Università degli Studi di Milano

Dipartimento di Scienze biomediche, chirurgiche e odontoiatriche

Scuola di Dottorato in
Scienze Fisiopatologiche, neuropsicobiologiche e assistenziali del ciclo della vita

Ciclo XXV

Anatomic assessment of the anterior mandible and relative hemorrhage risk in implant dentistry. A cadaveric and CT scan study

SSD MED/28

Dott. Gabriele Rosano
Matr. R08652

Tutor:
Dott. Massimo Del Fabbro

Direttore della Scuola:
Prof. Roberto L. Weinstein

a.a. 2011/2012

A Giulia
A mio figlio Lorenzo

ACKNOWLEDGMENTS

The Author would like to thank *Prof. Jean-François Gaudy*, MD, PhD, and *Dr. Silvio Taschieri*, MD, for their contribution respectively in the cadaveric dissection procedures and in the data analysis of CT scans from patients scheduled for dental implant surgery in mandible.

Abstract

Objectives: To evaluate prevalence, size, location and content of foramina and bony canals located on the lingual aspect of the mandibular midline.

Material and methods: The prevalence and the size of midline lingual foramina and canals visible above and/or below genial spines and their distances from the alveolar crest and the mandibular base were measured either in 60 dry mandibles from adult human cadavers or in 100 CT scans from patients scheduled for dental implant surgery in mandible. In addition, macro-anatomic dissections were performed on another 20 mandibles injected with red latex to investigate the vascular canal contents associated with these midline lingual foramina and canals.

Results: All mandibles investigated exhibited at least one lingual foramen at the midline above the genial spines (100% incidence). On the whole, a total of 118 and 188 foramina have been detected at the mandibular midline respectively in 60 dry mandibles and in 100 CT scans. The mean distance of the superior foramina and canals was 10.8 ± 2.7 (SD) mm from the alveolar crest by cadaveric analysis and 11.1 ± 2.1 (SD) mm in the CT scan study. Such distances were found to be far reduced in Class V to VI mandibles displaying a severe osseous atrophy, confirming the deep correlation between the "Class" of resorption of the anterior mandible (according to Cawood & Howell's classification of 1988) and the distance of the lingual foramina to the alveolar crest. The mean diameter of the superior foramina, measured at the entrance of the bony canal, averaged 0.9 ± 0.5 mm (SD). Macro-anatomic dissections showed clear sublingual vascular branches entering the midline mandible in 19 out of 20 mandibles studied (95%).

Conclusion: Blood vessels in the floor of the mouth may be in close proximity to the lingual cortical plate of the mandibular midline in most cases. This implies that bleeding can occur when the mandibular cortical plate is perforated even minimally and especially in case of severe osseous atrophies. Consequently, the Author suggests a careful planning of dental implant positioning at mandibular midline, possibly opting for the use of an even number of implants, in order to reduce the risk of violation of sublingual vessels afferent to midline lingual foramina.

Key words: dental implants, hemorrhage, lingual foramina, macro-anatomy, mandible, sublingual artery

INTRODUCTION

Surgical procedures carried out between the chin foramina are usually considered free from important neurovascular complications, due to the absence of important neurovascular structures.

In fact, interforaminal dental implant placement is generally considered as being a routinary procedure free from significant vascular complications, because of the good bone density of the median mandibular region and the absence of life-threatening endosseous vessels.

Nevertheless, a search of the literature between the years 1960 and 2012 disclosed 18 cases of life-threatening bleeding associated with dental implantation in the anterior mandible and the perforation of lingual periosteum (Krenkel & Holzner 1986, Laboda 1990, Mason et al. 1990, ten Bruggenkate et al. 1993, Ratschew et al. 1994, Mordenfeld et al. 1997, Darriba & Mendonca-Caridad 1997, Panula & Oikarinen 1999, Givol et al. 2000, Niamtu 2001, Boyes-Varley & Lownie 2002, Weibrich et al. 2002, Isaacson 2004, Kalpidis & Konstantinidis 2005, Woo et al. 2006, Dubois et al. 2010).

In such cases an immediate or delayed massive bleeding after surgery, the spreading of hematomas into the floor of the mouth and the lifting of the tongue with subsequent airway obstruction have been reported, showing how not so safe the placement of implants in the interforaminal region should be considered.

The diffusion of dental implant treatment has therefore involved a series of evaluations on the possible complications both of hemorrhagic and of neurosensorial type that may occur.

In this context, there is interest in the anatomy of both jaws and mainly in any particular anatomic variation such as the presence of one or more “lingual foramina” in the anterior mandible.

Nevertheless, in the description of surgical procedures involving the anterior mandible, the presence of lingual foramina and of their afferent neurovascular bundles is frequently omitted or considered as being an anatomic detail associated with a negligible clinical-surgical risk.

Moreover, no accurate description of the lingual mandibular foramina is given in human anatomy text-books (McMinn & Hutchins 1988; Woodburne & Burkel 1988; Williams et al. 1989; Agur 1991), while specific texts on cervicofacial anatomy tend to consider the presence of such foramina as irrelevant (Longman & McRae 1985).

The presence of lingual foramina and their location with respect to the mental spines is variable as reported from Suzuki & Sakai (1957), Sutton (1974), McDonnel et al. (1994) and Liang et al. (2006).

Literature provides controversial description of the anatomy of lingual foramina, as well as of the content of the associated endosseous canals.

If until some years ago the concepts of clinical anatomy on the issue were very conflicting and inaccurate, nowadays things have changed thanks to the very recent studies by Vandewalle et al. (2006) and Liang et al. (2006), who better described the location, the innervation and the vascularisation of the mandibular lingual foramina.

When dealing with the median anterior mandible, the reference anatomical pattern is provided by Liang et al. (2006) who, in a study on 50 dry human mandibles, classified medial mandibular foramina in “superior and inferior genial spinal foramina” according to their longitudinal location with respect to the mental spines (or genial spines).

Foramina localized at the same level of the mental spines and/or above them where defined as “superior spinal genial foramina”, while those localised below the mental spines were defined as “inferior spinal genial foramina”.

As described by the cadaveric studies by Bavitz et al. (1994) and Hofschneider et al. (1999) the arterial supply to the floor of the mouth and mental region is the sublingual or the submental artery. In 1994 Bavitz et al. reported that 53% of specimens had a small or missing sublingual artery, while 60% had a submental artery perforating the mylohyoid muscle into the mandibular anterior region.

Some years later, Hofschneider et al. (1999) found that the sublingual artery was present as main vascular supply in 70% of the cases and that a perforating submental artery was present in 41% of the cases.

On the contrary, more recently, Loukas et al. (2008) indicated that the main vascular supply to the anterior mandible is always the sublingual artery as a branch of the lingual or submental artery; in particular, the sublingual artery was found to originate from the lingual artery in 73% of the human cadavers examined and from the submental artery in the remaining 27%.

Moreover, such vessels anastomose and penetrate the lingual cortical plate of the anterior mandible through the lingual foramina of the mandibular midline, creating a rich parasymphyseal lingual plexus (Rosano et al. 2009) and, hence, anastomosing with the alveolar vessels (Cadenat et al. 1972; Krenkel et al. 1985; McDonnell et al. 1994; Tepper et al. 2001).

These anatomic considerations lay the basis on the role of the submental artery as either a supplementary or a principal vessel of this region and are worthy of attention in order to better understand the nature of haemorrhages deriving from perforation of the mandibular lingual cortical during implant surgery.

The aim of this anatomic study was to evaluate the prevalence, size, location and content of lingual foramina and vascular bony canals located on the lingual plate of the anterior mandible by either cadaveric dissection or CT scan imaging, so as to provide the tools to carry out dental implant interventions at this level in safe conditions, reducing the possible intra-operative risks arising from the lesion of lingual foramina and of their content.

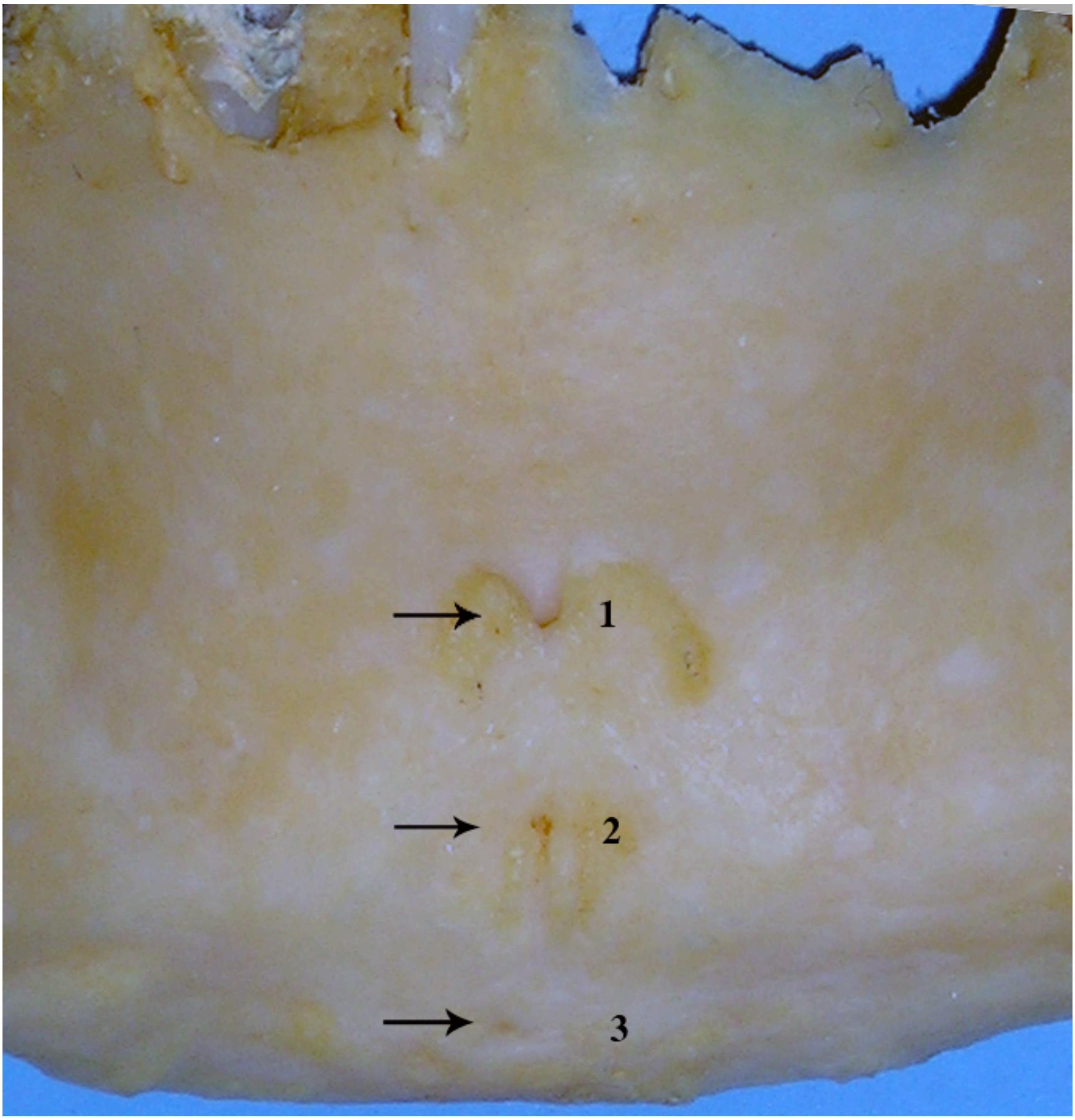
MATERIAL AND METHODS

The present anatomic study consisted of two parts where respectively a cadaveric and a CT scan analysis were accomplished.

The first part of the study consisted of 60 human cadavers with an age range of 59 - 90 years (mean age of 76 years) and equal gender distribution.
The mandibular specimens were derived from patients who had donated their body for research and were provided with ethical approval from the Department of Anatomy at the Faculty of Medicine René Descartes of Paris 5 (Paris 5 University, Paris).
60 dry human mandibles were morphometrically analyzed by measuring the incidence and the size of midline lingual foramina and canals visible above and/or below mental spines and their distances both from the alveolar crest and the mandibular base using a digital calliper of accuracy ± 0,02 mm (Mitutoyo 500-196-20 Digimatic Absolute Caliper; accuracy ± 0,02 mm).
Mandibles from edentulous cadavers were also included in our study.
The midline foramina were classified into "superior and inferior genial spinal foramina" according to their vertical location with respect to the mental spines in conformity with the classification proposed by Liang et al. (2007), as shown in *FIGURE 1*.
In addition, macro-anatomic dissections were performed on 20 mandibular specimens to investigate the vascular canal contents associated with these midline lingual foramina and canals, in order to better understand which are effectively the vascular risks related to the surgery of this anatomical region.
To accomplish this, the lingual arteries examined were injected with liquid latex mixed with red India ink through the external carotid arteries.
This allowed to estimate the vascular risks related to surgical procedures involving this anatomical region.

FIGURE 1.

This picture shows three midline foramina at the lingual side of the mandible: the foramen 1 classified as superior genial spinal foramen is located above the genial spines while the foramina 2 and 3 classified as inferior genial spinal foramina are below.



The second part of the study consisted of 100 CT scans from 100 patients scheduled for dental implant surgery in mandible at the Dental Clinic of the IRCCS Istituto Ortopedico Galeazzi, Università degli Studi di Milano. The age range of the subjects was 29-82 (mean: 55.5) years, with equal gender distribution.

The CT scans were performed using a 2000 SOMATOM Volume Zoom 4 slice CT scanner (Siemens AG, Medical Solutions, Forchheim, Germany) with slices of 0.5 mm thickness.

Coronal, axial and sagittal views of the mandibular midline were obtained by means of a software for 3D reconstruction (OneScan 3D, 3D-MED s.r.l., Brescia, Italy), offering a photorealistic rendering quality and able to import Dicom formatted CT images.

Both completely edentulous and partially edentulous mandibles were taken into consideration.

For each anterior mandible the type of resorption of the alveolar process was displayed according to Cawood & Howell's classification (1988), with a Class I mandible being a dentate mandible and a Class VI mandible referring to a depressed ridge form mandible, with some basal loss evident.

CT images were investigated for the presence of lingual foramina and vascular bony canals, housing branches of the sublingual artery, in the context of the mandibular midline.

Reformatted cross-sectional images were used to measure height and inclination of the jaw bones at the midline, using a digital sliding calliper scored in millimeters.

The course of the lingual vascular canals (LVCs) was assessed with respect to the alveolar ridge and the base of the mandible, as well as their diameter and the distance from their point of emergence to both the crest and the mandibular base, with a precision of 0.1 mm (*FIGURES 2, 3, 4*).

The presence of an intra-osseous anastomosis between the superior and inferior bony canals was also recorded (*FIGURES 2, 3, 5*).

The correlation between the mandibular Class of resorption and the distance between the LVCs emergence and the crest was also analysed.

Lingual foramina and canals were classified, accordingly to the first part of the study, into "superior and inferior genial spinal foramina and canals" according to their vertical location with respect to the mental spines in conformity with the classification proposed by Liang et al. (2007) (see *FIGURES 1, 6*). An appropriate flowchart collecting all the above-mentioned data has been realized (*FIGURE 7*).

FIGURE 2.

Cross-sectional views of the mandible at midline. The distance between the entrance of superior genial spinal foramina and the alveolar crest was measured by CT scan using a digital sliding calliper scored in millimeters. In this case Class I (FIG. 2A) and Class IV (FIG. 2B) anterior mandibles have been analysed. The picture 2B also evidences the entrance of the inferior genial spinal foramina at the mandibular lingual aspect and the intra-osseous anastomosis between the superior and inferior bony canals.

FIG. 2A

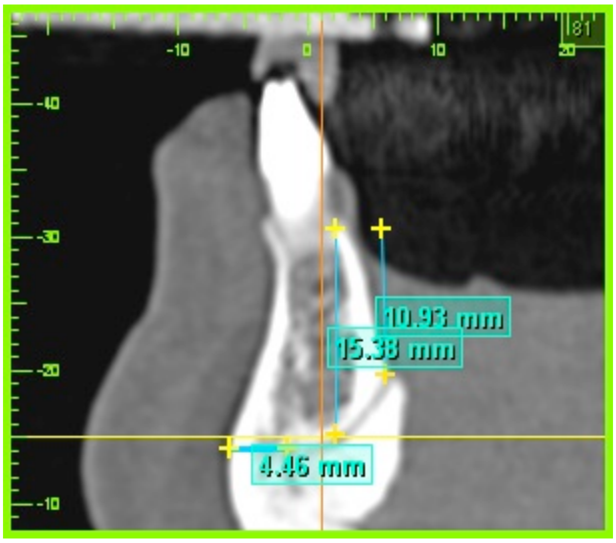


FIG. 2B

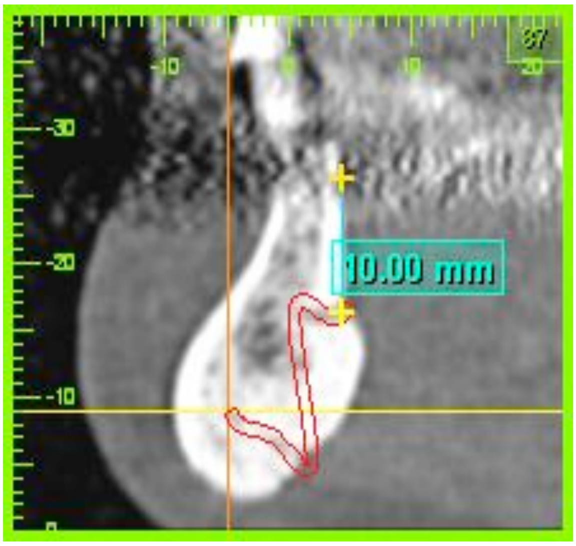


FIGURE 3.

Cross-sectional views of the mandible at midline. The distance between the entrance of superior genial spinal foramina and the alveolar crest was measured by CT scan using a digital sliding calliper scored in millimeters. In this case Class V (FIG. 3A) and Class VI (FIGS 3B, 3C) anterior mandibles have been analysed. The picture 3B also evidences the entrance of the inferior genial spinal foramina at the mandibular lingual aspect and the intra-osseous anastomosis between the superior and inferior bony canals.

FIG. 3A

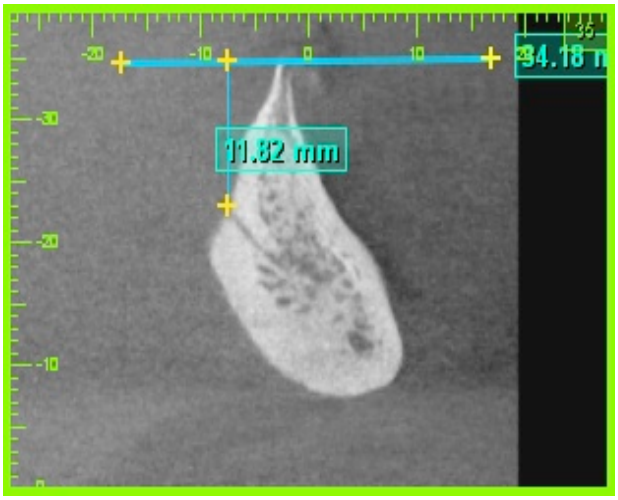


FIG. 3B

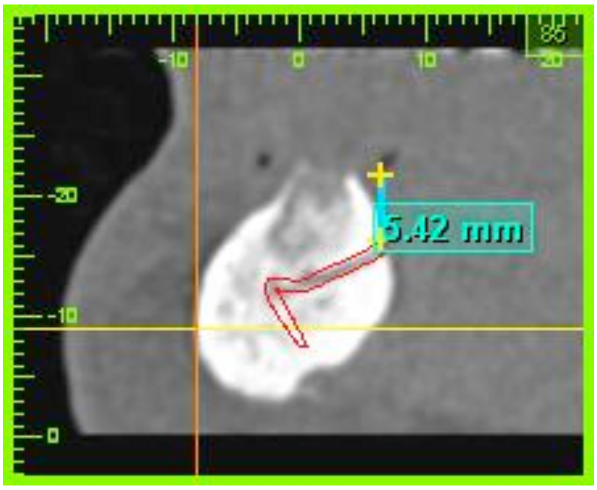


FIG. 3C

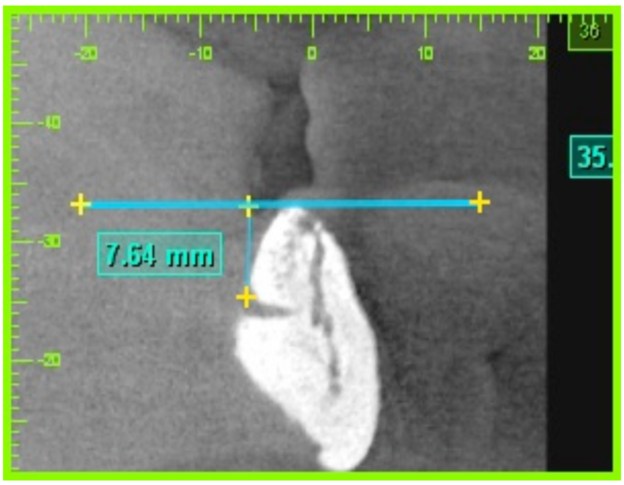


FIGURE 4.

Cross-sectional view of the mandible at midline. The distance between the entrance of superior genial spinal foramina and the mandibular base was measured by CT scan using a digital sliding calliper scored in millimeters. In this case a Class V anterior mandible has been analysed.

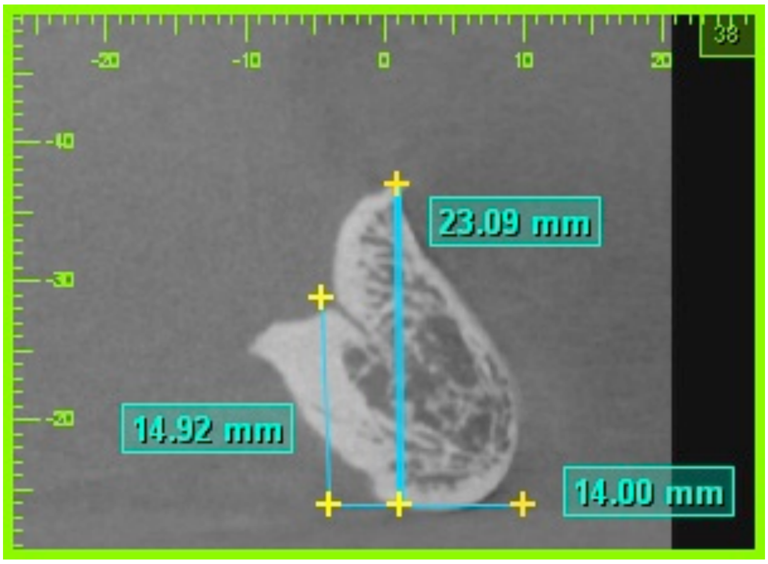


Figure 5.

3-D cross-sectional view of the midline mandible. The intra-osseous anastomosis between the superior and inferior lingual bony canals is evident.

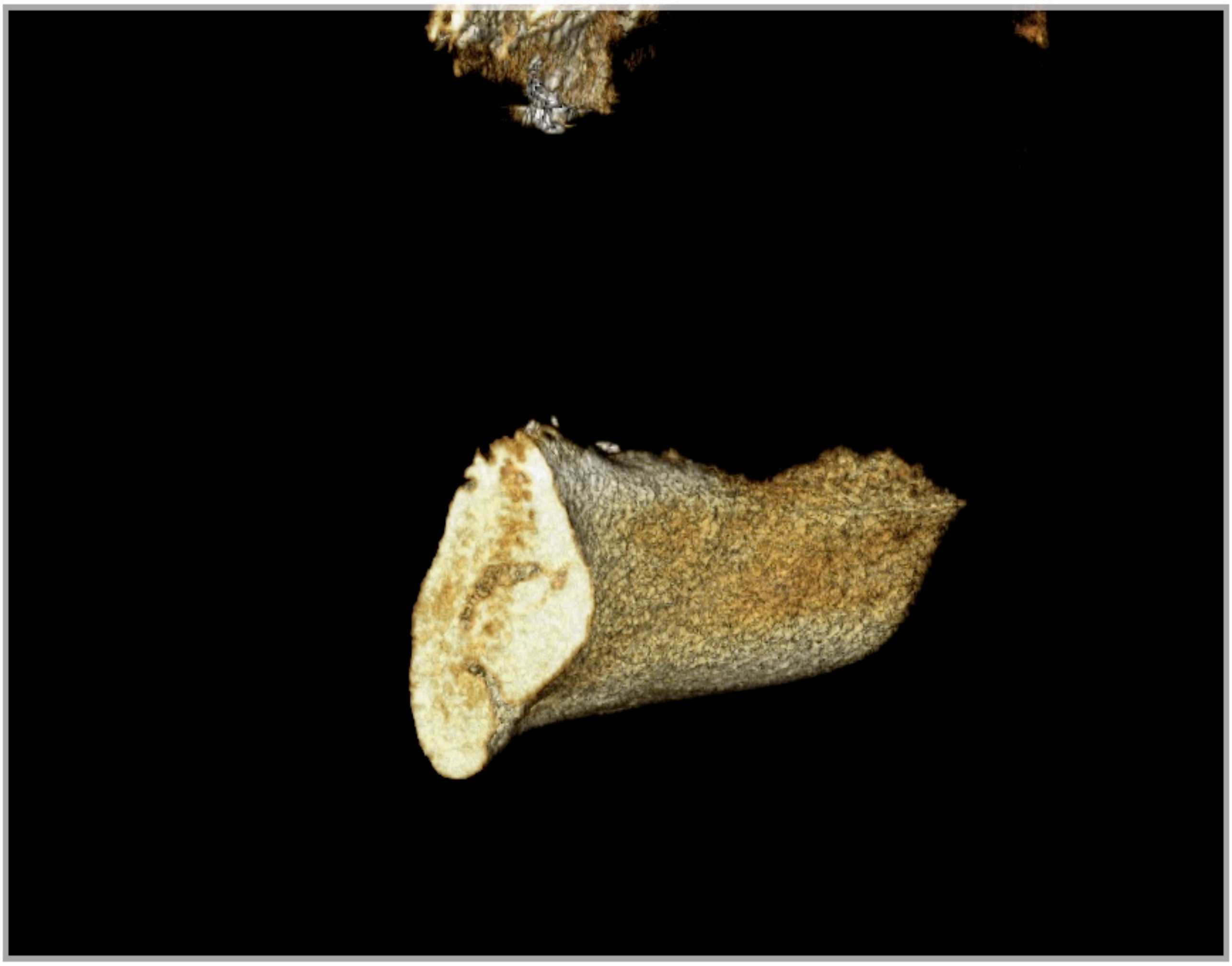


FIGURE 6.

CT 3-D view of the lingual aspect of the anterior mandible displaying a superior and an inferior genial spinal foramen, respectively above and below the genial tubercles.

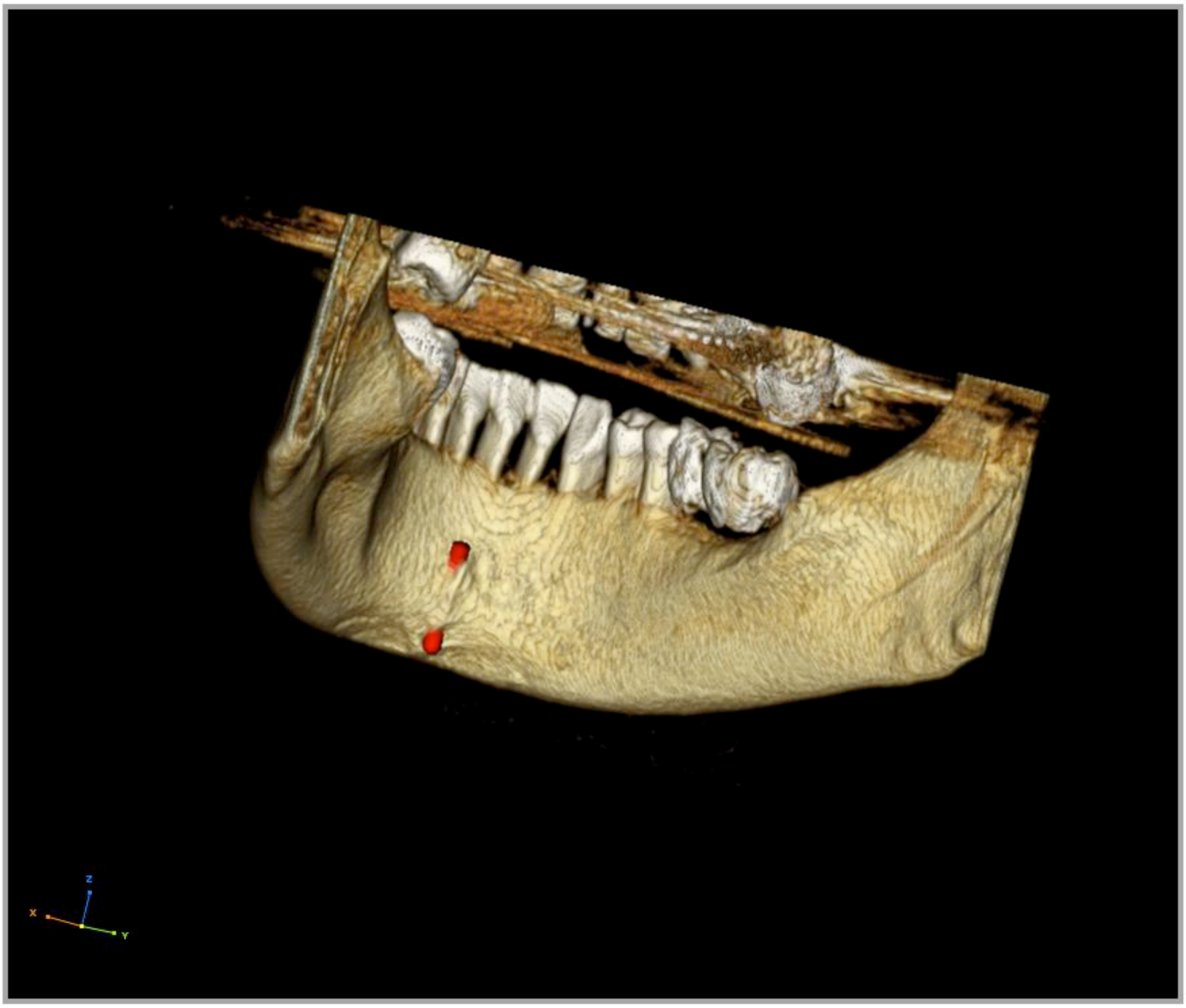


FIGURE 7.

FLOWCHART REGARDING CT SCAN ANALYSIS OF MANDIBULAR LINGUAL FORAMINA

CT SCAN N°	
SEX	
AGE	
CLASS OF RESORPTION ANTERIOR MANDIBLE (CAWOOD & HOWELL FROM I TO VI)	
ANTERIOR MANDIBLE HEIGHT	
MANDIBLE INCLINATION (INDICATE ANGLE FROM THE BASE)	
N°MIDLINE LINGUAL FORAMINA (1 TO 3)	
LOCATION *MLF* WITH RESPECT TO THE GENIAL SPINES (SUP VS INF)	
N° LATERAL LINGUAL FORAMINA AND INDICATE RIGHT AND/OR LEFT LOCATION	
DISTANCE SUPERIOR *MLF* FROM THE CREST	
DISTANCE INFERIOR MLF FROM THE CREST	
DISTANCE SUPERIOR *MLF* FROM THE BASE	
DISTANCE INFERIOR MLF FROM THE BASE	
COURSE OF SUPERIOR BONY CANALS (UPWARDS, DOWNWARDS, HORIZONTALLY)	
COURSE OF INFERIOR BONY CANALS (UPWARDS, DOWNWARDS, HORIZONTALLY)	
INTRAOSSEOUS ANASTOMOSIS BETWEEN SUP AND INF BONY CANALS: YES OR NOT?	

RESULTS

Cadaveric analysis

All of the 60 dry mandibles used for assessing foramina distribution had at least one lingual foramen (100% incidence).

Sixteen of them (27%) had 3 midline foramina at the lingual side of the mandibular midline; 26 mandibles (43%) had 2 foramina in the mandibular midline and 18 mandibles (30%) had a single foramen and canal.

On the whole, a total of 118 foramina have been detected at the mandibular midline in 60 dry mandibles.

When only one foramen was present, it was always located superiorly to the genial spines.

In mandibles having two midline foramina, the one with the greater diameter was above the genial spines while the smaller one was located below.

In mandibles showing three midline foramina, one superior and two inferior genial spinal foramina were found in 15 out of 16 cases.

The distribution of the number of foramina for each mandible is showed at *FIGURE 8*.

The mean height of the mandibles at midline was 23.6 ± 4.8 mm (SD) (range 17.9 – 30.2 mm).

The mean distance of the superior genial foramina and canals from the base of the mandible was 12.5 ± 2.1 mm (SD) (n = 61, range 9.5 – 20.4 mm), while the mean height of the inferior genial ones was 3.2 ± 2.3 mm (SD) (n = 57, range 0.2 – 9.6 mm) at the lingual side.

The mean distance of the superior genial foramina and canals from the alveolar crest was 10.8 ± 2.7 mm (SD) (range 3.8 – 17.2 mm).

The frequency of distribution of the foramina in function of these distances is showed by histograms at *FIGURES 9* and *10*.

The mean diameter of the superior genial foramina, measured at the entrance of the bony canal, averaged 0.9 ± 0.5 mm (SD), while the one of the inferior genial foramina was 0.9 ± 0.4 mm (SD) at the lingual side.

Evaluation of the macroanatomical dissections indicated that the main arterial supply to the anterior mandible is the sublingual artery as a branch of the lingual or submental artery.

Our dissection, which was macroanatomical and not microanatomical (under microscope), let us determine the vascular content afferent to the superior spinal genial foramina and canals and not to the inferior ones.
As a matter of fact, for right evaluation of the vascular content afferent to the inferior spinal genial foramina a more accurate dissection under microscope would have been necessary.
A clear vascular perforating branch entering superior spinal genial foramina as a single vessel from a sublingual-sublingual anastomosis was found in 19 out of 20 mandibular specimens studied (95% incidence) (*FIGURES 11, 12, 13, 14*).
Accordingly to the above-mentioned data, perforating cortical branches coming from sublingual arteries were found at an average height of 12.5 mm (9.5 – 20.4 mm) from the inferior mandibular border and reported a mean diameter of 0.9 mm at their entrance point at the lingual side of the mandible.

CT scan analysis
All of the 100 patients recruited for this CT study exhibited at least one lingual foramen at mandibular midline (100% incidence).
Eighteen mandibles (18%) had 3 midline foramina at the lingual side of the mandibular midline, 52 mandibles (52%) had 2 foramina in the mandibular midline and 30 mandibles (30%) had a single foramen and canal.
On the whole, a total of 188 foramina have been detected at the mandibular midline in 100 CT scans.
When only one foramen was present, it was always located superior to the genial spines. In mandibles having two midline foramina, the one with the larger diameter was located above the genial spines.
In mandibles showing three midline foramina, one superior and two inferior genial spinal foramina were found in 18 of 18 mandibles examined.
The mean distance of superior genial foramina respect to the alveolar crest was 11.1 ± 2.1 mm (range 3.5 – 18.3 mm) at the lingual side.
The mean distance of superior genial foramina respect to the mandibular base was 12.2 ± 3.0 mm (range 3.2 – 14.1 mm) at the lingual side.
Well defined bony canals, housing minor branches of the sublingual artery as demonstrated by anatomical dissections, were detected radiographically in all genial spinal foramina

(either superior or inferior) examined in this study and located in the context of the mandibular midline.

Such canals displayed two different intra-osseous courses with respect to the lingual foramina to which they are associated: 1) all bony canals afferent to the superior genial spinal foramina showed a downward direction with respect to their origin, while 2) those afferent to the inferior genial spinal foramina always showed an upward direction in the bone context.

An intra-osseous anastomosis between the superior and inferior bony canals was reported in 13 out of 100 mandibles (13%) analysed by CT scan (*FIGURES 2, 3, 5*).

A strong correlation between the "Class" of resorption of the anterior mandible (according to Cawood & Howell's classification of 1988) and the distance of the lingual foramina to the alveolar crest has been found.

In fact, the distance between such foramina/bone canals and the bone crest was found to be far reduced in Class V to VI mandibles displaying a severe osseous atrophy.

This would confirm that the more resorbed the bone crest is, the higher the risk of violation of sublingual vessels afferent to midline lingual foramina during implant placement at the anterior mandible.

FIGURE 8.

Distribution of the absolute and relative (between parentheses) frequencies of the several patterns observed for the foramina located above (a) or below (b) to the genial spine in the 60 dry mandibles examined. For the horizontal axis labels, 1a/0b 1a/1b, 1a/2b corresponds to mandibles with one foramen located above and, respectively, 0, 1 or 2 foramina located below the genial spine, while 2a/1b means that two foramina were located above and one below the spine.

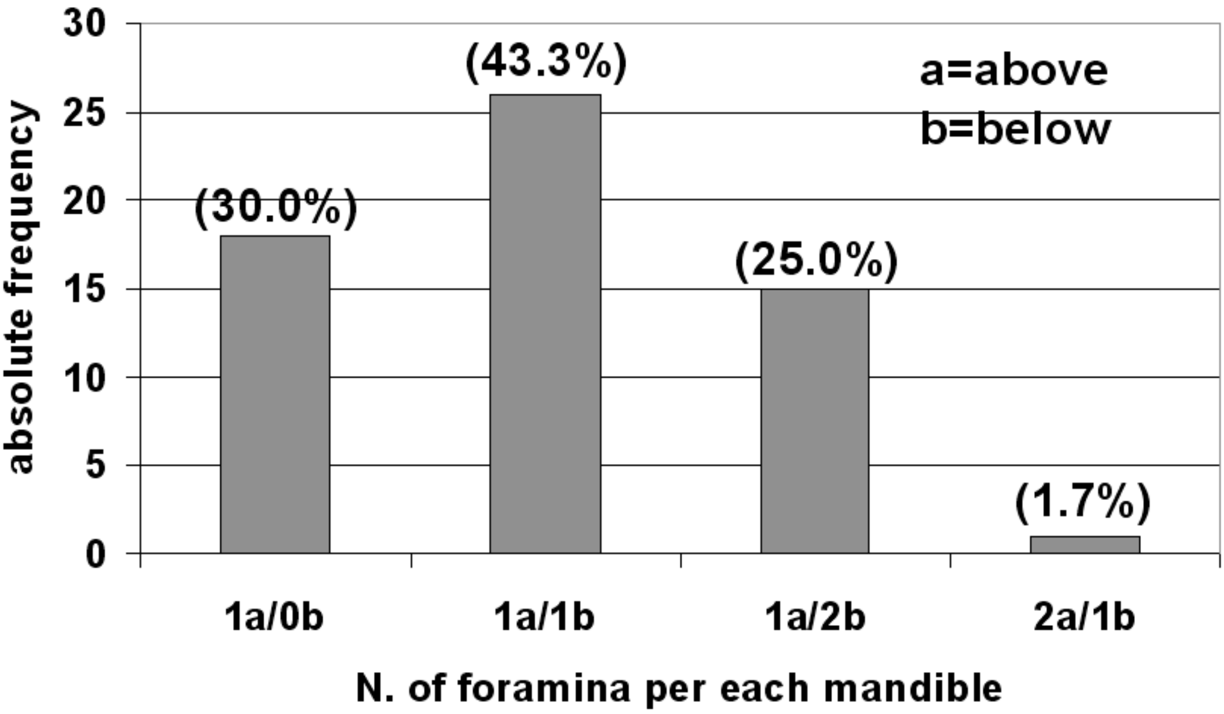


FIGURE 9.

Distribution of the superior genial foramina according to the vertical distance respect to the mandible base.

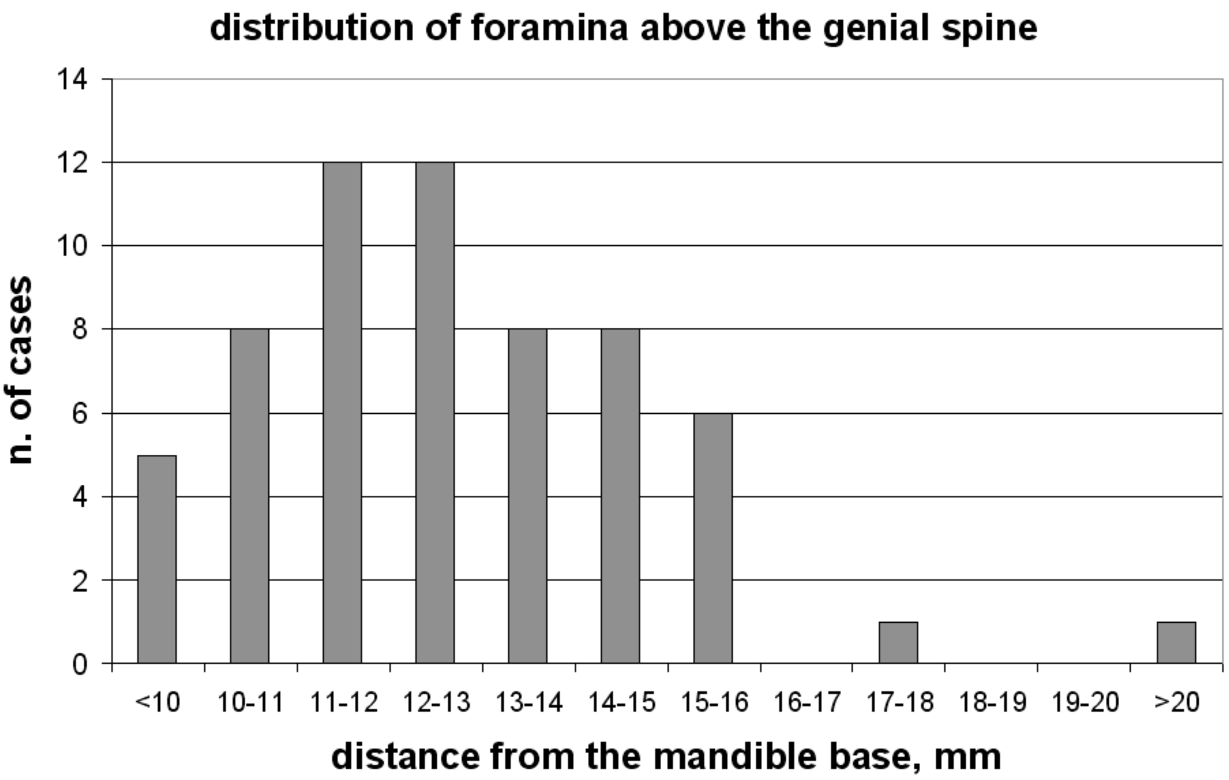


FIGURE 10.

Distribution of the inferior genial foramina according to the vertical distance respect to the mandible base.

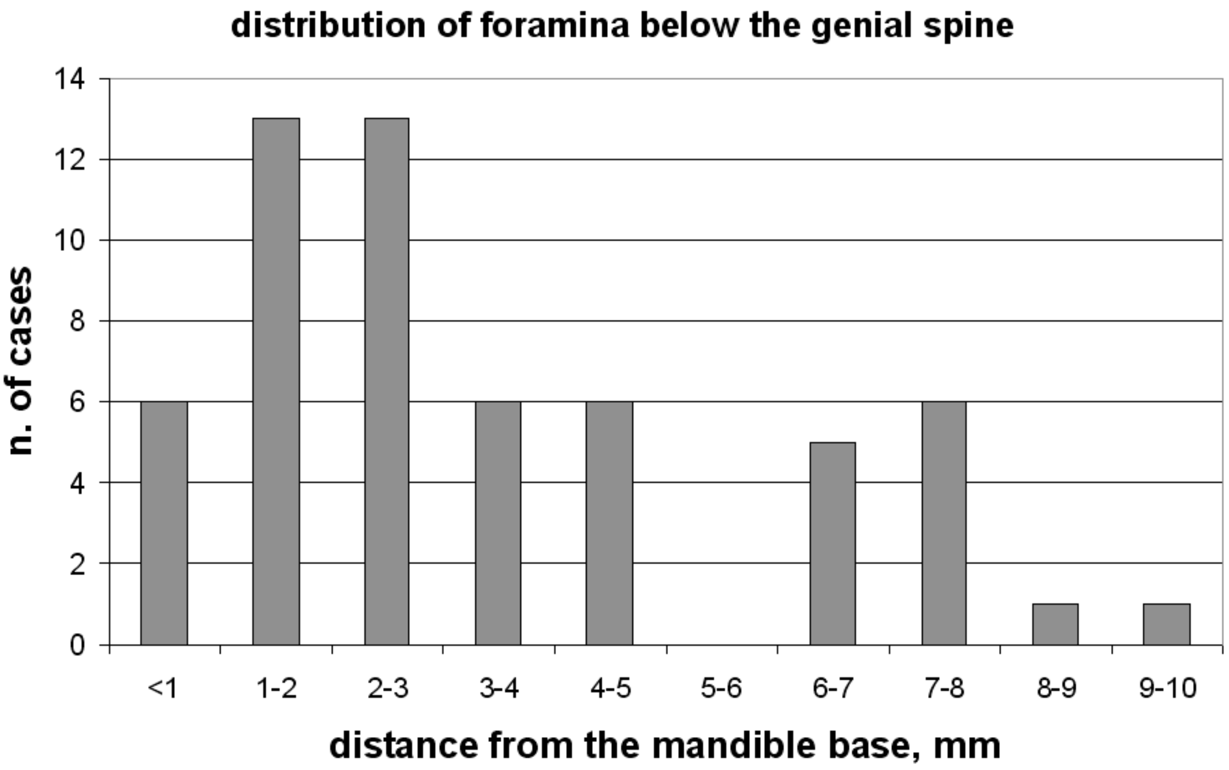


Figure 11.

This picture shows clear sublingual vascular perforating branches entering superior spinal genial foramina at mandibular midline (Rosano et al. 2009).

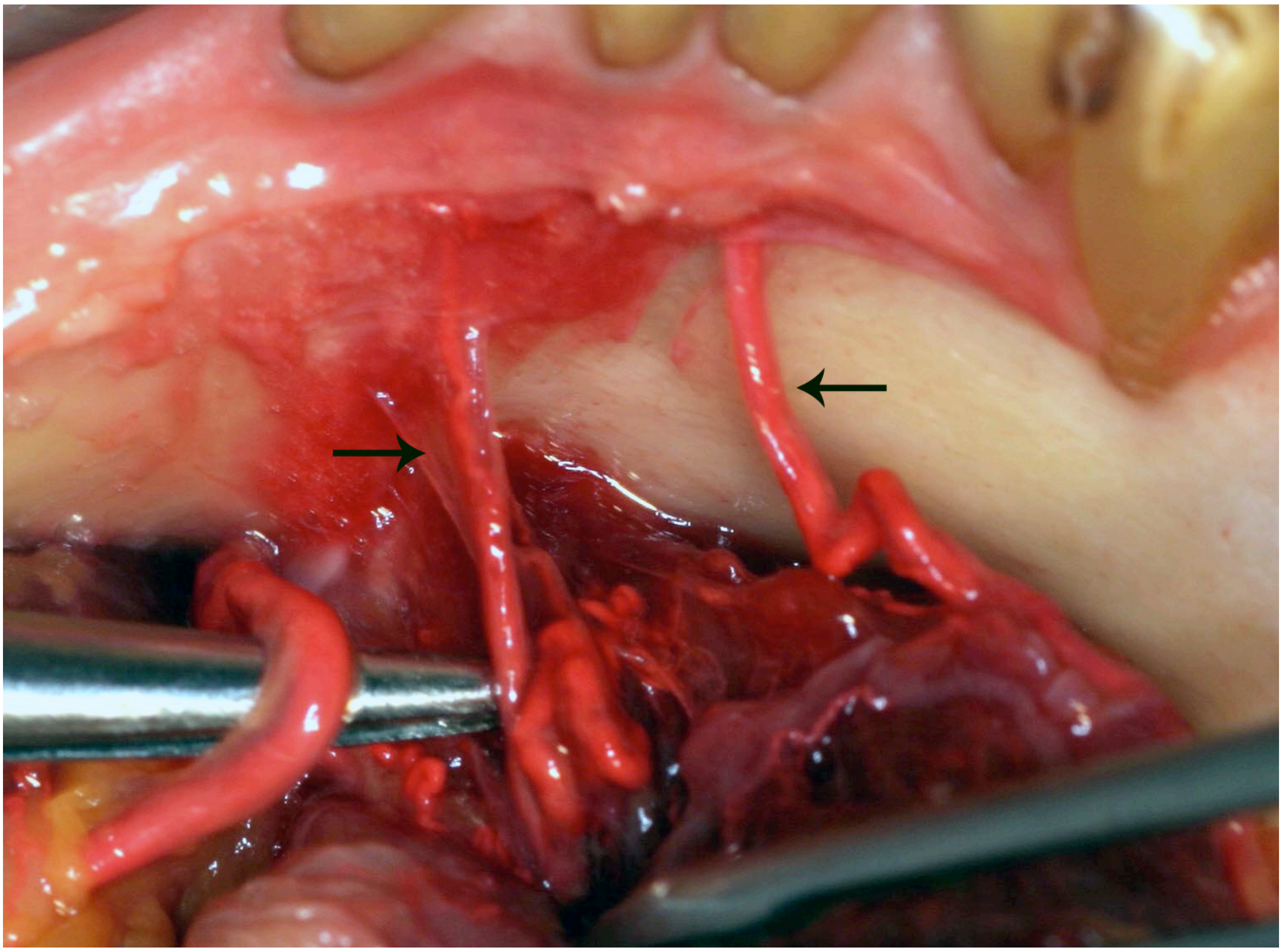


FIGURE 12.

This picture shows clear sublingual vascular perforating branches entering superior spinal genial foramina at mandibular midline (Rosano et al. 2009).

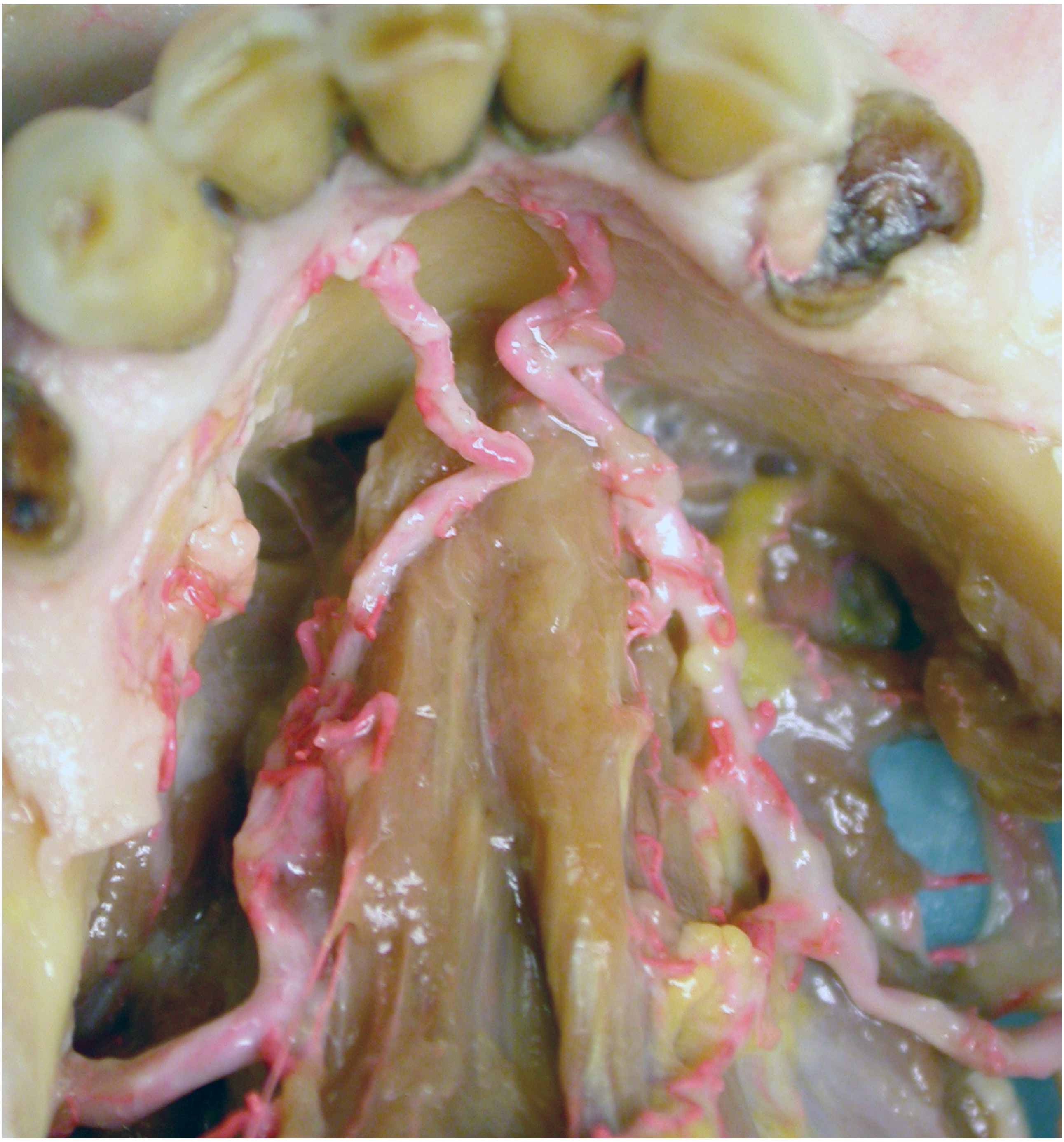


FIGURE 13.

The following anatomic pictures (FIGS 13A, 13B) show a consistent sublingual vessel coursing in the floor of the mouth (FOM) and in close proximity to the lingual aspect of the anterior mandible.

FIG. 13A

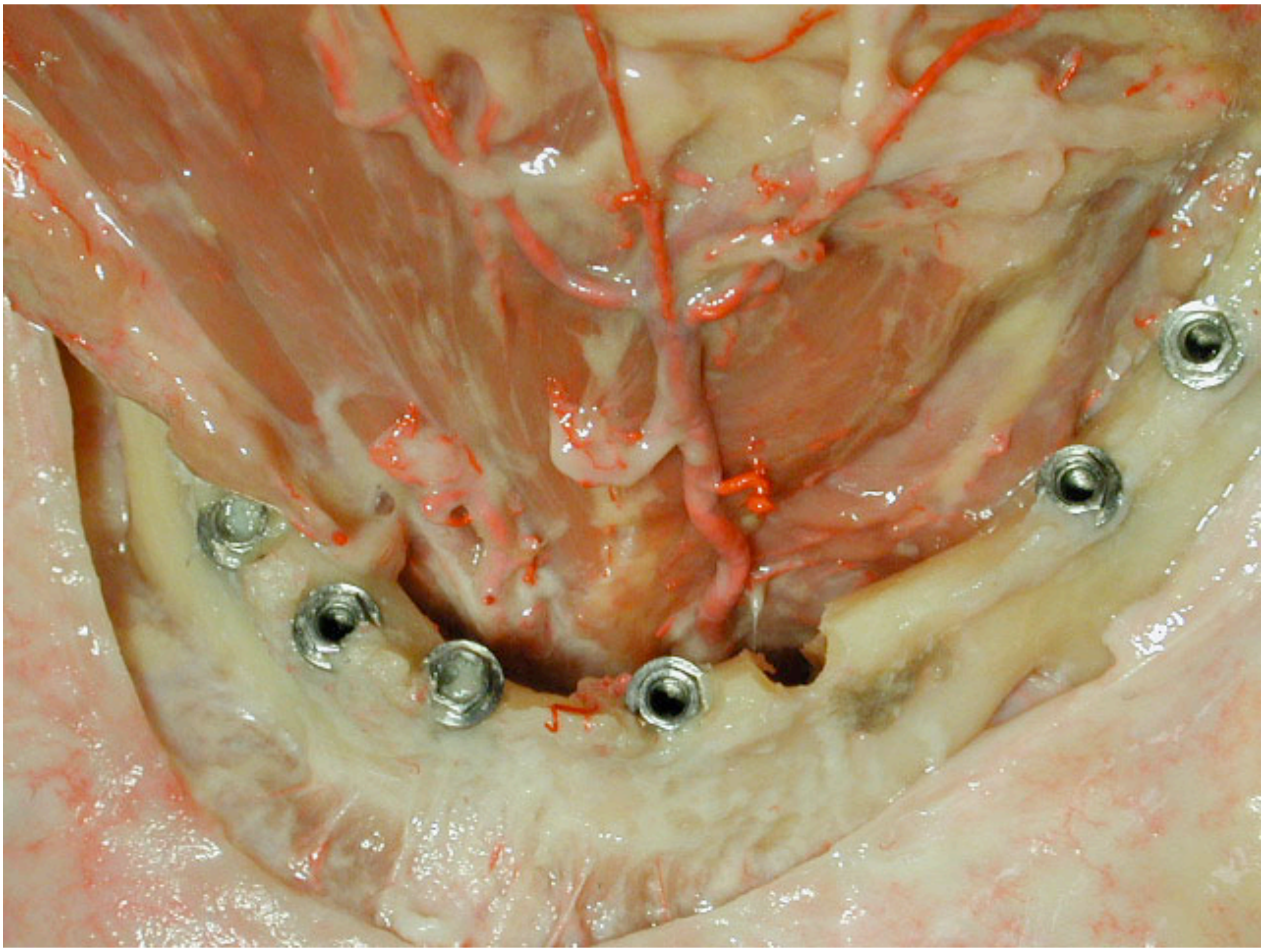


FIG. 13B

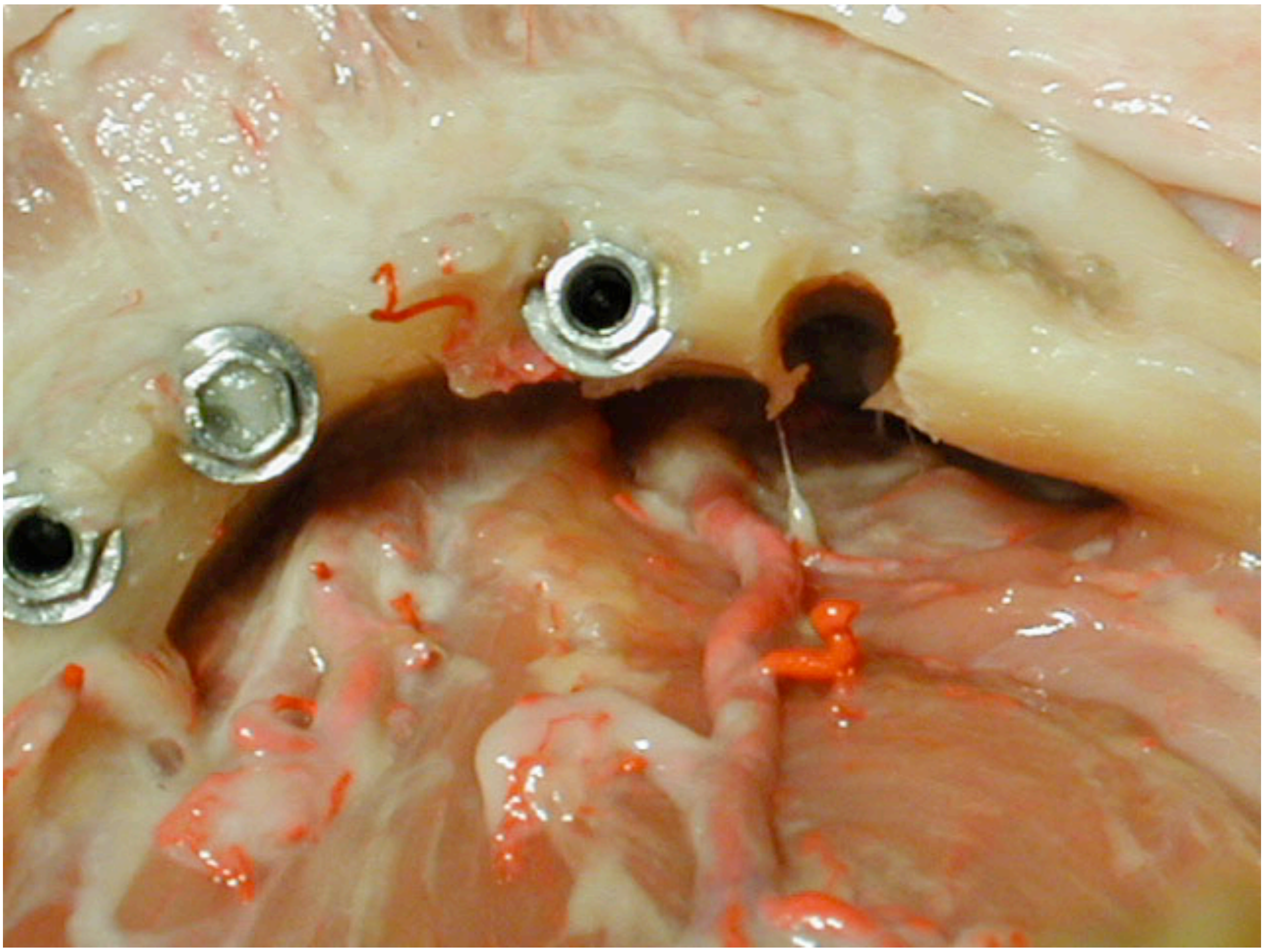
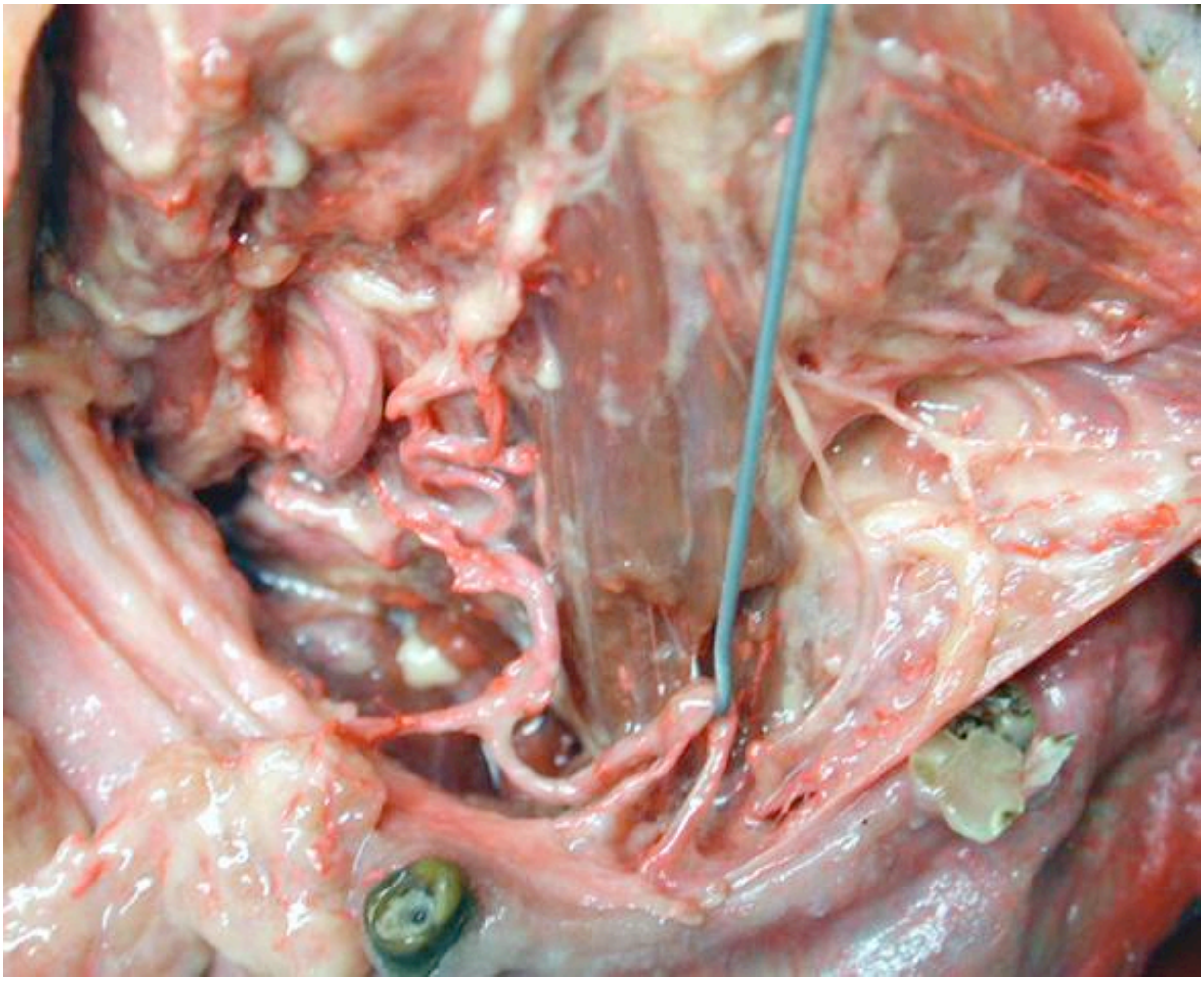


FIGURE 14.

A clear vascular plexus deriving from the anastomosis of sublingual vessels in the FOM and in close contact with the lingual cortical plate of the midline mandible is well evident in this cadaveric picture.



DISCUSSION

The presence of a superior genial spinal foramen in 100% of the mandibles investigated was in accordance with previous reports by McDonnell et al. (1994) (99%) and Liang et al. (2007) (98%).

Shiller & Wiswell (1954), similarly to the present study, found that when mandibles have a single foramen it is always superior to the genial spines, and in those mandibles having two or more foramina, the second or the third foramen is nearly always located inferiorly to the genial spines.

The clinical relevance of this anatomic feature is underlined by the growing diffusion of implant treatments at the mandibular midline and by reports of complications deriving from such procedures.

Past reports of life-threatening haemorrhage and haematoma formation in the floor of the mouth secondary to implant treatment have been reported.

A search of the literature between the years 1960 and 2012 disclosed 18 cases of life-threatening bleeding associated with dental implantation (Krenkel & Holzner 1986; Laboda 1990; Mason et al. 1990; Ten Bruggenkate et al. 1993; Ratschew et al. 1994; Darriba & Mendonca-Caridad 1997; Mordenfeld et al. 1997; Panula & Oikarinen 1999; Givol et al. 2000; Niamtu 2001; Boyes-Varley & Lownie 2002; Weibrich et al. 2002; Isaacson 2004; Kalpidis & Konstantinidis 2005; Woo et al. 2006; Dubois et al. 2010).

In these cases a drilling depth of 15 mm during implant site preparation was most often reported, and the arterial damage was induced by instrumentation through a perforation of the lingual cortical plate.

Such depth is consistent with the average height of the vascular perforating branches entering the mandible respect to its inferior border, as determined in the present study.

The results of the present study are in agreement with the study by Loukas et al. (2008) where perforating branches from the sublingual arteries were identified in 98% of specimens to enter through a middle lingual canal as a single vessel at an average height of 10.3 mm from the mandibular inferior border.

The size of these perforating branches, as determined in the present study, seems sufficient to justify their implication in severe haemorrhaging episodes during implant surgery in the anterior mandible.

In order to better understand the modalities of haemorrhage and haematoma formation in the FOM, it is essential to consider the rich parasymphyseal lingual plexus to which vascular branches from the anastomosis of the left and right sublingual arteries are afferent.
As a matter of fact, the vascularisation of the intercanine lingual region of the mandible is totally deriving from the intra-osseous alveolar branches of the sublingual arteries.
Below the mucous membrane of the front section of the mouth floor, the two sublingual arteries anastomose and penetrate the lingual cortical of the mandible through the lingual foramina of the mandibular midline hence anastomosing with the central alveolar vessels (Cadenat et al. 1972; Krenkel et al. 1985; McDonnell et al. 1994; Tepper et al. 2001). Therefore, the presence of the genial spinal foramina enables the formation of anastomosis between the sublingual arteries and the inferior alveolar ones.
In conclusion, the central mandibular and parasymphyseal lingual regions are supplied through a very rich vascular plexus, whose violation during surgical procedures may have critical consequences (Cadenat et al. 1972; Ragot & Poirot 1983; Krenkel et al. 1985; Hofschneider et al. 1999).
In the youngest subjects, the vascularisation afferent to the mandible is purely of centrifugal type.
In the elderly individuals, tooth loss and atherosclerotic changes of the inferior alveolar artery lay the basis for a gradual passage from a circulation of centrifugal type to a centripetal one (Bradley 1981).
This new circulatory pattern is strictly dependent on the vascularisation of the periosteum, muscles and soft tissues related to mandibular bone (Cadenat et al. 1972; Castelli et al. 1975; Bradley 1981).
For this reason, particular care must be paid to the preparation of wide lingual mucoperiosteal flaps in elderly people, trying to avoid laceration during flap elevation.
The perforation of the lingual cortex of the anterior mandible during drilling of the implant site may cause a damage to anatomical structures located in the floor of the mouth, such as the sublingual artery and vein, the perforating submental artery and vein, the submandibular ganglion, the lingual nerve, the hypoglossal nerve, the sublingual gland, the deep lip of submandibular gland and submandibular duct.
In a cadaveric study Hofschneider et al. (1999) reported that 70% of specimens had a sublingual artery in the mandibular anterior region (similarly to the findings of the present

macro-anatomical dissection), while 41% had a branch of the submental artery perforating the mylohyoid muscle into the same region.

On the contrary, Bavitz et al. (1994) found that a perforating submental artery was present in 60% of the cases, while the sublingual artery was small or missing in 53% of the cases. These observations revealed the significance of the submental artery as either an important supplementary or a principal source of blood supply to the floor of the mouth (FIGURES 15, 16).

For this reason, it’s still controversial whether external ligation of the lingual or facial artery is more likely to be needed.

FIGURE 15.

This anatomic design shows the course of the sublingual artery in the FOM as well as its anastomosis with a vascular perforating branch deriving from the submental artery in the submandibular space.

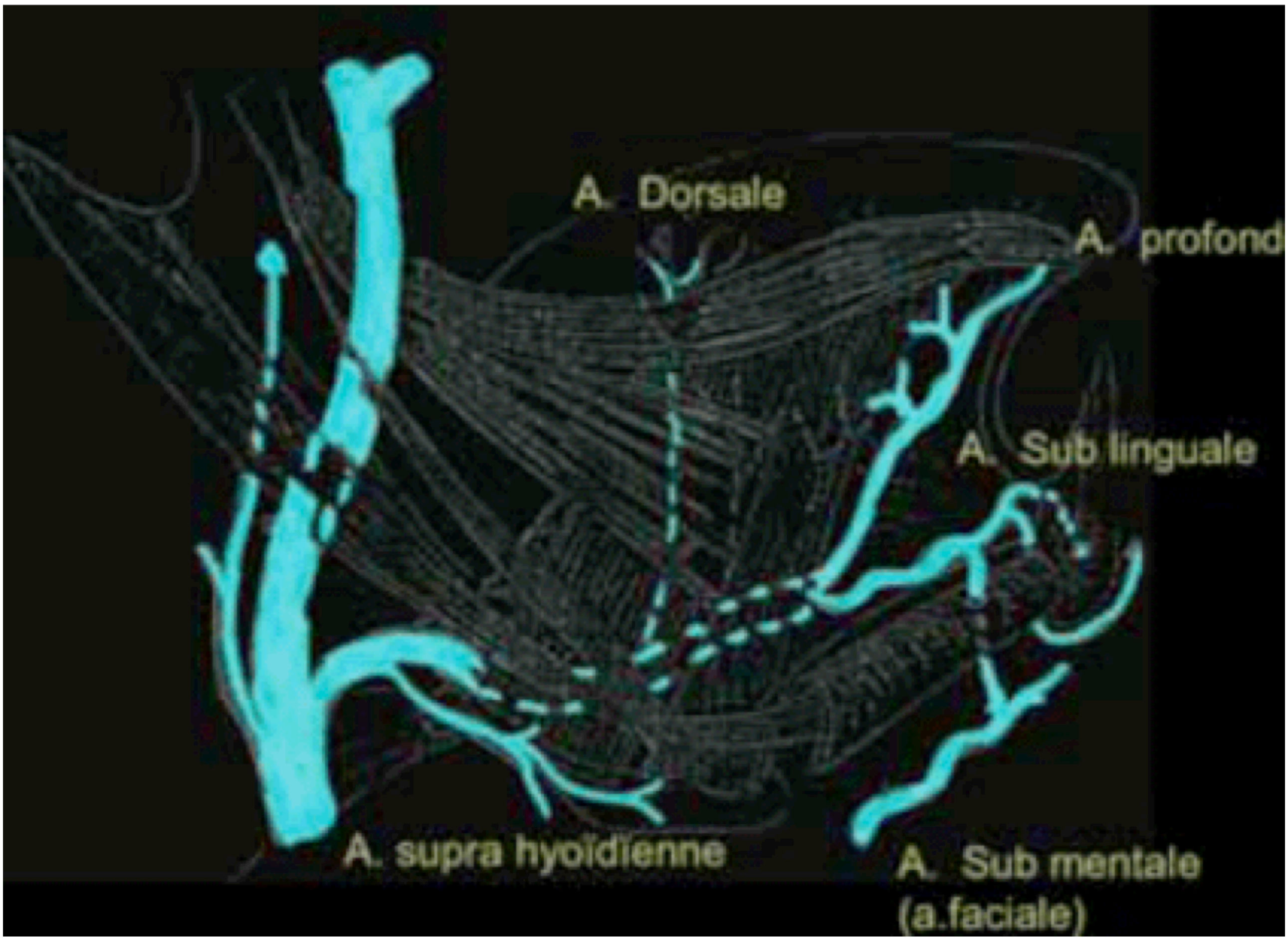


FIGURE 16.

These anatomic pictures (FIGS 16A, 16B) show the course of the submental artery in the submandibular region as well as its anastomotic branches perforating the mylohyoid muscle and entering the FOM.

FIG. 16A

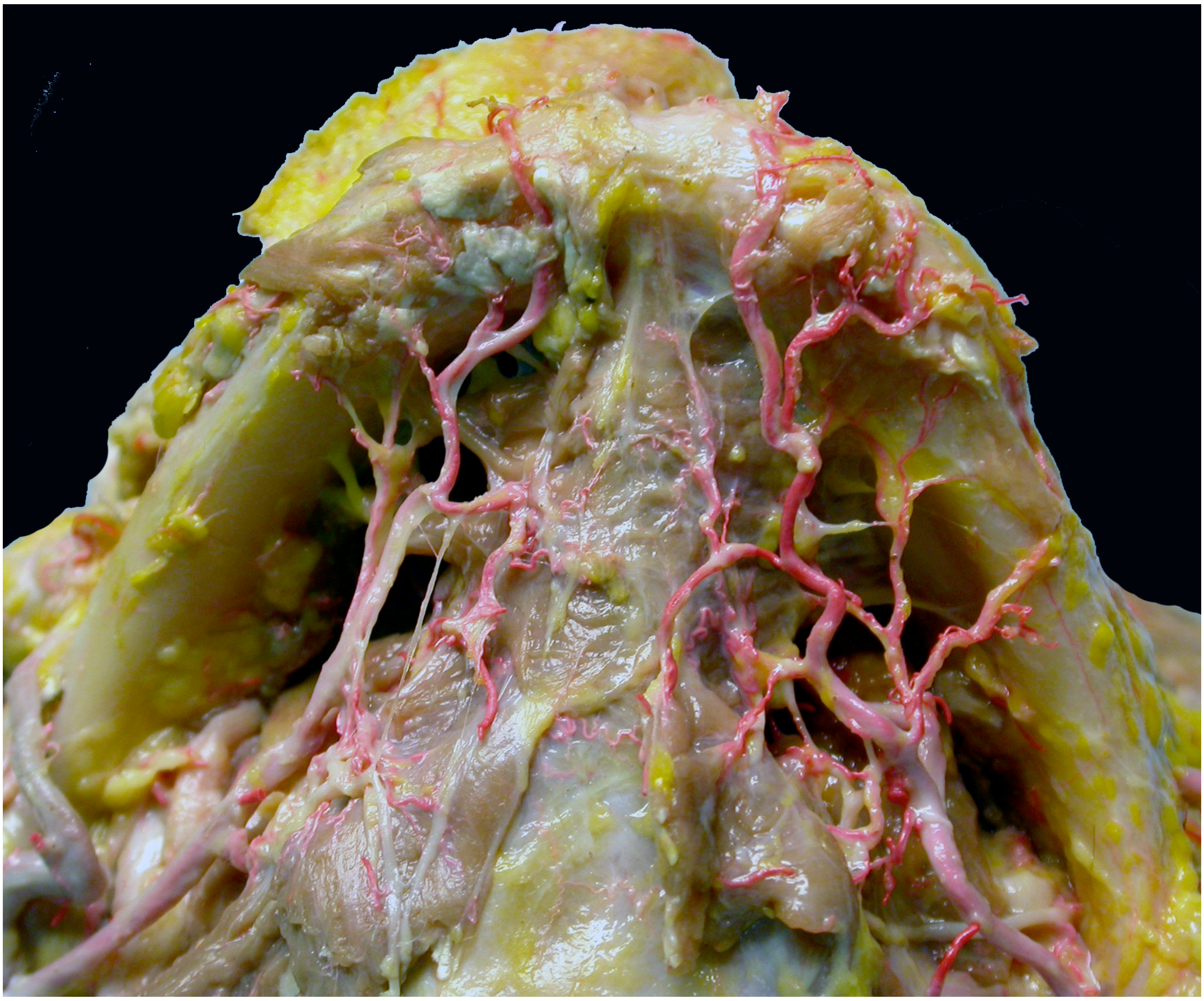
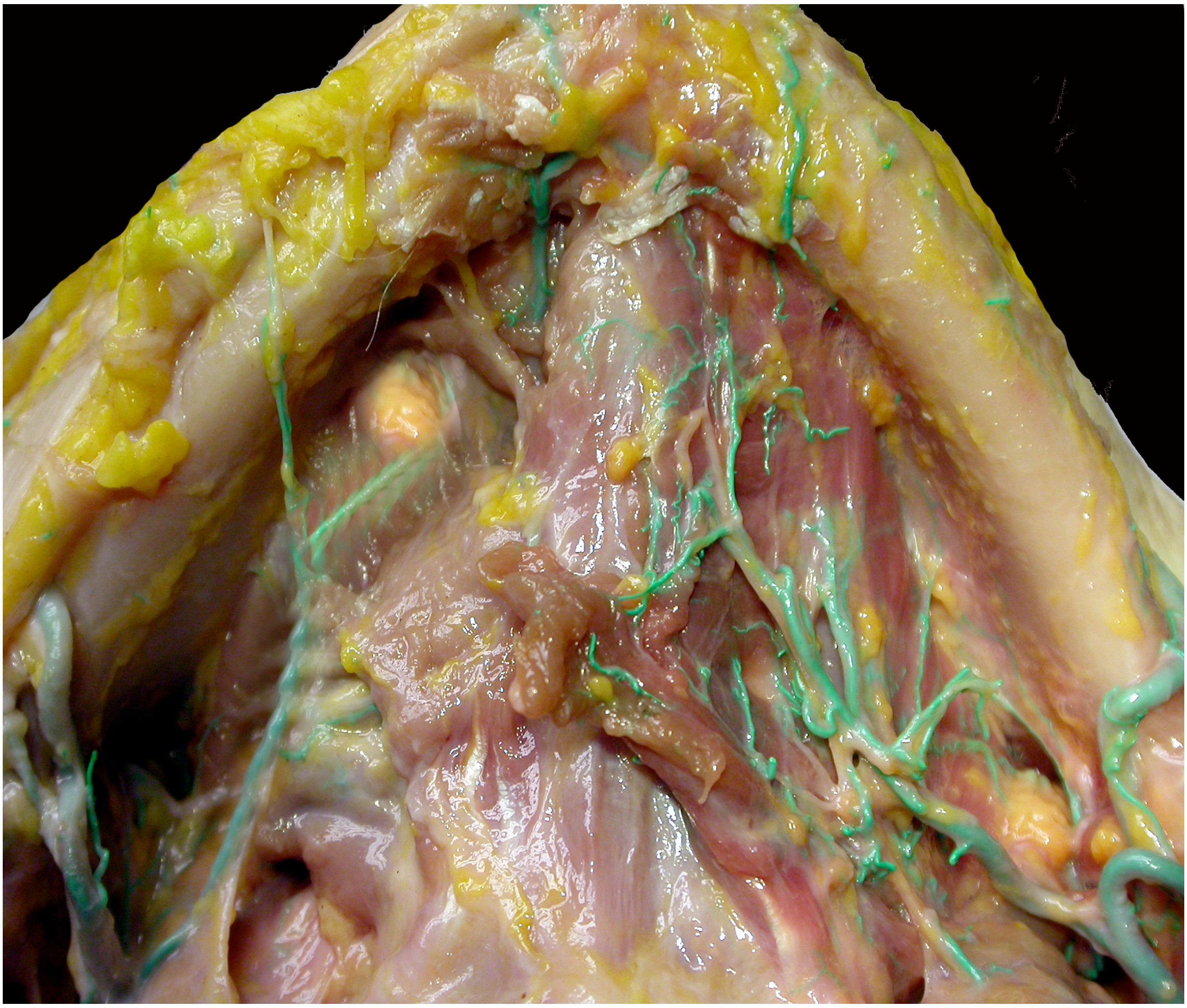


FIG. 16B



ANATOMIC CONSIDERATIONS RELATED TO SUBLINGUAL HEMORRHAGE

It is widely accepted that the sublingual artery, the major branch of the lingual artery, is the main nutrient vessel to the floor of the mouth (FOM).

Yet, the importance of the submental artery in supplying blood to sublingual anatomical structures has also been established (DuBrul 1980; Bavitz et al. 1994; Hofschneider et al. 1999).

Mechanical injury to one or more branches of the local arterial plexus may potentially lead to dangerous hemorrhage.

Detailed knowledge of the regional fine arterial anatomy is, therefore, imperative for the implant surgeon.

The lingual artery is the third consecutive and the second anterior branch of the external carotid artery arising at the level of the hyoid bone.

The vessel courses anteriorly, disappears at the posterior border of the hyoglossus muscle and continues anterosuperiorly, deep to the hyoglossus muscle, to enter the substance of the tongue (DuBrul 1980; Bavitz et al. 1994; Homze et al. 1997).

The lingual artery supplies the body and apex of the tongue through the terminating deep lingual artery and dorsal branches, respectively.

At the anterior border of the hyoglossus muscle, the lingual artery gives rise to the sublingual artery.

This important vessel courses forward in the FOM, near the medial and superior surface of the mylohyoid muscle, medially to the sublingual gland and inferomedially to the sub-mandibular duct and the lingual nerve (DuBrul 1980; Bavitz et al. 1994).

The sublingual artery with a mean diameter of approximately 2 mm supplies the anatomical structures of the FOM including the sublingual gland, the mylohyoid, geniohyoid and genioglossus muscle, the mucous membranes of the FOM and the lingual gingiva (DuBrul 1980; Bavitz et al. 1994).

In addition, the sublingual artery releases several alveolar branches for complementary blood supply to the lingual anterior cortical plate of the mandible (Krenkel et al. 1985; Bavitz et al. 1994; Hofschneider et al. 1999).

Superior, inferior and large middle subdivisions of the sublingual alveolar branches have been identified in human specimens.

Krenkel et al. (1985) described an ascending branch that was further divided to a medial and a lateral arteriole, while a descending branch was divided to an inferior and a superior arteriole.

All smaller branches enter the cortical plate through various accessory lingual foramina.

A thorough description of the routes of the sublingual alveolar branches has been recently reported and three main ramifying patterns have been identified (Hofschneider et al. 1999).

The most common configuration was present in 44% of the specimens and corresponded to the pattern presented by Krenkel et al. (1985).

Another pattern (12%) included cranial, middle and caudal branches while the least widespread (9%) incorporated a medial and a lateral alveolar branch (Hofschneider et al. 1999).

The facial artery is normally the fourth consecutive and the third anterior branch of the external carotid artery, unless it originates together with the lingual artery by a common linguofacial trunk.

The artery arises usually below the posterior belly of the digastric muscle, enters the submandibular triangle, turns laterally at the superior border of the submandibular gland and courses anteroinferiorly to the lower border of the mandible (DuBrul 1980).

The facial artery crosses the mandibular border near the anterior border of the masseter muscle, turn again and follows a tortuous course anterosuperiorly to supply portions of the face.

The submental artery, with an average diameter of 2 mm, is one of the most important cervical branches of the facial artery.

The submental artery arises from the facial artery prior to crossing the mandibular border and courses interiorly along the inferior surface of the mylohyoid muscle together with the mylohyoid nerve.

The vessel supplies the lymph nodes of the submandibular triangle, the anterior belly of the digastric muscle and the mylohyoid muscle (DuBrul 1980; Bavitz et al. 1994; Martin et al. 1993).

Relevant vascular anastomoses and reported variations

The inferior alveolar arteries reach the symphysis of the mandible by the terminating incisive arteries.

In addition, complementary blood supply to the lingual inter-canine region of the mandible is derived from the alveolar branches of the sublingual arteries (Cadenat et al. 1972; Ragot & Poirot 1983; Krenkel et al. 1985; Hofschneider et al. 1999).

Underneath the mucous membrane in the anterior part of the FOM, the sublingual artery anastomoses with its fellow of the opposite site and penetrates the cortical plate through the accessory anterior lingual mandibular foramina to anastomose with the central alveolar vessels (Cadenat et al. 1972; Krenkel et al. 1985; McDonnel et al. 1994; Tepper et al. 2001).

The entrance of these alveolar arteries to the mandible establishes the anastomosis between the lingual and the inferior alveolar arteries.

In conclusion, the central and parasymphyseal lingual mandibular regions are irrigated by a very rich vascular plexus (Cadenat et al. 1972; Ragot & Poirot 1983; Krenkel et al. 1985; Hofschneider et al. 1999).

The blood supply to the mandible is primarily centrifugal in younger individuals.

Eventual loss of teeth and arteriosclerotic changes of the inferior alveolar artery in older people set the ground for a gradual shift to a centripetal blood circulation (Bradley 1981).

This new circulatory pattern is increasingly dependent on the external blood supply provided by the periosteal, muscular and other soft tissues related to the mandible (Cadenat et al. 1972; Castelli et al. 1975; Bradley 1981).

Thus, the external vascular supply to the lingual aspect of the anterior mandible becomes very important, especially in surgical procedures involving extensive reflection of lingual mucoperiosteal flaps.

The mylohyoid muscles unite in the midline and separate the sublingual and submandibular/mental spaces forming a diaphragm that supports the tongue and forms the floor of the mouth. The sublingual and submental arteries follow parallel pathways as they run forward along the surface of the mylohyoid muscle (DuBrul 1980).

The sublingual artery is located on the superior and medial plane of the muscle, while the submental artery runs on its inferior and lateral aspect.

The sublingual and submental arteries normally anastomose through their muscular mylohyoid branches.

The mylohyoid muscle may actually be considered as an extensive anastomosing field between the two vessels (DuBrul 1980; Bavitz et al. 1994).

These widespread anastomoses were considered as the foundation for an anatomic variation in the vascular supply to the area: the partial replacement or even substitution of one artery by the other via a large branch penetrating the mylohyoid muscle to the other side (DuBrul 1980).

Bavitz et al. (1994) conducted a relevant cadaveric study and reported that in 53% of the cases the sublingual artery was either small, unimportant or absent.

A sizeable perforating branch from the submental artery was present to supply the structures of the FOM in 60% of the dissections.

The vessel perforating the myloyhoid muscle was, in the majority of the cases, half the calibre of the feeder artery and was therefore considered as its terminating branch.

In another pertinent study the incidence of a missing sublingual artery (29%) and the frequency of a large submental perforating branch (2.1 mm diameter) to the sublingual region (41%) were significantly lower (Hofschneider et al. 1999).

A sublingual artery without a complementary submental branch was isolated in 59% of the dissections (Hofschneider et al. 1999).

In both studies (Bavitz et al. 1994; Hofschneider et al. 1999), a variation with a large perforating submental branch in addition to a normal size sublingual artery was reported.

None of the studies was able, however, to identify a sublingual vessel perforating the mylohyoid muscle into the submandibular region.

Despite the reported different incidence rates, these observations revealed the significance of the submental artery as either an important supplementary or a principal source of blood supply to the FOM.

For this reason some authors also posed the dilemma of whether the facial or the lingual artery should be ligated first in case an extraoral approach were required to control hemorrhage in the sublingual region (DuBrul 1980; Hofschneider et al. 1999).

Accessory anterior lingual mandibular foramina

Numerous reports have described several accessory foramina on both the buccal and lingual surfaces of the mandible (Porter & Sweet 1942; Shiller & Wiswell 1954; Sutton 1974; Chapnick 1980; Krenkel et al. 1985; McDonnel et al. 1994; Tepper et al. 2001).

The term “accessory” refers to foramina other than the two major openings of the mandibular canal housing the inferior alveolar neurovascular bundle.

Since heavy hemorrhage and formation of hematomas in the FOM may derive from perforations of the lingual cortical plate during implant site preparation, identification of the lingual foramina in the anterior region of the mandible may reduce the likelihood of these life-threatening incidents.

The reported variability in distribution, incidence, size and contents of the accessory lingual foramina has caused considerable confusion.

The most consistent of these foramina is the “median, central, midline or middle” lingual foramen (Kalpidis & Setayesh 2004).

Located in the midline at or somewhat superiorly to the genial tubercles the median lingual foramen has been detected with a frequency ranging between 85% and 100% in dry mandibles and specimens (Shiller & Wiswell 1954; Sutton 1974; Krenkel et al. 1985; McDonnel et al. 1994; Tepper et al. 2001; Liang et al. 2007; Rosano et al. 2009).

The mean reported diameter of the foramen is 0.54 mm (Shiller & Wiswell 1954) and its distance to the inferior alveolar border averages 10 to 13.7 mm (Shiller & Wiswell 1954).

The associated canal extends deeply into the mandible on a buccolingual axis (McDonnel et al. 1994; Tepper et al. 2001).

Contrary to earlier reports describing a neurovascular bundle, more recent investigations identified a single nutrient vessel entering the median lingual foramen (McDonnel et al. 1994; Tepper et al. 2001).

Further histologic examination revealed a plexus of small perivascular veins and occasionally some fine vasomotor neural fibers surrounding a single branch of the sublingual artery (McDonnel et al. 1994), but no nerves were detected (McDonnel et al. 1994; Tepper et al. 2001).

Accessory lateral lingual mandibular foramina

The topographic orientation and description of the remaining accessory lingual mandibular foramina, better known as “lateral lingual foramina”, is even more difficult to pinpoint with certainty.

The differences in the number of lateral foramina in various studies could be attributed to the different techniques employed in assessing foramina, with cadaveric and dry skulls demonstrating a higher number than radiologic studies.

The limited spatial resolution of CT probably yields a lower value in the detection rate of the foramina.

Such “lateral lingual foramina” situated posteriorly to the genial tubercles at a distance of 12.2 mm to 34.0 mm from the menton (mean value 23.3 mm) and with a mean distance of almost 6 mm from the inferior mandibular border were first properly described by Tepper et al. (2001).

Tepper et al. (2001) also reported an incidence of lateral lingual foramina of 53% in 70 patients, but no positional definition of foramina was accomplished.

More recently, Katakami et al. (2008) and Von Arx et al. (2011) evidenced a higher regional frequency of lingual foramina in the premolar area.

Katakami et al. (2008) have investigated the regional frequency and the anatomical properties of lateral lingual mandibular foramina through a retrospective investigation of limited CBCT images obtained clinically.

The course of lateral lingual canals and their anastomoses to mandibular canals were observed on serial cross-sectional images.

The observed anastomoses of lingual and mandibular canals were classified into the following three types based on the position of anastomosis:

Type 1. Anastomosis in the anterior loop of the mandibular canal;

Type 2. Anastomosis in the adjacent area of the mental foramen;

Type 3. Anastomosis in the posterior area of the mental foramen.

Katakami et al. (2008) detected 154 lingual foramina in 190 examinations of 181 patients.

Thirty-one of the 154 lingual foramina showed anastomoses to the mandibular canals in the premolar area via well defined lingual canals.

Thirty of the 31 lingual canals were connected to the anterior loop of the mandibular canal or an adjacent area of the mental foramen.

Thirty lingual canals were observed from the lingual foramina existing in the area between the first premolar and the first molar, and the remaining lingual canal from the third molar area.

The results of the anatomic study by Katakami (2008) demonstrated that: 1) lateral lingual mandibular foramina are frequently present in the second premolar area (39.7%); 2) lingual foramina in the area between bilateral canines have no anastomosis to the mandibular canal and 3) no lingual foramina were observed above the mandibular canals and mental foramina.

On the contrary, in the study by von Arx et al. (2011), the right mandibular first premolar area showed the highest frequency (27.5%) of lingual foramina in the posterior region.

The Authors also found a mean vertical distance of 7.07 mm between the posterior lingual foramina (foramina between the mesial aspects of the first premolars and the distal aspects of the third molars) and the lower mandibular border.

The sublingual artery, which is a branch of the lingual artery, plays a main role in supplying the floor of the mouth above the mylohyoid muscle.

Previous studies also showed that branches of the submental artery, which diverge from the facial artery, perforated the mylohyoid and digastric muscles and were distributed in the perimandibular region (Flanagan 2003; Kalpidis & Setayesh 2004).

Mardinger et al. (2007) reported that many blood vessels were present in the perimandibular region from the cuspid to second molar, and that most vessels in the anterior perimandibular region were found in the superior area of the mylohyoid muscle, while most vessels were in the inferior area of the mylohyoid muscle in the posterior perimandibular region.

In reference to these anatomical reports, it is suggested that lingual foramina close to the midline area contain a branch of the sublingual artery, and lingual foramina in the second premolar area contain a branch of the sublingual artery, submental artery, or anastomosis of these arteries.

Injury to the soft tissue adjacent to the lingual foramen can cause serious bleeding by damage to these arteries.

Thus, either the midline lingual foramina or the lateral ones are clinically significant anatomical structures even if they are less than 1.0 mm.

However, clinical problems during implant placement rarely occur unless the lingual cortex is perforated, because the possibility of the presence of lateral lingual foramina in the superior area of the mandibular canal and its anterior branch is extremely low.

Osseous morphologic characteristics of the anterior mandible

After tooth extraction, the basal osseous structure remains fairly stable, whereas the alveolar bone undergoes an inevitable life-long resorptive process in most individuals.

Residual ridge reduction is considered the end result of complex interactions between numerous functional, anatomic, inflammatory and systemic factors (Kingsmill 1999).

Besides a significant inter- and intra-individual variability observed during bone remodelling, the alveolar processes are resorbed in a predictable manner.

Bone loss in the anterior mandible is primarily horizontal from the labial side.

This resorptive pattern, in combination with the protrusion of genial tubercles, results frequently in a lingually angulated trajectory of the anterior mandibular region.

Implant placement with favourable prosthetic angulation may induce lingual perforations in the inclined atrophic edentulous mandible and, consequently, severe hemorrhage.

In addition, the reduced height of the residual alveolar ridge may generate lingual fenestrations far closer to the inferior mandibular border and provide access to muscular and vascular structures located deeper in the FOM.

The sublingual fossa is a distinct osseous depression on the lingual aspect of the anterior alveolar ridge, superiorly to the mylohyoid muscle, in the region extending between the lateral incisor and first premolar.

Part of the sublingual gland, which is on the mylohyoid muscle, is located in the sublingual fossa.

The sublingual fossa varies greatly in anatomy, from being barely discernable to severely pronounced.

As a consequence, instrumentation for the placement of an implant in a region where an extremely concave sublingual fossa is present is more likely to cause perforations of the lingual cortical plate.

Tomographic scans, providing a detailed view of the lingual osseous architecture, along with a proper flap elevation may really help to avoid dangerous hemorrhage in presence of extreme sublingual undercuts (Tepper et al. 2001; Kalpidis & Setayesh 2004).

CLINICAL CONSIDERATIONS RELATED TO SUBLINGUAL HEMORRHAGE

Airway control

In case a vascular trauma occurs during implant placement, surgeons should be prepared for the control of a severely compromised oropharyngeal airway.

An impending airway loss is manifested by several cardinal clinical signs and symptoms including tachypnea, dyspnea, employment of accessory muscles of respiration, stridor, cyanosis, decreased phonation, inability to swallow.

However, all these clinical signs may be absent until a significant airway occlusion, dictating the necessity of an immediate intervention, is established.

The airway control options include: close observation, orotracheal intubation, fiber-assisted nasotracheal intubation, tracheostomy or cricothyroidotomy.

The decision for the appropriate airway management depends upon the surgical setting, level of experience, available personnel, size of hematoma, severity of bleeding, upper airway symptomatology, patient's medical history and clinical course of each case.

Bleeding control

Once the airway is controlled, basic bleeding control measures are instituted.

Hemorrhage is controlled by gauze tamponage, application of hemostatic agents, cauterization or digital compression.

The gradually elevated local extravascular pressure along with the compression from adjacent soft tissues frequently limit the internal intraoral hemorrhage encountered during or after surgical procedures.

Surgical decompression of the hematoma with drainage may actually have a reverse effect by lowering the established pressure and hence promoting further bleeding (Goldstein 1981).

Since the anatomic distortion of the offended vessel area makes surgical maneuvers in the region very challenging, some surgeons tend to defer surgical exploration of the area for bleeding control.

In such cases, patients are closely monitored in anticipation of hemorrhage self-resolution aided by local management of bleeding.

This approach was adopted successfully in a few cases following implant surgery.

When the bleeding after implantation is not restricted and the local conservative maneuvers are ineffective, a surgical exploratory procedure is preferred in order to identify the hemorrhagic source and obtain resolution of bleeding.
Should an extraoral approach be necessary for ligation of the feeder artery, classic anatomy would impose ligation of the lingual artery in Pirogoff's triangle to stem uncontrolled sublingual bleeding (DuBrul 1980).

Preventive measures

Contemporary dental implant placement has become a highly specialized field that requires both long-term and ongoing training.
When performed by experienced operators, the placement of dental implants in the anterior mandibular region should be considered a relatively safe surgical procedure with low complication rates.
However, the reviewed reports have clearly demonstrated that serious bleeding and potentially fatal upper airway obstruction (UAO) may turn this seemingly safe procedure into a difficult situation.
First, adequate training of the operator (1) is considered a fundamental preventive measure to avoid this life-threatening complication.
Computed tomography (CT) (2) is also recognized as the most reliable and effective preoperative diagnostic examination in oral implant placement, as it provides a detailed three-dimensional reconstruction of the bone morphology including the shape of the residual ridge, the lingual accessory mandibular foramina with related canals and the spatial arrangement of the sublingual fossae.
Alternatively, proper preoperative digital palpation (3) of the lingual mandibular surface may be of assistance in evaluating the possibility of osseous perforations during implantation.
Moreover, surgical lingual probing and adequate elevation of the lingual mucoperiosteal flap (4) provide a detailed view of the osseous contour (Givol et al. 2000).
In fact, proper lingual flap elevation shields the underlying soft tissues, musculature and sublingual vessels when the perforation of the lingual cortical plate of the mandible occurs during instrumentation (Givol et al. 2000; Niamtu 2001).

CONCLUSIONS

In contrast to 2-D imaging, CT has the advantage of not being sensitive to beam orientation. Thus, we found it possible to visualize the superior and inferior genial spinal foramina and their bony canals with CT more easily than was reported with conventional radiographic results.

Hofschneider et al. (1999) were the first to mention the possibility of visualising bone canals by means of CT, while, two years later, Tepper et al. (2001) also clearly demonstrated the high incidence of such bone canals by CT scan examination.

The presently reported description of canal dimensions and locations must be given importance during surgery, since potential damage to the vessels afferent to the lingual canals during surgery at the anterior mandible, such as implant placement, cannot be excluded.

The length of implants to be placed in the anterior mandible should also be well considered. Several authors agree that it's no longer necessary to achieve bicortical anchorage (Ivanoff et al. 2000; Pierrisnard et al. 2003) and careful evaluation should be made before using implants longer than 13 mm in the anterior mandible.

Based on our study of human cadavers, it results that vessels in the floor of the mouth may be in close proximity to the lingual cortical plate of the mandibular midline in most of cases and that bleeding can occur when the mandibular cortical plate is perforated even minimally.

Care should be taken to recognize situations where this complication may occur.

Consequently, it's strictly recommended:

- an accurate preoperative planning of the surgical procedures concerning the median mandible, considering the degree of osseous atrophy and of mandibular inclination and, if possible, the radiographic identification of these endoosseous canals through computed axial tomography (FIGURES 17, 18);
- an adequate operator's surgical training in the preparation manoeuvres of the lingual mucoperiostal flaps mainly in elderly patients in order to avoid the accidental laceration of the rich vascular plexus surrounding the genial spinal foramina;
- a precise knowledge of the loco-regional anatomy;

- carefully consider the positioning of the implants at mandibular midline, opting if possible for the use of an even number of implants (ideally 4) in the interforaminal region and thus avoiding any possible traumas to the lingual cortical plate of the mandibular midline.

This implant-prosthetic treatment planning is even more necessary in case of severe osseous atrophies.

As reported by the present study, the distance between such foramina/bony canals and the bone crest was found to be far reduced in Class V to VI mandibles displaying a severe osseous atrophy.

This would confirm that the more resorbed the bone crest is, the higher the risk of violation of sublingual vessels afferent to midline lingual foramina during implant placement at the anterior mandible.

Although dental CT is a relatively complex examination method involving relatively high exposure to radiation, the method has nevertheless proven to be effective as a standard for visualization of the anatomic conditions of the maxilla and the mandible.

The high incidence of lingual bony canals along with the reported cases of severe postoperative bleeding complications underline the need for an efficient tool for accurate presurgical diagnosis.

Dental CT seems to be particularly suitable, since the high resolution analysis of the entire body of the mandible provides not only an image of the skeletal conditions, but also of the sites of entrance of the vessels into the lingual mental region.

In addition, the value of CT in the forensic aspects of sufficient documentation, diagnosis and treatment planning should not be underestimated.

Figure 17.

Cross-sectional view of the midline mandible showing the site of entrance of a superior genial spinal foramen at the mandibular lingual aspect.

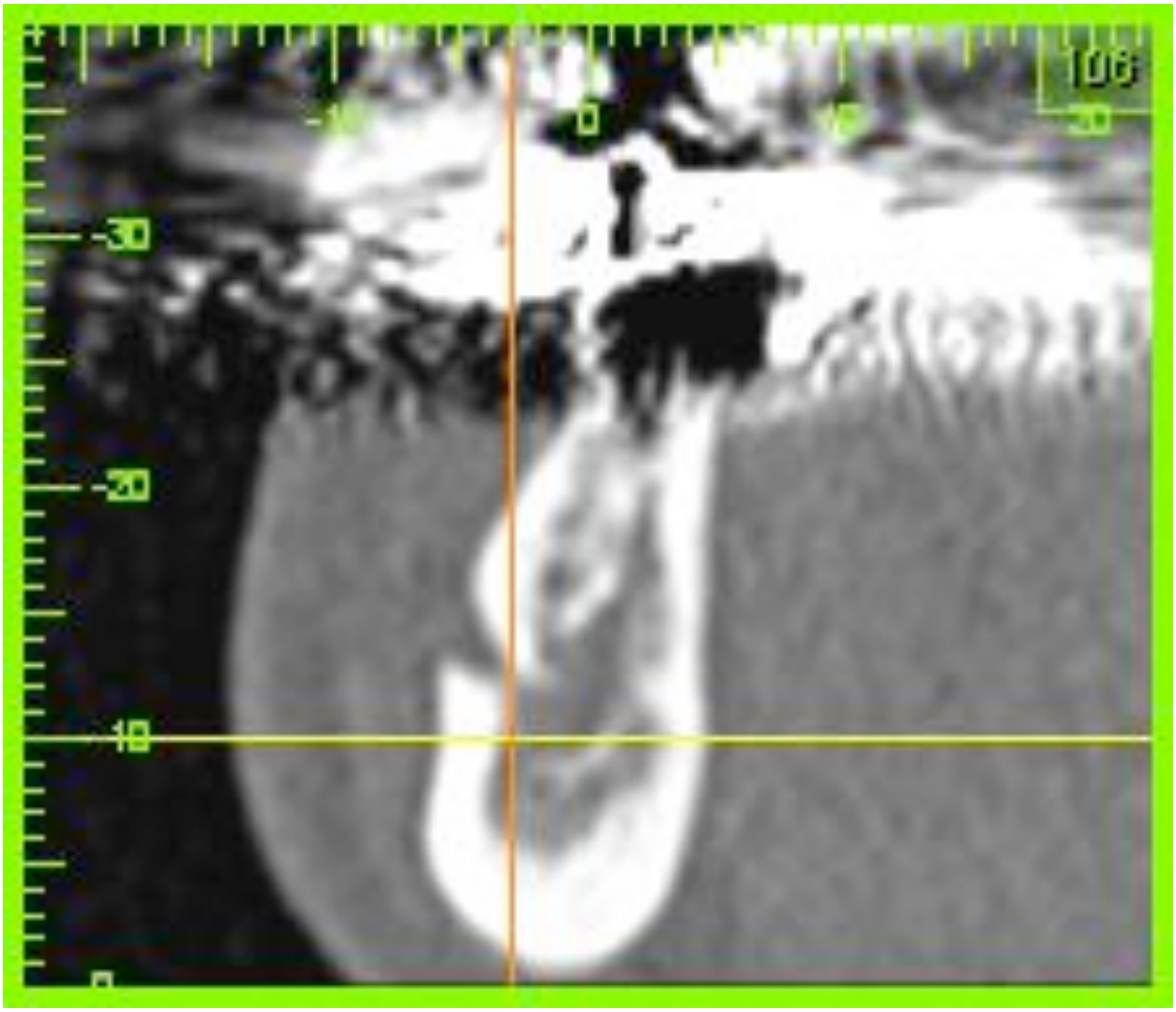


FIGURE 18.

Figs 18A, 18B, 18C show transversal dental CT scans of anterior mandibles providing an image of the sites of entrance of the vessels into the lingual mental region.

FIG. 18A

3D transversal CT scan of the anterior mandible.

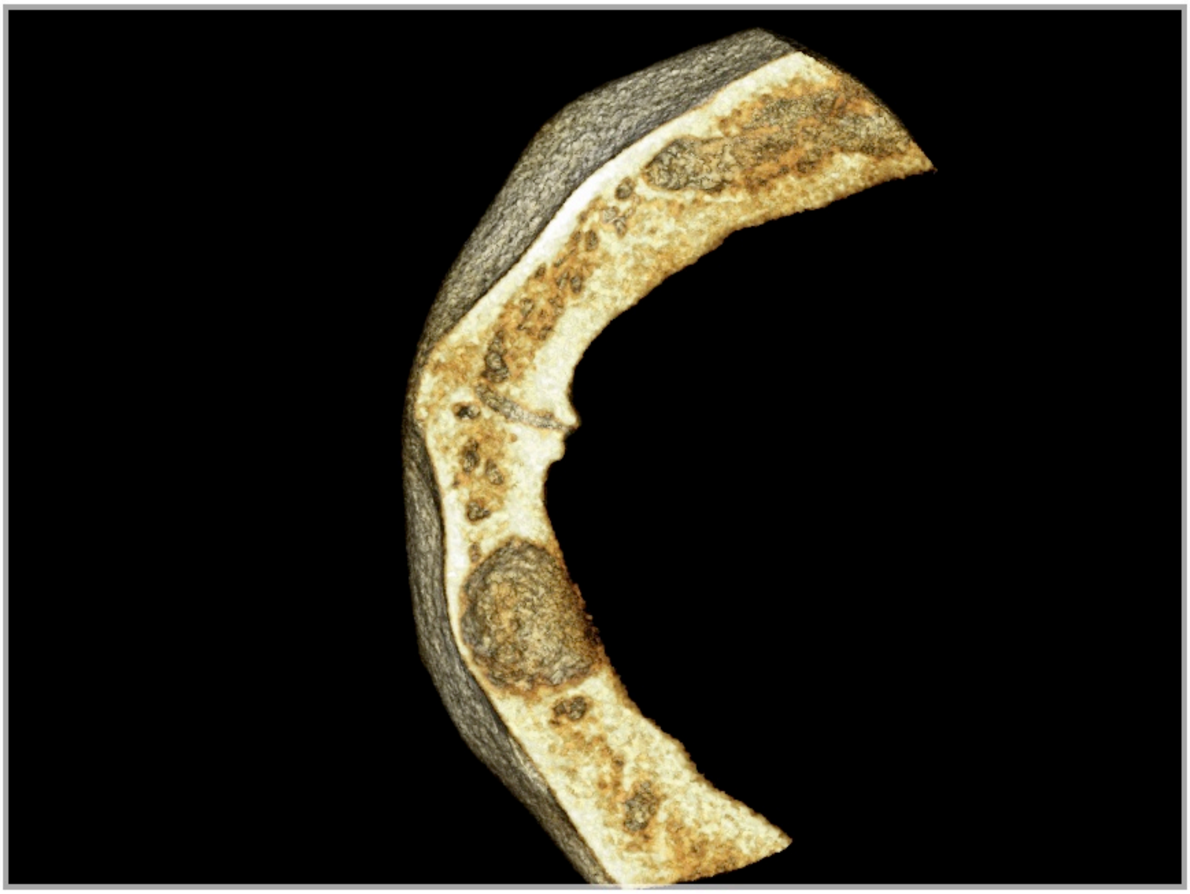


FIG. 18B

FIG. 18C

REFERENCES

Agur, A.M.R. (1991) Grant's atlas of anatomy, 9th edn. Baltimore: Williams and Wilkins. P 501.

Bavitz, B., Harn, S. & Homze, E. (1994) Arterial supply to the floor of the mouth and lingual gingival. Oral Surg Oral Med Pathol 77: 232-235.

Boyes-Varley, J.G. & Lownie, J.F. (2002) Hematoma of the floor of the mouth following implant placement. SADJ 57: 64-65.

Bradley, J.C. (1981) The clinical significance of age changes in the vascular supply to the mandible. Int J Oral Surg 10 (Suppl. 1): 71-76.

Cadenat, H. & Barthélémy, R. (1972) Importance de la vascularisation mandibulaire en chirurgie maxillo-faciale. Rev Stomatol 73 : 60-65.

Castelli, W.A., Nasjleti, C.E. & Diaz-Perez, R. (1975) Interruption of the arterial inferior alveolar flow and its effects on mandibular collateral circulation and dental tissue. J Dent Res 54: 708-715.

Darriba, M.A. & Mendonca-Caridad, J.J. (1997) Profuse bleeding and life-threatening airway obstruction after placement of mandibular dental implants. J Oral Maxillofac Surg 55: 1328-1330.

DuBrul, E.L. (1980) Sicher's Oral Anatomy, 7th edn. St. Louis: Mosby.

Givol, N., Chaushu, G., Halamish-Shani, T. & Taicher, S. (2000) Emergency tracheostomy following life threatening hemorrhage in the floor of the mouth during immediate implant placement in the mandible canine region. J Periodontol 71: 1893-1895.

Hofschneider, U.B., Tepper, G., Gahleitner, A. & Ulm, C. (1999) Assessment of the blood supply to the mental region for reduction of bleeding complications during implant surgery in the interforaminal region. Int J Oral Maxillofac Implants 14: 379-383.

Isaacson, T.J. (2004) Sublingual hematoma formation during immediate placement of mandibular endosseous implants. J Am Dent Assoc 135: 168-172.

Katakami, K., Mishima, A., Kuribayashi, A., Shimoda, S., Hamada, Y. & KobayashI, K. (2009) Anatomical characteristics of the mandibular lingual foramina observed on limited cone-beam CT images. Clin Oral Implants Res 20; 386-390.

Kalpidis, C.D. & Konstantinidis, A.B. (2005) Critical hemorrhage in the floor of the mouth during implant placement in the first mandibular premolar position: a case report. Implant Dent 14: 117-124.

Krenkel, C., Holzner, L. & Poisel, S. (1985) Hematoma of the mouth floor following oral surgery and its anatomical characteristics. Dtsch Z Mund Kiefer Gesichtschir 9: 448-451.

Krenkel, C. & Holzner, K. (1986) Lingual bone perforation as causal factor in threatening hemorrhage of the mouth floor due to a single tooth implant in the canine region. Quintessence Int 37: 1003-1008.

Laboda, G. (1990) Life-threatening hemorrhage after placement of an endosseous implant: Report of case. J Am Dent Assoc 121: 599-600.

Liang, X., Jacobs, R., Lambrichts, I. & Vandewalle, G. (2006) Lingual Foramina on the Mandibular Midline Revisited: A Macroanatomical Study. Clin Anat 19: 000-000.

Longman, R.B. & McRae, D.A. (1985) Clinical Anatomy for Dentistry. New York: Churchill Livingstone. Pp 35-38.

Loukas, M., Kinsella Jr, C.R., Kapos, T., Tubbs, R.S. & Ramachandra, S. (2008) Anatomical variation in arterial supply of the mandible with special regard to implant placement. Int J Oral Maxillofac Surg 37: 367-371.

Mason, M.E., Triplett, R.G. & Alfonso, W.F. (1990) Life threatening hemorrhage from placement of a dental implant. J Oral Maxillofac Surg 48: 201-204.

McDonnel, D., Reza Nouri, M. & Todd, M.E. (1994) The mandibular lingual foramen: A consistent arterial foramen in the middle of the mandible. J Anat 184: 363-369.

McMinn, R. & Hutchins, R.T. (1988) Colour Atlas of Human Anatomy, 2nd edn. Chicago: Year Book Medical Publishers. Pp 20-24.

Mordenfeld, A., Andersson, L. & Bergstorm, B. (1997) Hemorrhage in the floor of the mouth during implant placement in the edentulous mandible: A case report. Int J Oral Maxillofac Implants 12: 558-561.

Niamtu, J 3rd. (2001) Near fatal obstruction after routine implant placement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 92: 597-600.

Panula, K. & Oikarinen, K. (1999) Severe hemorrhage after implant surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 87: 2.

Ragot, B. & Poirot, G. (1983) Contribution à l'étude anatomique de la vascularisation de la région antérieure de la mandibule. Rev Odonto-Stomatol 12 : 49-54.

Ratschew, C., Czernicky, W. & Watzek, G. (1994) Lebensbedrohliche Blutung Nach Implantation im Unterkiefer. Dtsch Zahnarztl Z 49: 65-67.

Rosano, G., Taschieri, S., Gaudy, J-F., Testori, T., Del Fabbro, M. (2009) Anatomic assessment of the anterior mandible and relative haemorrhage risk in implant dentistry. A cadaveric study. Clin Oral Implants Res 20 (8): 791-795.

Shiller, W.R. & Wiswell, O.B. (1954) Lingual foramina of the mandible. Anat Rec 119: 387-390.

Sutton, R.N. (1974) The practical significance of mandibular accessory foramina. Aust Dent J 19: 167-173.

Suzuki, M. & Sakai, T. (1957) The foramina on the lingual surface of the mandible in the Japanese. Med J Shinahu Univ 2: 1-8.

Ten Bruggenkate, C.M., Krekeler, G., Kraaijenhagen, H.A., Foitzik, C. & Oosterbeek, H.S. (1993) Hemorrhage of the floor of the mouth resulting from lingual perforation during implant placement: A clinical report. Int J Oral Maxillofac Implants 8: 329-334.

Tepper, G., Hofschneider, U.B., Gahleitner, A. & Ulm, C. (2001) Computed tomographic diagnosis and localization of bone canals in the mandibular interforaminal region for prevention of bleeding complications during implant surgery. Int J Oral Maxillofac Implants 16: 68-72.

Vandewalle, G., Liang, X., Jacobs, R. & Lambrichts, I. (2006) Macroanatomical and Radiologic Characteristics of the Superior Genial Spinal Foramen and Its Bony Canal. Int J Oral Maxillofac Implants 21 : 581-586.

Von Arx, T., Matter, D., Buser, D. & Bornstein, M. (2011) Evaluation of location and dimensions of lingual foramina using limited cone-beam computed tomography. J Oral Maxillofac Surg 69: 2777-2785.

Weibrich, G., Foitzik, C.H. & Kuffner, H. (2002) Life threatening oral hemorrhage into the distal right mandible. Mund Kiefer Gesichtschir 6: 442-445.

Williams, P.L., Warwick, R., Dyson, M. & Bannister, L.H. (1989) Gray's Anatomy, 37th edn. London: Longman. Pp 367-370.

Woo, B. M., Al-Bustani, S. & Ueeck, B.A. (2006) Floor of the mouth haemorrhage and life-threatening airway obstruction during immediate implant placement in the anterior mandible. Int J Oral Maxillofac Surg 35: 961-964.

Woodburne, R.T. & Burkel, W.E. (1988) Essentials of Human Anatomy, 8th edn. New York: Oxford University Press. Pp 253-255.