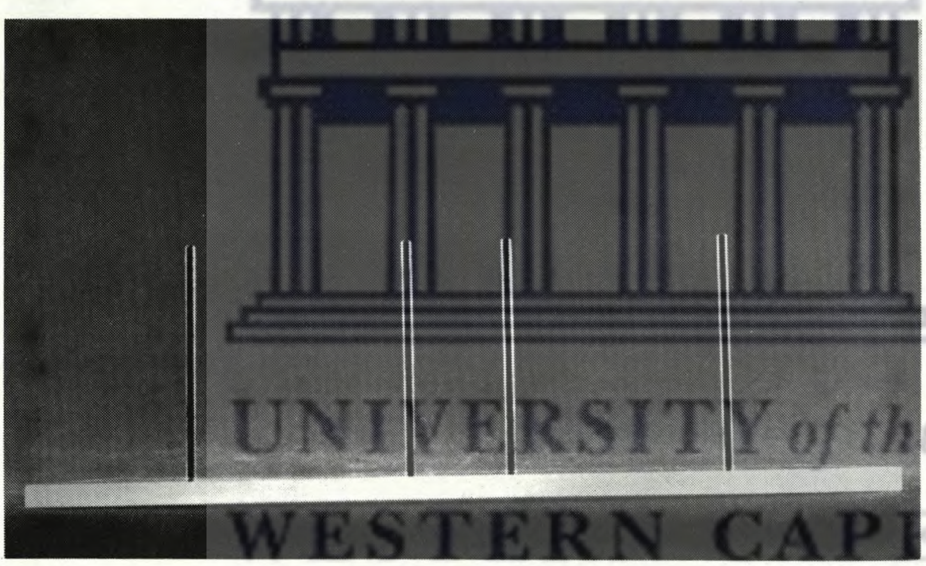
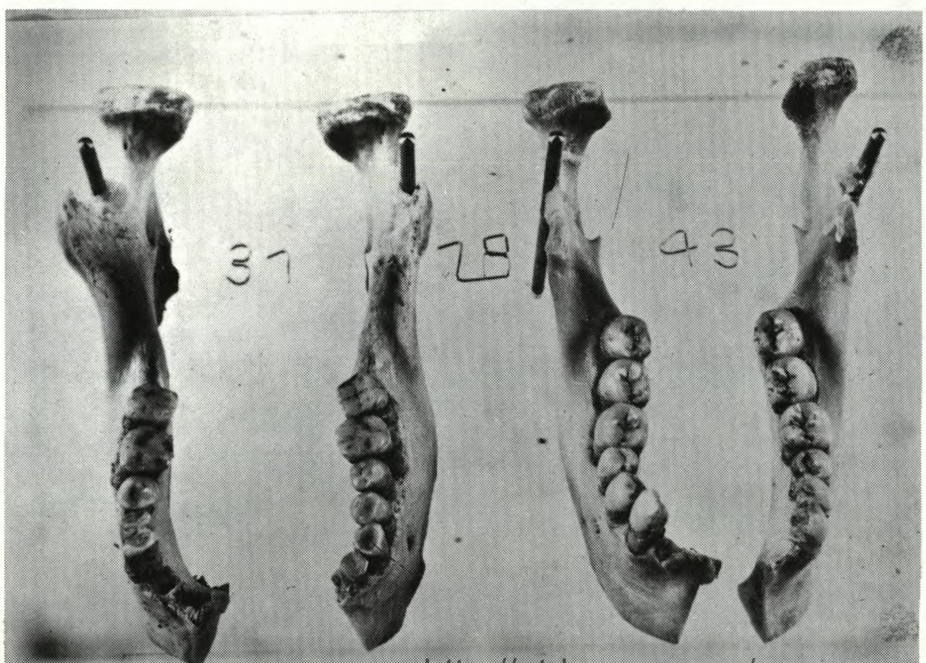


Fig. 5



Figs. 6 to 8

Double mandibular foramina.

Fig. 6

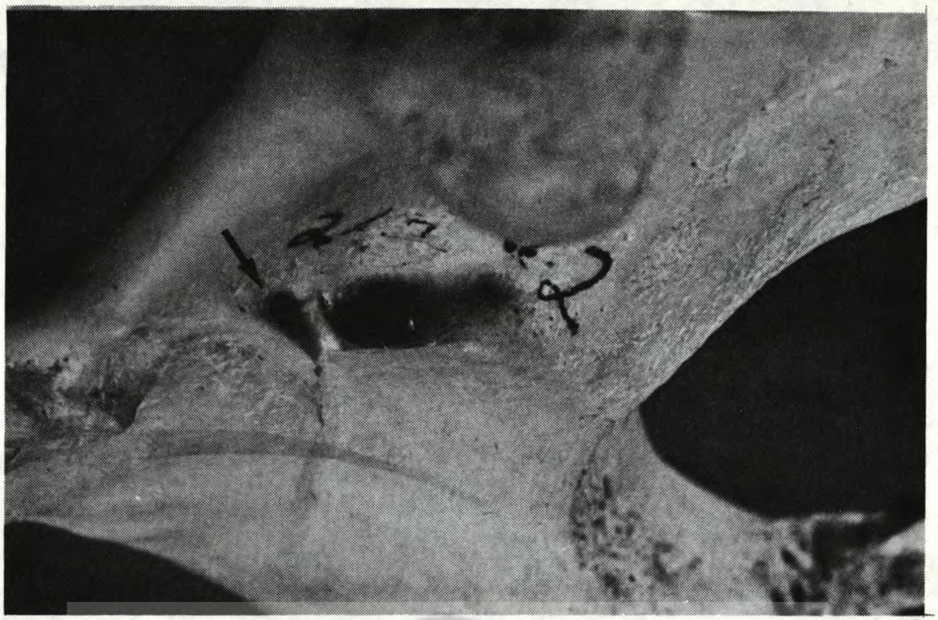


Fig. 7

Fig. 8

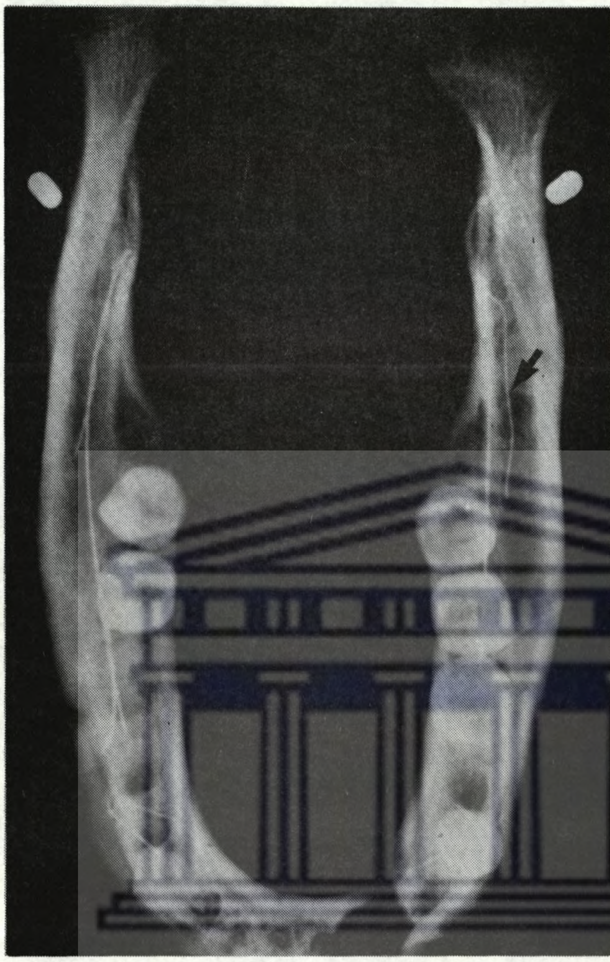


Fig. 10 A radiograph of the mandible in the vertical position. The right side shows the mandibular canal lying buccally to the last molar tooth. On the same side, the accessory canal, leading off the mandibular canal, appears to lie superimposed on the mandibular canal whereas on the left side it is not (arrow).

Fig. 11 An accessory canal joining the mandibular canal (large black arrow). Small black arrow indicates position of mylohyoid groove. The mental foramen can be seen inferiorly to the second premolar tooth (white arrow).

Fig. 12 The upper mandible shows a canal leading to the distal root of the third molar tooth (black arrow). The large white arrow indicates the brass wire in the mylohyoid groove, superimposed on the mandibular canal. More anteriorly, the small black arrow indicates the position of two mental foramina. The small white arrows, bilaterally, indicate the lingual canal. The lower mandible shows an accessory nutrient canal (black arrow) leading into the mandibular canal.

Fig. 13 Canals leading to the apex of the third molar tooth, bilaterally (small black arrows). L.R.P. present bilaterally as indicated by white arrow.

Fig. 11

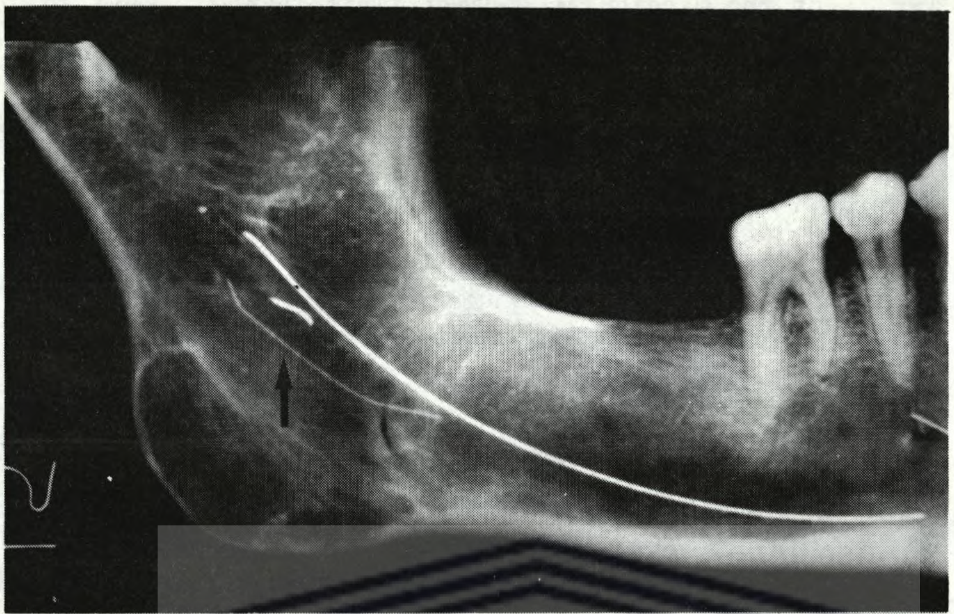


Fig. 12

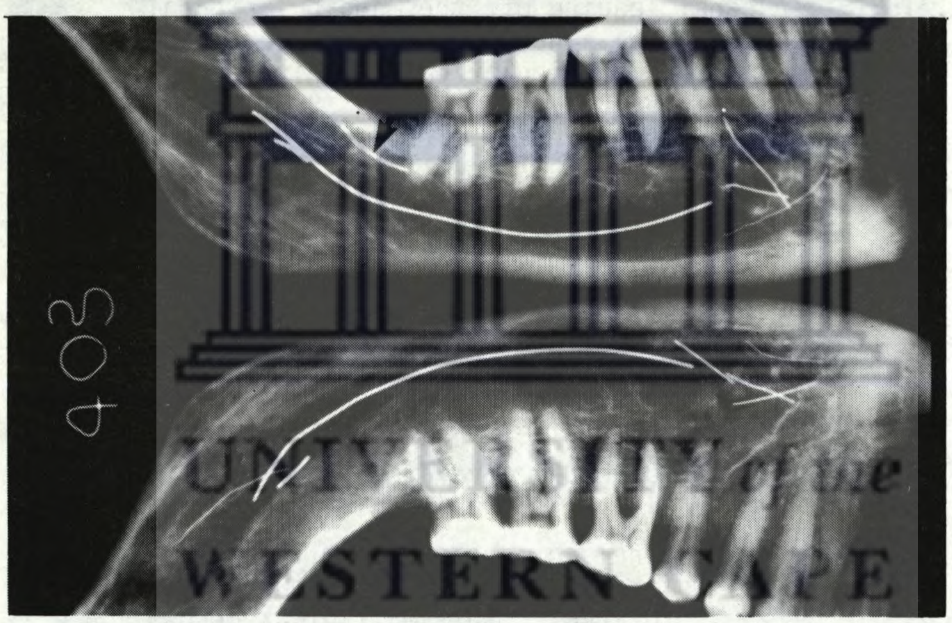


Fig. 13

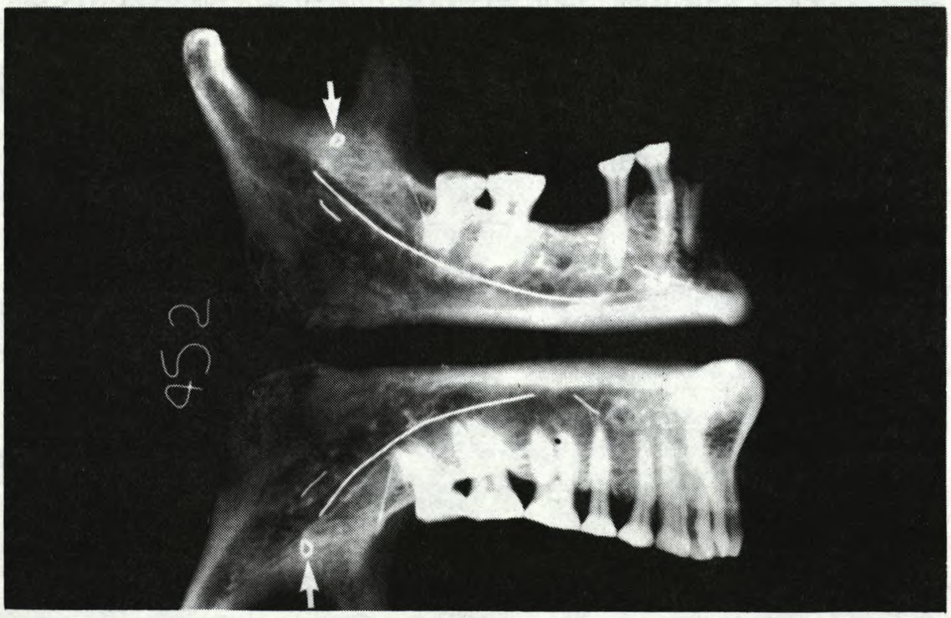


Fig. 14 A canal leading off the mandibular canal (black arrow). Accessory canal in the region of the mandibular foramen (white arrow). The mandibular canal runs close to the inferior border of the mandible.

Fig. 15 A canal leading off the mandibular canal (black arrow). The mylohyoid groove appears as a second mandibular canal (white arrow).

Fig. 16 i) Circular brass wire indicating L.R.P. (large black arrow).

ii) Canal commencing distal to the mandibular foramen and joining the mandibular canal (large white arrow).

iii) Mylohyoid groove appearing as second mandibular canal (curved black arrow).

iv) A canal commencing distal to the last molar tooth and running toward the apex of the tooth (small black arrow).

v) Mental foramen inferior to the medial root of the first molar tooth (small white arrow).

Fig. 17 A canal commencing in the roof of the mandibular canal and looping back towards that canal (black arrow).

Fig. 14

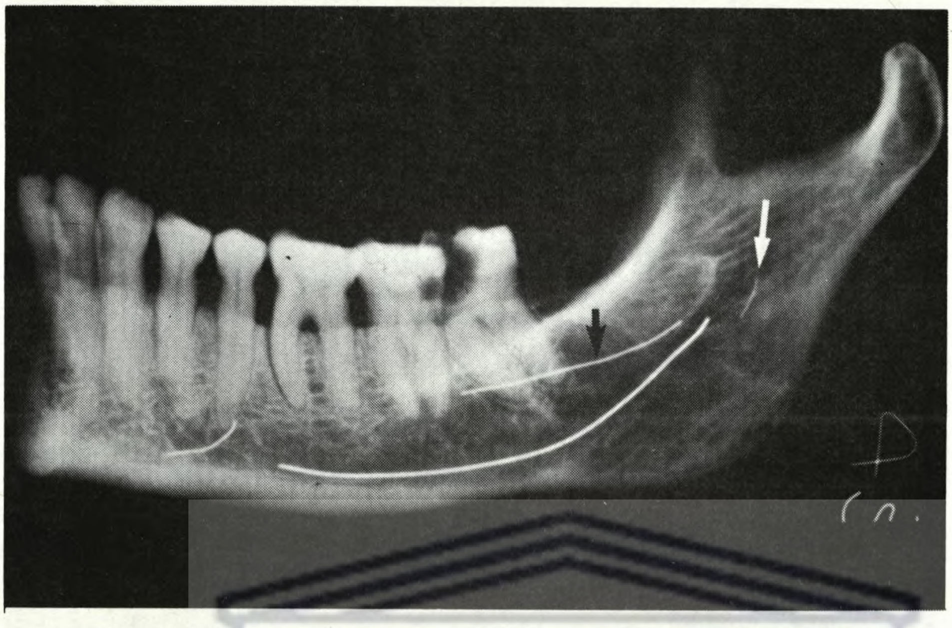


Fig. 15

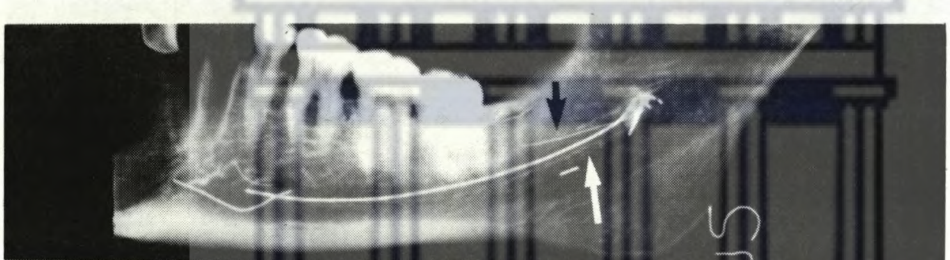


Fig. 16

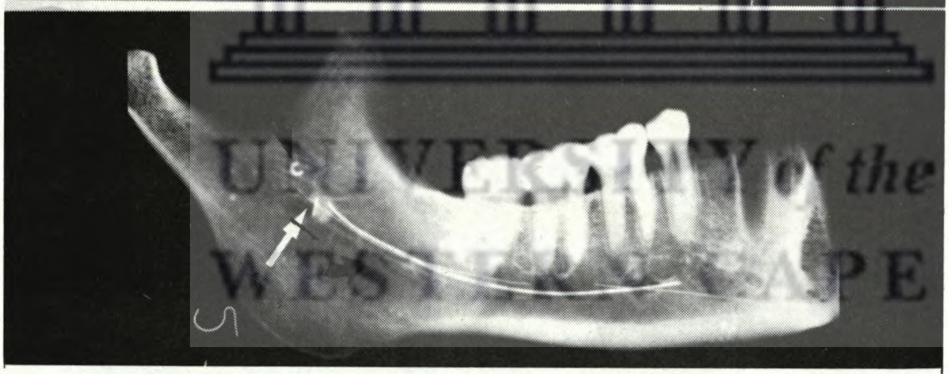


Fig. 17

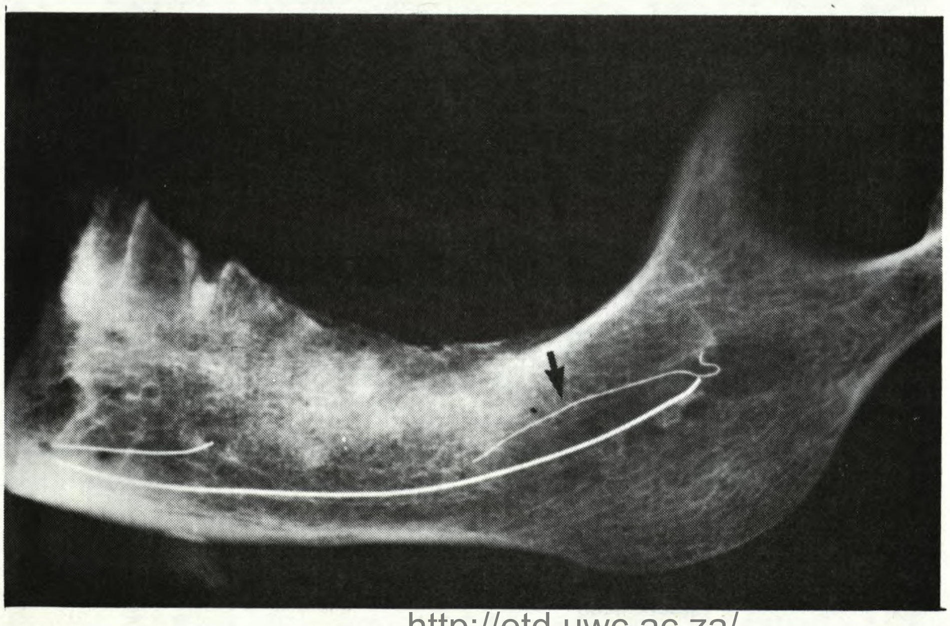


Fig. 18 to 19

Mandibular canals opening onto
the alveolar ridge.

Fig. 20

A mylohyoid groove appearing as a double
mandibular canal, bilaterally commencing
from one mandibular foramen.

Fig. 18

Fig. 19

Fig. 20

Figs. 21 to 23 Double mental foramina.

Fig. 21

Fig. 22

Fig. 23

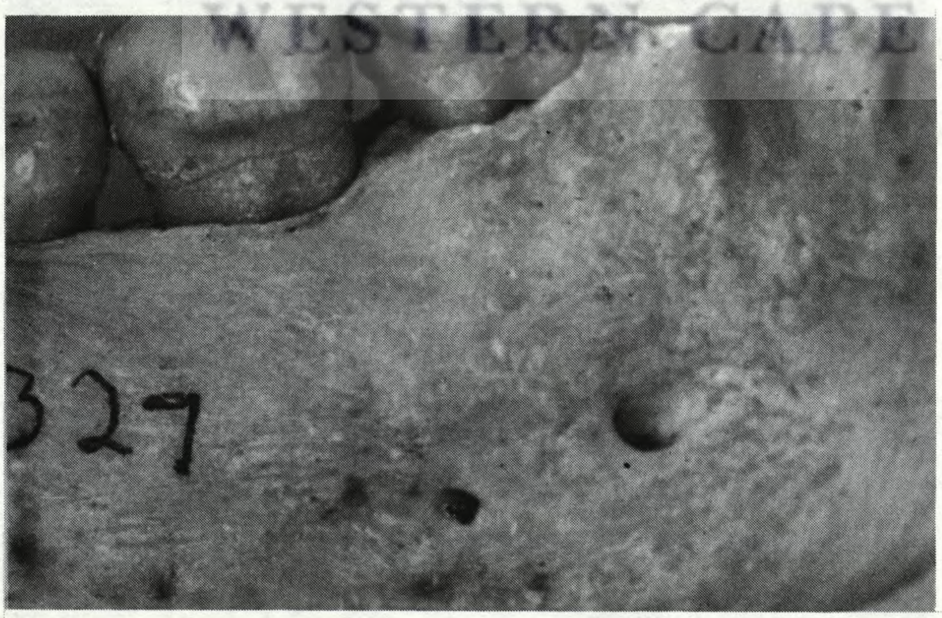


Fig. 25

An oval shaped foramen with two incisive foramina or, alternatively, a minor type of accessory mental foramen.

Fig. 26

The extra-osseous commencement of the incisive canal showing the distinct groove between the two foramina. An accessory foramen is seen in the groove.

Fig. 27

An unusual foramen leading off the mandibular canal or a variation of the mylohyoid canal.

Fig. 25

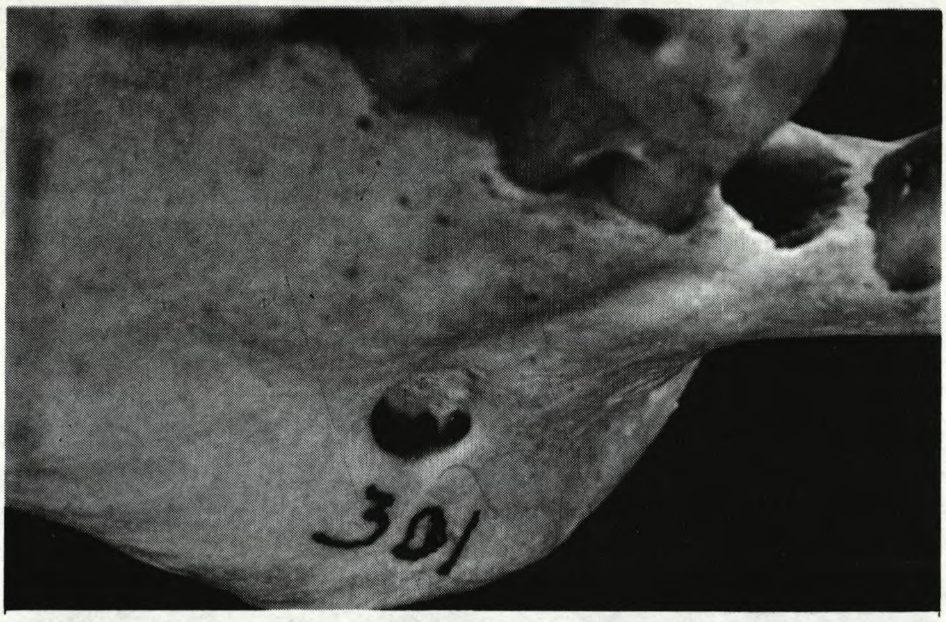


Fig. 26

Fig. 27

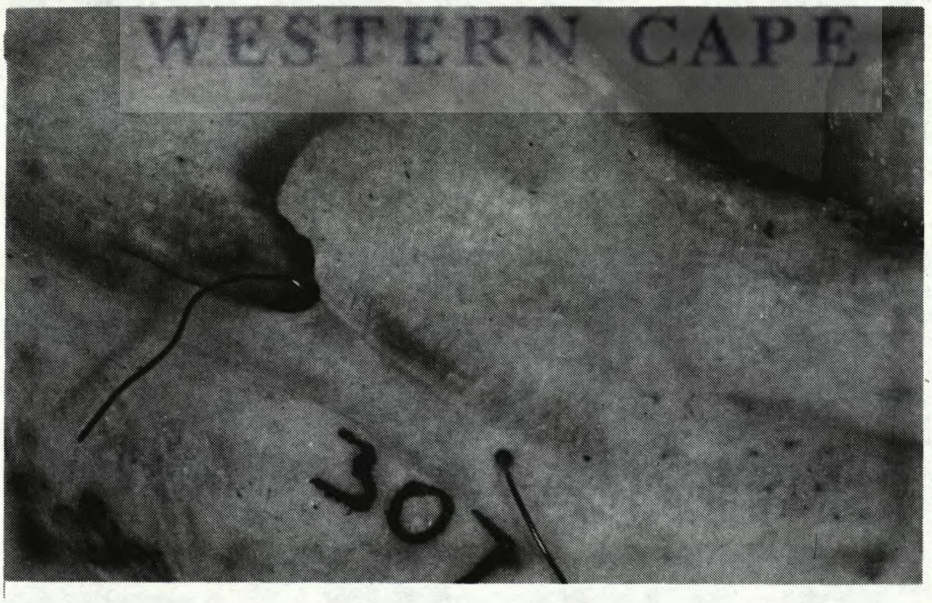


Fig. 28

Three additional foramina on the buccal side of a mandible.

Fig. 29

A damaged mental foramen due to the encroachment of periodontal disease.

Fig. 30

The conversion of the mandibular canal into a groove due to extensive resorption of bone. Nerve tissue is still visible in the posterior part of the lower mandible.

Fig. 28

Fig. 29

Fig. 30

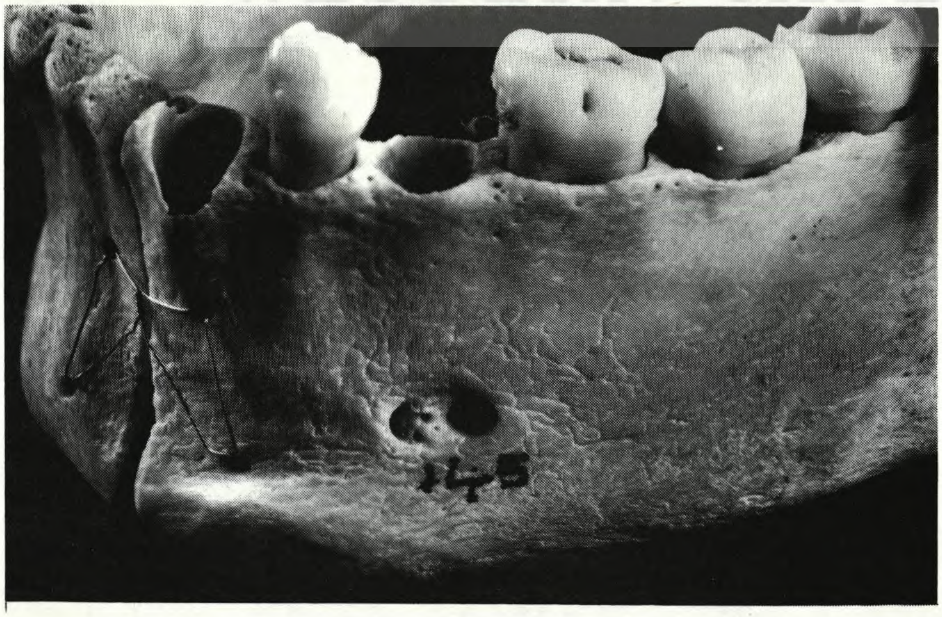
Figs. 31 to 33

Mandibles showing foramina for the exit of mental nerves and also foramina for the extra-osseous commencement of the incisive nerve. Hemimandibles No. 203 had belonged to one person. The groove between the two foramina in each case is clearly visible.

Fig. 31

Fig. 32

Fig. 33



Figs. 34 and 35

Oval mental foramina not possessing mental canals.

Fig. 36

A further example of a double mental foramen.

Fig. 34

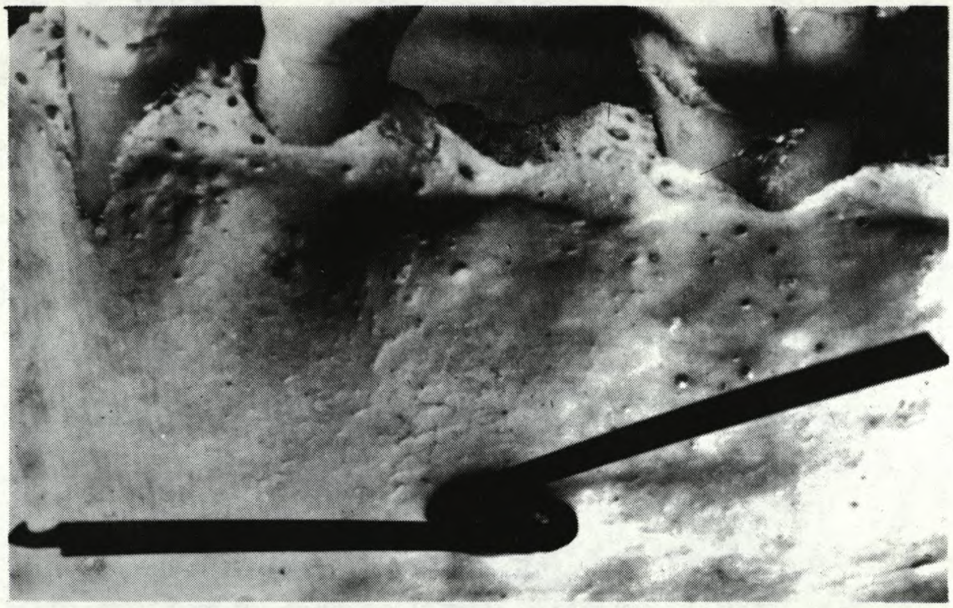


Fig. 35

Fig. 36

Figs. 37 to 39

Major type of accessory mental foramina.

Fig. 37

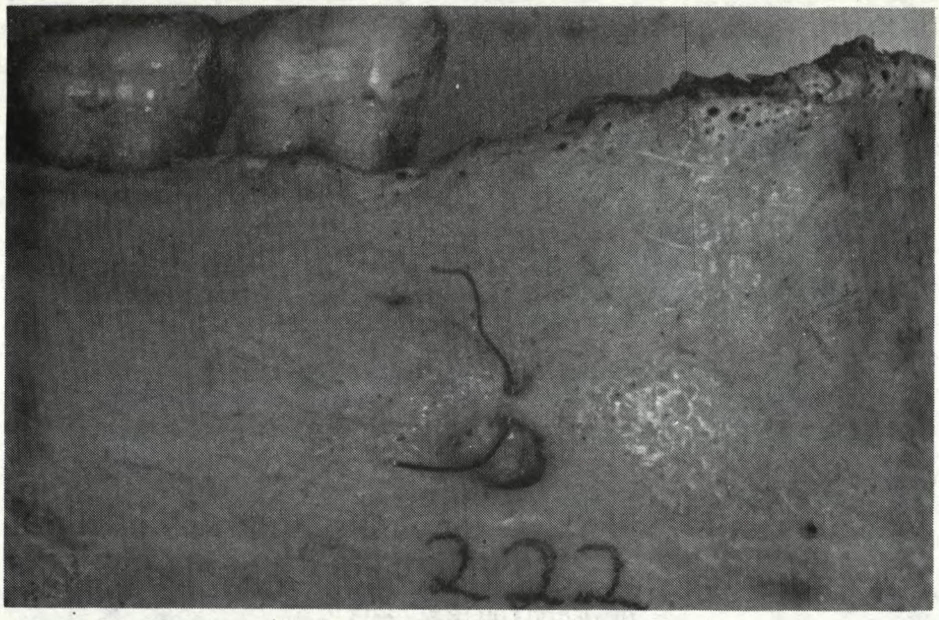
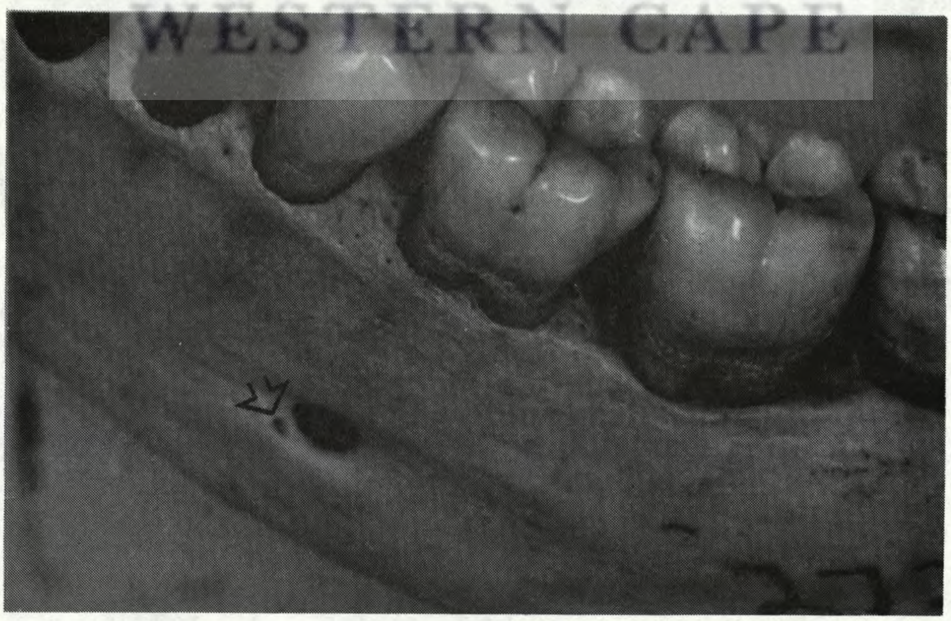


Fig. 38

Fig. 39



Figs. 41 to 46

Mylohyoid canals commencing from within the mandibular canal.

Note: i) The bone covering the canal in each case is completely smooth and shows no sign of a groove.

ii) Accessory nutrient canals (small black arrows).

Fig. 41

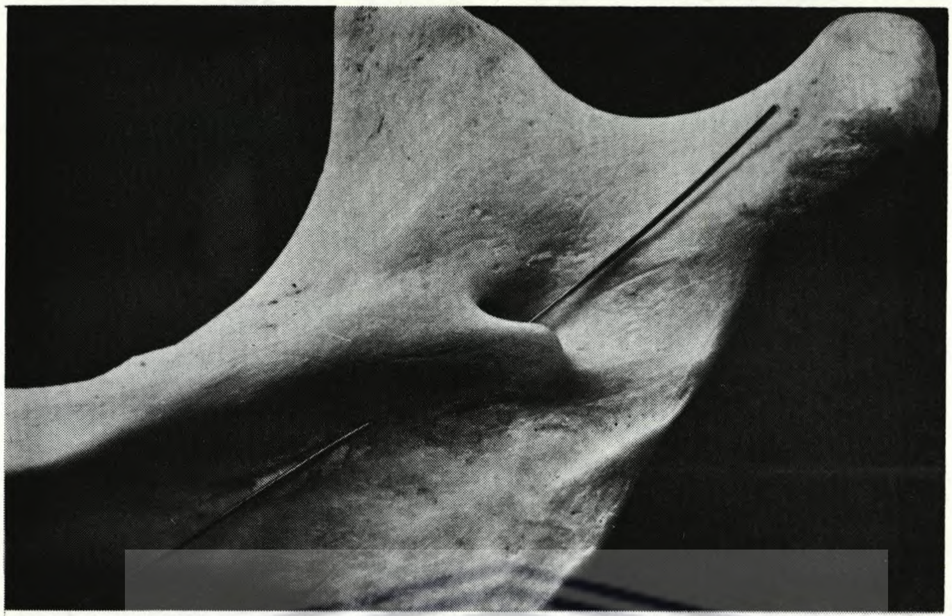


Fig. 42

Fig. 43

Figs. 44 to 46

Mylohyoid canals commencing from within the mandibular canal.

Note:
i) The bone covering the canal in each case is completely smooth and shows no sign of a groove.
ii) Accessory nutrient canals (small black arrows).

Fig. 44

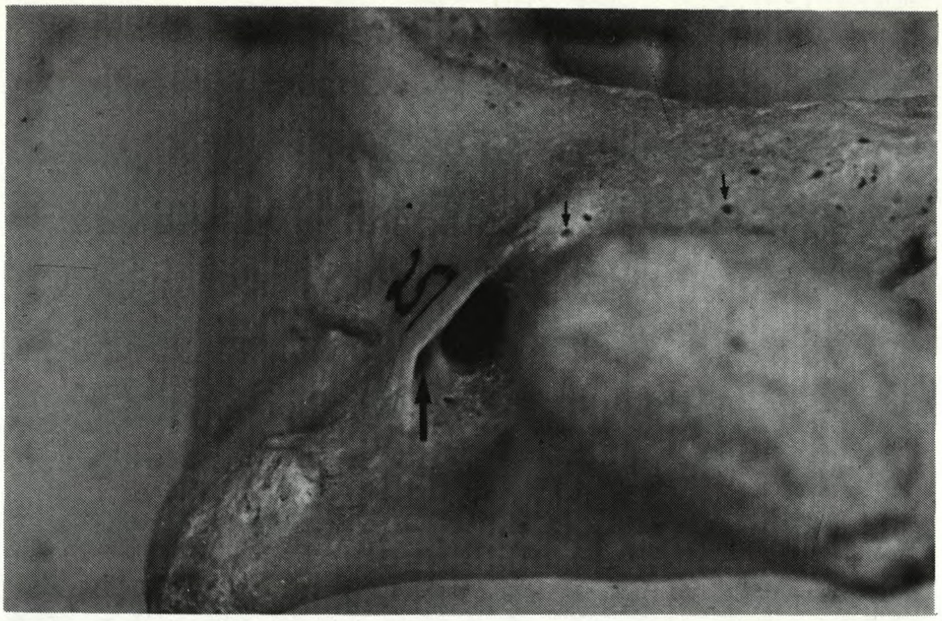


Fig. 45

Fig. 46

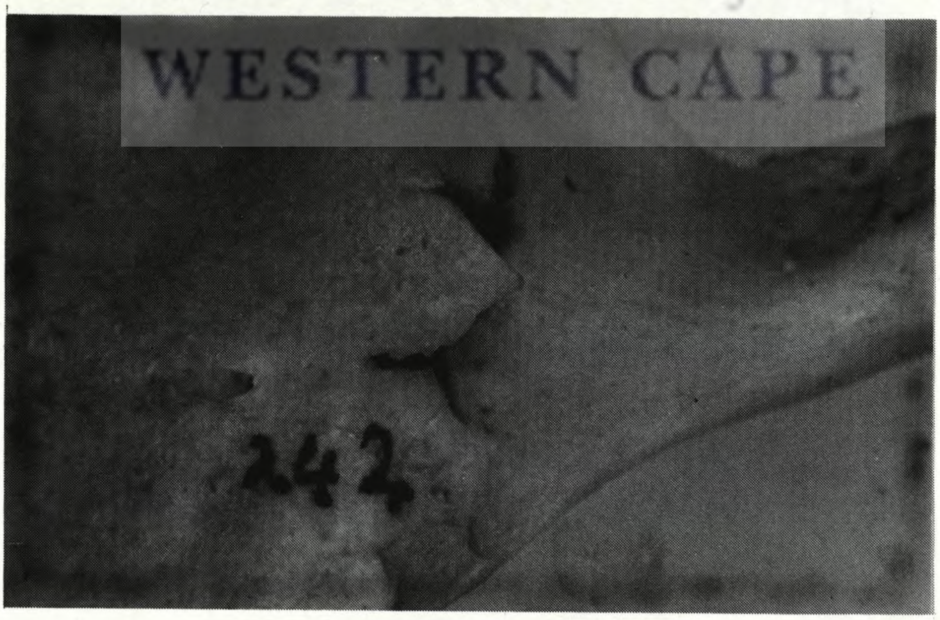


Fig. 47

Two unusually large foramina commencing distal to the last molar tooth on each side.

Fig. 48

Multiple nutrient foramina around the mandibular foramen. Brass wire indicator seen pasted in mylohyoid groove. The same mandible as seen in Fig. 11.

Fig. 49

Multiple nutrient foramina, one of which appears almost large enough to be classified as a second mandibular foramen. The arrow on the left indicates a mylohyoid canal commencing outside the mandibular canal.

Fig. 47

Fig. 48

Fig. 49