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A Study on Mandibular Vascular Canals: The Risk of Hemorrhage During Implant Surgery

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A Study on Mandibular Vascular Canals: The Risk of Hemorrhage During Implant Surgery

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Abstract

Dental implants are commonly used to replace missing teeth in the anterior mandible. This area is vascularized by the sublingual artery, which can be damaged during the implant procedure. This investigation aims to determine the variation in the sublingual artery and its relevant lingual foramina, such that it can be avoided by dental surgeons in the future. Dry mandibles (n=43) were acquired and the distance from the internal superior border of the mandible to the lingual foramen was measured and compared to the total height of the anterior mandible. 67% of foramina were found at a distance greater than 50% below the internal superior border of the mandible, and there was a significant difference in the number of foramina on the left half of the anterointerior mandible (2.3 ± 1.1) compared to the right half (1.4 ± 1.1) (P=0.021). These results imply increased vascularization in the lower half of the anterior mandible as well as on the left half of the same area. Dental surgeons should take extra care when working in these areas in order to minimize risk of sublingual hemorrhaging

Keywords

Lingual Artery, Sublingual Artery, Lingual Foramen, Sublingual Hemorrhaging, Dental Implant

Co-Authorship Statement (where applicable)

This thesis was written and completed by Prabhsimrat Singh Gill under the supervision of Dr. Khadry Galil, Dr. Kat Willmore, Dr. Tim Wilson, and Dr. Hiran Perinpanayagam. Experiments were designed and carried out jointly by Prabhsimrat Singh Gill and Dr. Khadry Galil.

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List of Abbreviations

LA – Lingual Artery

SL – Sublingual Artery

DL – Deep Lingual Artery

GG – Genioglossus Muscle

MH – Mylohyoid Muscle

GH – Geniohyoid Muscle

AM – Anterior Mandible

LF – Lingual Foramen

ALF – Accessory Lingual Foramina

RLF – Right Lingual Foramen

LLF - Left Lingual Foramen

SLF – Superior Lingual Foramen

ILF – Inferior Lingual Foramen

List of Appendices (where applicable)

Chapter 1

1 Literature Review

1.1 General Anatomy of the Mandible

The mandible is the lower jaw bone and helps define the antero-inferior border of the mouth. The lower row of teeth is attached to the mandible via alveolar processes, which are thickened ridges of bone in the mandible that hold the teeth in place. The mandible is in close relation with the maxilla, which is the bone forming the superior portion of your mouth. This bone has its own alveolar processes as well as teeth, and together these structures allow for chewing of food. The mandible articulates with the temporal bone at the Temporo-Mandibular joint (TMJ). This joint is surrounded by a capsule and has an articular disc which divides the joint into an upper and lower half. The upper half of the joint allows for translational movement (forward and back) whiles the lower joint allows for rotational movement (initial movement when opening jaw). During development, the mandible actually begins as two halves but fuses at the midline to form one single bone (Moore, DalleyII, & Agur, 2014). The mandible consists of a body where the alveolar processes and teeth insert into. This body curves upwards posteriorly to form the ramus, which ultimately terminates in two large protuberances. The anterior and posterior protuberances are known as the coronoid process and the condyle of the mandible respectively. The condyle is what articulates with the temporal bone to form the TMJ.

The mandible has a couple of important foramen through which blood vessels and nerves can enter or leave. The mandibular foramen is found on the medial side of the mandible where the body of the mandible angles upwards to form the ramus, and forms the mandibular canal which exits as the mental foramen. The contents of this canal include the inferior alveolar artery, inferior alveolar vein, and inferior alveolar nerve. The inferior alveolar nerve is a branch off the mandibular nerve which comes off of cranial nerve V (trigeminal nerve). This nerve gives off the nerve to mylohyoid before entering the mandibular canal and supplying sensory information to the lower set of teeth. Before terminating, it gives off the mental nerve which will exit the mandible via the mental foramen and supply the skin of the chin and lower lip (Greenstein & Tarnow, 2006). The inferior alveolar nerve has the possibility of being damaged during dental implant surgery. However, extensive studies have been done on its variation in position and how to avoid hitting this nerve during surgery, particularly as it branches into the mental nerve (Ivey, Wilson, Merrifield, Shimizu, & Galil, 2014). The main variation found is that the inferior alveolar nerve can undergo an "anterior loop" in which it extends anteriorly from the mental foramen. The mean length of this loop was 6.95 mm in length (Greenstein & Tarnow, 2006) and its presence made it easier to damage the nerve during implant surgery.

The inferior alveolar artery is a branch off the maxillary artery, which in turn is a branch of the external carotid artery. This artery's distribution follows that of the corresponding nerve, as outlined above. The inferior alveolar artery will enter the mandibular foramen and travel through the incisive canal until it anastomoses with its counterpart on the other side via the incisor branch, which also supplies the bottom row of teeth as it moves anteriorly (Flanagan, 2003). As this vessel travels through the mandible, it lets off several branches that travel through what are known as nutrient canals. These arteries travel with branches from the inferior alveolar nerve to supply the mandibular bone (Ogawa, Fukuta, Nakasato, & Nakasato, 2016). Once the inferior alveolar artery leaves the mandible and becomes the mental artery via the mental foramen, it will supply the chin and bottom lip and will anastomose with the submental and inferior labial arteries. This artery also has been known to anastomose with the submental and sublingual artery within the mandible (Kawai & al, 2006). Presently, there does not seem to be much if any literature on the effects of dental implant surgery on the inferior alveolar artery. However, it has been mentioned that this surgery can affect the artery indirectly by damaging one of its anastomoses (Flanagan, 2003).

1.2 The Lingual Foramen and other relevant foramina

The lingual foramen is a foramen found at the midline of the mandibular body on the lingual side, typically level with the genial bodies (McDonell, Nouri, & Todd, 1994) (Figure 1.2.1). Variations of this foramen have been found and it is not uncommon to find multiple lingual foramina in a mandible. These variations were classified as either superior or inferior genial spinal foramina depending on their location relative to the genial spine (Bernardi &

Rastelli, 2014). The main vessel traveling through this foramen is the sublingual artery which branches off the lingual artery and supplies the floor of the mouth as well as the mandible. However, the contents of the foramen vary based on its position. A lingual foramen higher than normal may contain branches of the main lingual artery, whereas a lower lingual foramen is more likely to have the actual sublingual artery travelling through it (Bernardi & Rastelli, 2014). The anterior mandible was thought to be a safe place for surgery, but with the discovery of this foramen and its contents it is clear surgeons must be careful working in this area.

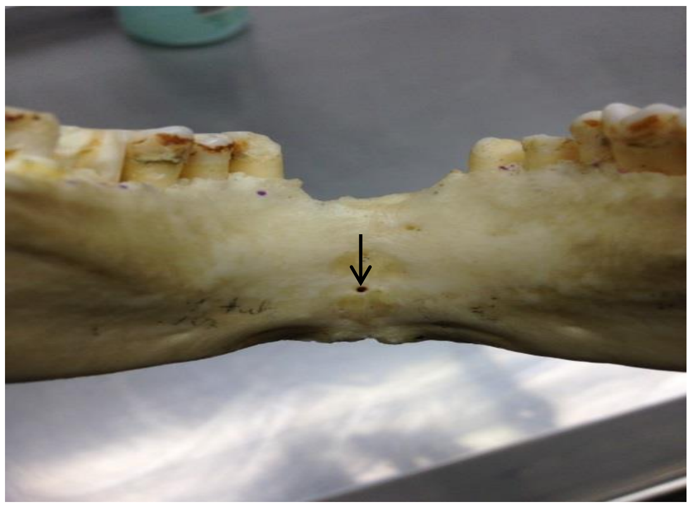


Figure 1.2.1 A Posterior view of the interforaminal region of the mandible. The Lingual Foramen is indicated in the center by the black arrow

1.3 Vasculature of the Mandible

The sublingual artery is a blood vessel that arises from the lingual artery, which in turn comes off of the external carotid artery. The lingual artery is usually the third branch coming off the external carotid, and arises close to the hyoid bone (Niamtu, 2001). The artery is characterized by its inferior loop before moving superior and anteriorly into the tongue. The lingual artery then passes under the hyoglossus muscle and splits at its anterior border to form the sublingual and deep lingual arteries (Figure 1.3.1). The deep lingual artery travels more superiorly to supply the tongue whereas the sublingual artery tends to travel more inferiorly and let off branches supplying not only the tongue, but the floor of the mouth and the mandible as well (Bavitz & Harn, 1994). This supply of the mandible is done via the lingual foramen (Bernardi & Rastelli, 2014). It is worth noting that the lingual artery seems to be resistant to atherosclerosis and therefore maintains a strong blood flow even in aged patients (Flanagan, 2003). As a result damage to this artery may be more serious than most.

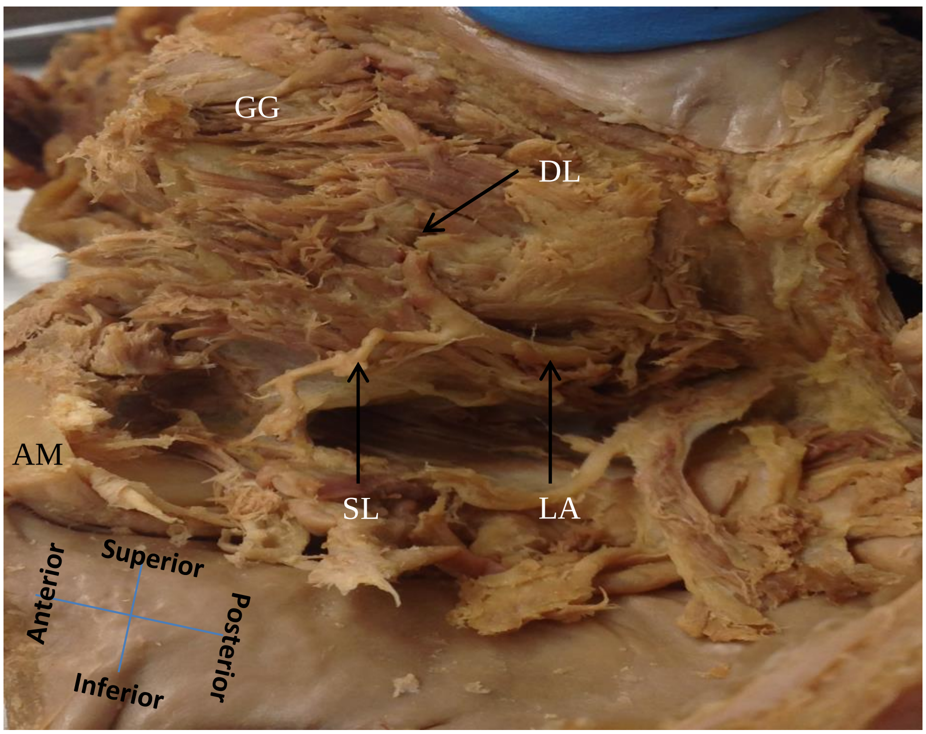


Figure 1.3.1 The Lingual Artery (LA) can be seen branching into its inferior sublingual branch (SL) and superior deep lingual branch (DL). The Genioglossus (GG) and anterior mandible (AM) are also labelled

The venous drainage of the mouth and tongue do not seem to be well researched in the literature. There are three major veins that drain the floor of the mouth and tongue. The sublingual vein, the deep lingual vein, and the dorsal lingual veins. These three have been collectively dubbed the “lingual veins” and will drain into the internal jugular vein. The sublingual veins drain the floor of the mouth whereas the deep and dorsal lingual veins drain the tongue. The latter two veins typically follow the lingual and deep lingual artery, however they are usually found superficial to Hyoglossus rather than deep to it.

Other vessels have been found to supply the oral cavity as well. The inferior alveolar artery arises as a branch of the maxillary artery, which is one of the last branches off the external carotid. It is known to enter the mandible via the mandibular foramen and supply the bone as well as the teeth (Castelli, 1962). The submental artery will also supply the oral cavity. The fourth branch of the external carotid is known as the facial artery. This artery lets off the submental artery as it passes through the submandibular gland (Faltaous & Yetman, 1996). This artery will pass over the mylohyoid and supply the floor of the mouth as well as skin in the submental area (Faltaous & Yetman, 1996). In several cases (53% of donors in one study), the sublingual artery was either not present or very small. In these cases, the submental artery would enlarge and perforate the mylohyoid (Bavitz & Harn, 1994) (Figure 1.3.2). Therefore, it is important to note the presence of this artery in cases where the sublingual artery is missing.

This presents an interesting dilemma for dental surgeons who notice a bleeding artery. A feature of arteries is that when they are severed, they tend to retract into the tissue, occasionally causing them to no longer be visible. As a result, a dental surgeon is presented with a growing hemorrhage for which they have no visible source (Gakonyo, Butt, Mwachaka, & Wagaiyu, 2015). The natural course of action would be to ligate the source of the affected artery. In this case, that artery is thought to be the lingual artery. However, if the sublingual artery is not present in an individual a ligation of the lingual artery will have no effect, block off blood supply to other regions unnecessarily, and waste time in an already delicate situation. The same situation is true if the artery entering the lingual foramen does not have a contribution from the sublingual artery, which occurs in approximately 17.6% of individuals. In these situations, the submental artery which has been known to replace the sublingual artery in the floor of the mouth when it is missing will also enter the lingual foramen to supply the mandible (Gakonyo et al., 2015). Damage to this vessel would therefore necessitate ligation of the facial artery; however this is not common knowledge and is typically not done in time to prevent surgical intervention. It is worth noting that in 8.9% of individuals the vessel entering the lingual foramen is an anastomoses of both the sublingual and submental vessels, and therefore a dual ligation would be required to completely stop bleeding.

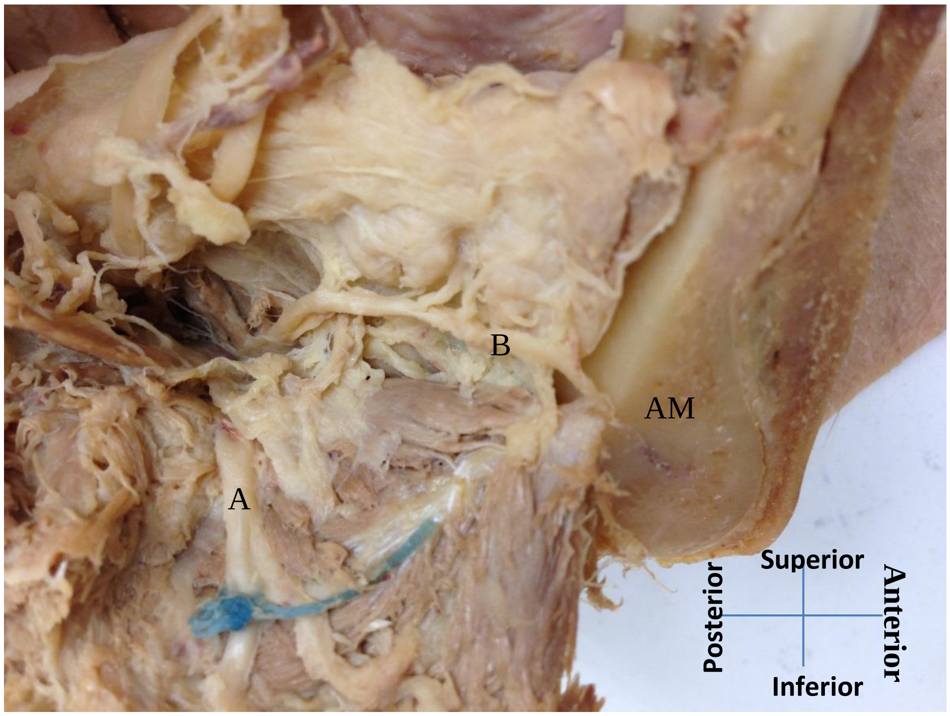


Figure 1.3.2 In this dissection, the Lingual Artery (A) has branched, but both branches are supplying the tongue and therefore the sublingual branch to the floor of the mouth is not present. In this situation, a branch of the submental artery (B) has enlarged and perforated the mylohyoid to supply the floor of the mouth via various visible accessory branches. It can also be seen entering the lingual foramen and supplying the anterior mandible (AM)

1.4 The Floor of the Mouth

The floor of the mouth is comprised of several fascial spaces, as well as various muscles that allow for stability in this region. Two very important spaces that contain the blood released from severed vessels during dental implant surgery are the submental and sublingual spaces.

The sublingual space lies on either side of the tongue. Its borders consist of the mylohyoid muscle inferiorly, the mucosa and floor of the mouth superiorly, and the mandible anteriorly (La, 2011) (Figure 1.4.1). It is a bilateral space which consists of various structures, including but not limited to the lingual artery, lingual nerve, hypoglossal nerve, and glossopharyngeal nerve. Since the sublingual artery is not mentioned in literature often, it is not mentioned as being a component of the sublingual space. However, since the mandible composes the anterior border of the sublingual space and the sublingual space is the major space that swells when the sublingual artery is damaged, it can be reasoned that this artery also lies within the space. Interestingly, damage to the sublingual artery will cause hemorrhaging that can leave the sublingual space and enter the submandibular space (Tomljenovic, Herrmann, Filippi, & Kühl, 2015). This is likely due to a defect in the mylohyoid muscle that is present in approximately 77% of individuals known as a "boutonnierre" (White, Davidson, Harnsberger, Haller, & Kamya, 2001). The mylohyoid is typically the border between the sublingual and submandibular spaces but with this defect those spaces become continuous, resulting in a less contained and more difficult to manage bleed (Figure 1.4.2). The 2 spaces are sometimes collectively known as the submandibular space, with the sublingual space being called the "supramylohyoid portion of the submandibular space" and the submental space being called the "inframylohyoid portion of the submandibular space" (Hartmann, 1999)

The borders of the submental space consist of the hyoid bone inferiorly, the mandible superiorly, and the anterior bellies of the 2 digastric muscles laterally. Some of its contents include the mylohyoid nerve and vessels, submental branch of the facial artery, and the facial vein (Ural et al., 2011). Unlike swelling in the sublingual space, which is more visible in the mouth due to the noticeable swelling of the tongue, the submental swelling can be seen externally and is therefore a good clinical indicator for a dental surgeon.

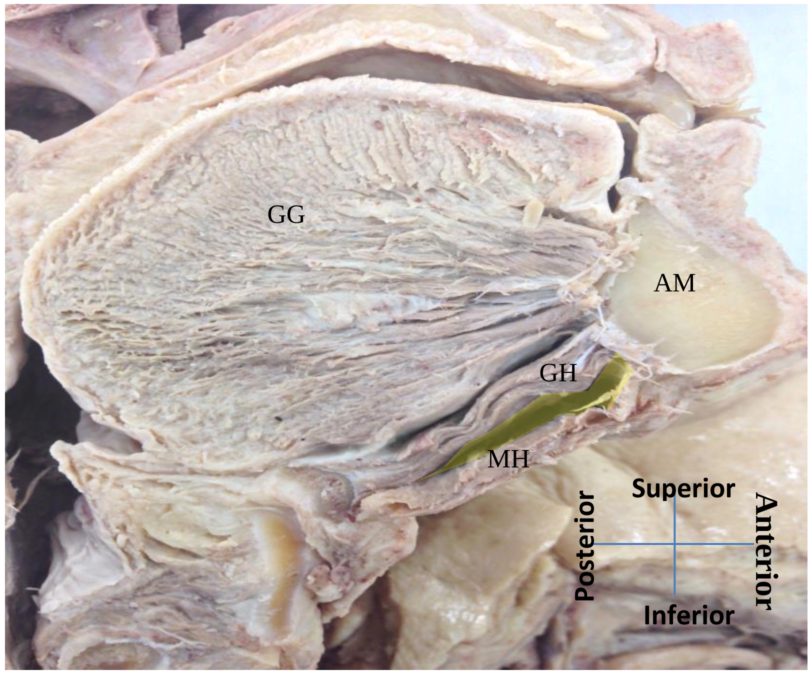


Figure 1.4.1 The sublingual space can be seen highlighted in yellow, superior to the mylohyoid muscle (MH). geniohyoid (GH), genioglossus (GG), and the anterior mandible (AM) are also depicted. The submental space would be found inferior to the mylohyoid muscle

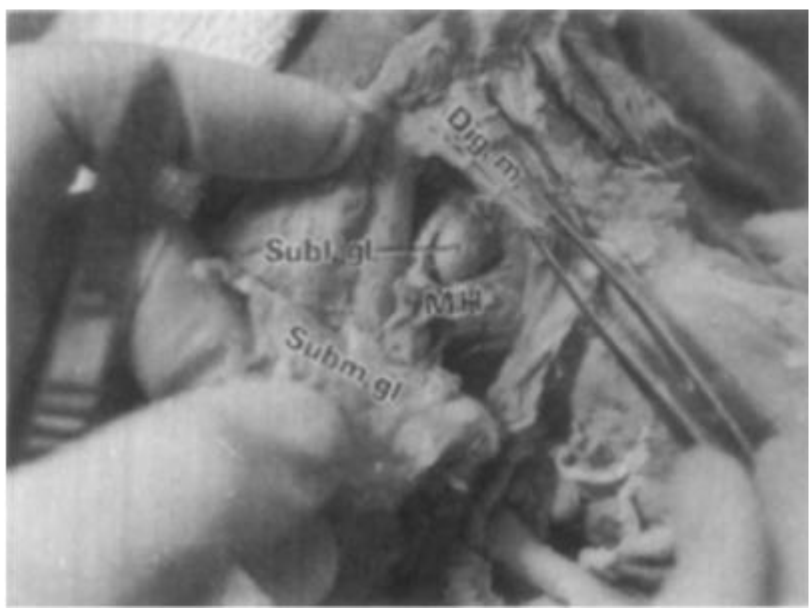


Figure 1.4.2 The mylohyoid boutonniere can be seen as a space in the mylohyoid muscle (MH). In this scenario, the sublingual gland can be seen passing through the boutonnierre, thus leaving its usual position deep to the muscle.

1.5 Dental Implants and Subsequent Hemorrhaging

Dental implants are commonly used for replacing missing or broken teeth and have a high success rate (five year functional success rates of approximately 90%) (Brooks, 2000). The need for dental implants is directly related to age, and as a result dental implant surgery is becoming more popular as the proportion of the population over the age of 65 years continues to rise (Misch, 2014). The implant itself is used to support other structures such as crowns or dentures, and sufficient time is allowed for the implant to integrate itself into the bone.

Because dental implants are inserted into the bone, risk of damaging vessels and nerves is present. This damage is most common when an implant is inserted in the anterior mandible, as this is where the sublingual, submental, and inferior alveolar arteries are known to anastomose within the mandible (Castelli, 1962). In general, these vessels are well defined and their paths are understood. However, hemorrhaging is likely to occur when abnormal vessels or vessels that are not very well defined are present. A big contributor for the seriousness of this condition is the weakness of the lingual floor. The floor is fairly lax and easily expanded when filled with blood, resulting in a diffuse haemotoma that is spread over a large area and is therefore more difficult to drain (Pigadas, Simoes, & Tuffin, 2009).

The hemorrhaging can happen at various depths and stages in the implant procedure. Before the implant itself is placed, the area is typically probed to determine whether enough bone is present for implant integration. During this procedure, bleeding can occur if an artery is perforated (Mordenfield & Andersson, 1997). In the case of (Mordenfield & Andersson, 1997), the bleeding was spotted immediately and the implant was put on hold while the immediate concern was addressed. Another possibility is the hemorrhage occuring after the placement has completed. In the case of (Felisati et al, 2012), the procedure was completed and the dental surgeon did not observe any complications. The patient was asked to stay in the waiting room for an observation period and it was during this time that slow swelling of the sublingual and submandibular regions began, resulting in emergency procedures. In both types of hemorrhaging, the first symptom is echymosis (discoloration due to bleeding beneath the tissue) in the tongue and sublingual tissue due to the damaged blood vessels. As the tongue begins to move upwards against the palate and oropharynx, the dental surgeon must act to stem the bleeding. However, a major concern with this hemorrhaging is that most dental surgeons do not have the tools to stop the bleeding as well as drain the blood. The dental surgeon's primary objective becomes securing the airway, which can typically be done using a laryngeal mask (Niamtu, 2001). At this point, the patient needs to be transferred to the hospital where the resources to stabilize the damaged vessels are available (figure 1.5.1). Fortunately, the procedure is simple and involves tying the bleeding artery and cleaning out any excess blood. Patient's are generally discharged in good health within a week. However, as this bleeding can lead to death by asphyxiation if not treated in a timely manner, it is still an issue that needs to be addressed further in the literature (Felisati et al, 2012).

Figure 1.5.1 A patient who had severe hemorrhaging following a dental implant procedure. A tracheotomy was performed to secure the airway before surgery

There have been cases where a bleeding artery in this region was not life-threatening. In the case of (Flanagan, 2003), the bleeding was detected after removal of the old tooth but before placement of the implant. In this situation, a vasoconstricter as well as compression of the affected vessel by a sponge tamponade were enough to stop the bleeding, and this is the first course of action in this situation before the patient is sent to the hospital.

1.6 Current Interventions

Because this is a problem that has been around for several years, dental surgeons have done research to try to better understand ways they can avoid damaging these vessels during surgery. The major issue is the variability of the sublingual artery and the foramen it travels through, and so some dental surgeons have tried to visualize these structures before surgery in order to avoid them.

Radiographs have become a popular method of imaging among dental surgeons due to their ability to cover a wide portion of the jaw, allowing them to quickly locate abnormal structures such as tumors, cavities, signs of bone loss, etc. They are also inexpensive, easy to use, and the image is produced relatively quickly. As a result, studies were conducted to see if radiography is a suitable candidate for detecting the lingual foramen. It was found through a cadaveric study that the lingual foramen is found in 99% of the population (McDonnell, Reza Nouri, & Todd, 1994). However, when radiographic imaging was used in the lingual interforaminal region, the lingual foramen was not reliably visible, with visibility ranging from 4.7% of patients (Jaju, Jaju, Agarwal, & Singh, 2014) up to 49% of patients (McDonnell et al., 1994). Since a foraminal prevalence rate of 99% is known, the maximum visibility rate of 49% found in the literature is not enough for radiographs to be considered a reliable way to detect this foramen. There are a couple of reasons why this scan is not effective. First, the cervical vertebrae are imaged clearly in radiography, and since they are midline they obstruct the view of the lingual foramina (Figure 1.6.1). Another reason is the orientation of the canals themselves. If the canals are not positioned parallel to the direction of the x-ray beams, they will not be depicted (Jaju et al., 2014).

A more reliable method that has been proposed is using Cone-Beam Computed Tomography (CBCT) to identify the lingual foramen. CBCT is an improvement over regular computed tomography in that it has a fast scan time, lower radiation exposure for patients, and a higher resolution (Scarfe, Farman, & Sukovic, 2006). In addition, CBCT imaging is able to take an object and visualize it as a three dimensional image, whereas radiographs take three dimensional objects and compress them into two dimensional images (Patel, Dawood, Pitt Ford, & Whaites, 2007). CBCT is more reliable than radiography in that it has been found to clearly image lingual foramen in about 75% of patients (Jaju & Jaju, 2011). However, there are still two issues with this method of visualization. The first is that the 75% visualization rate of the foramen, while significantly better than the 49% seen with radiographs, still misses 24% of foramen. Additionally, all scans cost money which the patient must pay for if uninsured. CBCT images can cost a patient anywhere from $150-$700. Therefore, many patients may not be willing or able to pay the extra money to have the scan done, even if it may result in a safer procedure. The goal then becomes finding an alternative to finding the artery which is cost effective for the patient, but also provides the dental surgeon with enough information such that they do not damage the vessel.

One physical landmark that has been proposed for use is the genial tubercles of the mandible. As mentioned above, the lingual foramen was thought to be lined up between the superior and inferior genial tubercles. Therefore, it was thought that these tubercles could be used to approximate the location of the lingual foramen. However, several studies have shown that the lingual foramen and its variations can be found above the genial tubercles (Nagar, Bhardwaj, & Prakash, 2001) as well as below (McDonnell et al., 1994). Unfortunately, the actual distance above and below the tubercles has not been measured, but it is still evident that there is a large variation in the position of the lingual foramen with respect to the genial tubercles, and therefore these structures are not reliable landmarks for locating this foramen.

Chapter 2

2 Introduction

2.1 Background

Dental implant surgery has become an effective way of replacing teeth in patients who have lost their natural teeth for a variety of reasons. The procedure involves inserting titanium screws into the bone of the mandible, onto which an artificial tooth or crown can be mounted. The screws are so effective because the titanium will incorporate itself into the bone over time, allowing for artificial teeth that are stable and do not put any significant mechanical strain on the mandibular bone. These implants are most often done in the anterior mandibular interforaminal region, defined as the region that spans between the two mental foramina. While this region was originally thought to be a relatively safe place for surgical procedure, it has recently been shown that there are extensive anastomoses of blood vessels in the anterior mandible formed by branches of the inferior alveolar artery, the submental artery, and sublingual artery. Damage of these arteries either within the mandibular bone, or in the soft tissue as a result of a dental drill perforating the bone can cause severe hemorrhaging in the patient and require surgical intervention.

The most common cause for this abnormal bleed is damage to the sublingual artery, a vessel that branches from the lingual artery and supplies the floor of the mouth, before ultimately entering the lingual aspect of the anterior mandible via the lingual foramen. The variation in this artery and its associated foramina is not well documented in the literature and as a result many dental surgeons are not aware of its presence until it has already been damaged. This hemorrhaging can also occur as a result of damage to the submental artery, which replaces the sublingual artery in 50% of individuals. However, damage to this vessel is less common.

The purpose of this study is to examine the anatomical relationship between the sublingual vessel and its associated foramina to better understand why this vessel is being damaged during surgical procedure and how this damage can be prevented.

2.2 Objectives

1. Establish the location and size of the primary lingual foramen as well as any accessory foramina in the interforaminal region of the mandible

2. Observe the sublingual artery's path into the mandible and how this path may result in damage during implant surgery

3. Characterize variations in both the sublingual artery and lingual foramina as they relate to the mandible

Chapter 3

3 Methods

3.1 Subject Collection

For the purpose of this study, 43 dry mandibles and 12 embalmed heads were obtained from the cadaver lab at the University of Western Ontario, London, ON, Canada. Use of cadaveric material is in accordance with the Anatomy Act of Ontario and Western's Committee for Cadaveric Use in Research. The mandibles were stored in their own separate boxes along with their corresponding skull. The embalmed heads were separated from their donor bodies and kept in sealed, individual bags and periodically soaked with Detol to avoid dessication. Ten of the heads were bisected because of previous use in a medical school anatomy dissection lab. Mean age of cadaveric specimens was 83 years ± 6.99, with 36.36% being male and 63.64% being female. Individual donor information can be found in Appendix C. Unfortunately, the age and sex of the dry mandible donors has been lost over time and could not be retrieved. Both the dry mandibles and the cadaveric specimens were included in the study regardless of their state of dentition.

3.2 Study Design

3.2.1 Study of the Lingual Foramina

There are a multitude of foramina all along the lingual surface of the mandible, but for the purposes of this study only those foramina in the interforaminal region were measured. The entire lingual surface of the mandible was examined using a magnifying glass and visible foramina were noted. The interforaminal region was then marked and all foramina outside of this region were excluded from the study. A digital caliper was used to measure each foramen's distance from the superior and inferior alveolar surface. In addition, the diameter of the lingual foramen was measured; however the diameter of the other foramina was not measured due to their small size, which the caliper could not accurately measure. For this process, a second measurer was used to ensure interrater reliability among measurements. Both individuals took measurements separately, and were blinded to each other's values until the entire set of dry mandibles was complete.

3.2.2 Study of the Submental and Sublingual Arteries – Bisected Heads

The bisected tongues were pulled medially away from the vestibule of the mouth to expose their lateral surfaces. The mucosa along this surface was stripped away delicately using a probe to expose the muscle fibers of the tongue underneath. The hyoid bone was then used as a landmark to locate the hyoglossus muscle, running superiorly from the bone and eventually merging with the muscular fibers of the genioglossus muscle. The muscle is typically found slightly superficial to genioglossus, and therefore a probe was effective in separating the muscles from one another (figure 3.2.1). Once isolated, the hyoglossus was cut at its superior border and reflected laterally. The lingual artery is typically found underneath this muscle, however the depth varies and dissection of the genioglossus may be required in order to locate the vessel (figure 3.2.2). Once isolated, the sublingual branch was located and this vessel was followed anteriorly in order to fully appreciate its branching into the floor of the mouth and mandible (figure 3.2.3). At the lingual foramen where the vessel enters the mandible, the genioglossus had to be scraped from its origin at the genial tubercles in order to fully visualize the vessel. The deep lingual artery was also typically identified where the lingual artery bifurcated, but this branch was not followed anteriorly.

The submental artery was also isolated in the cadaveric specimens. Initially, the facial artery was identified by reflecting the skin and fascia of the face. This vessel was found crossing over the mandible, and was typically anterior to the facial vein. As this vessel crossed the mandible, the submental artery was located as a branch moving anteriorly and superficial to the mandible. This vessel would then enter the mandible via unnamed foramina on the anterior surface of the chin, below the mental foramen. As mentioned previously, the submental artery has an accessory branch which typically enlarges when the sublingual artery is absent or insignificant. In these specimens, an enlarged branch proximal to where the submental artery entered the anterior mandible was located and followed superiorly as it pierced the mylohyoid muscle. This branch was followed into the oral cavity until it reached the lingual foramen (figure 3.2.4). The mylohyoid was not damaged during this process as it seems to be a valuable landmark to delineate the portion of the submental artery supplying the face and mandible from the portion supplying the oral cavity. It is worth noting that in the specimens that had an accessory submental branch to the floor of the mouth, there was still a primary vessel supplying the chin.

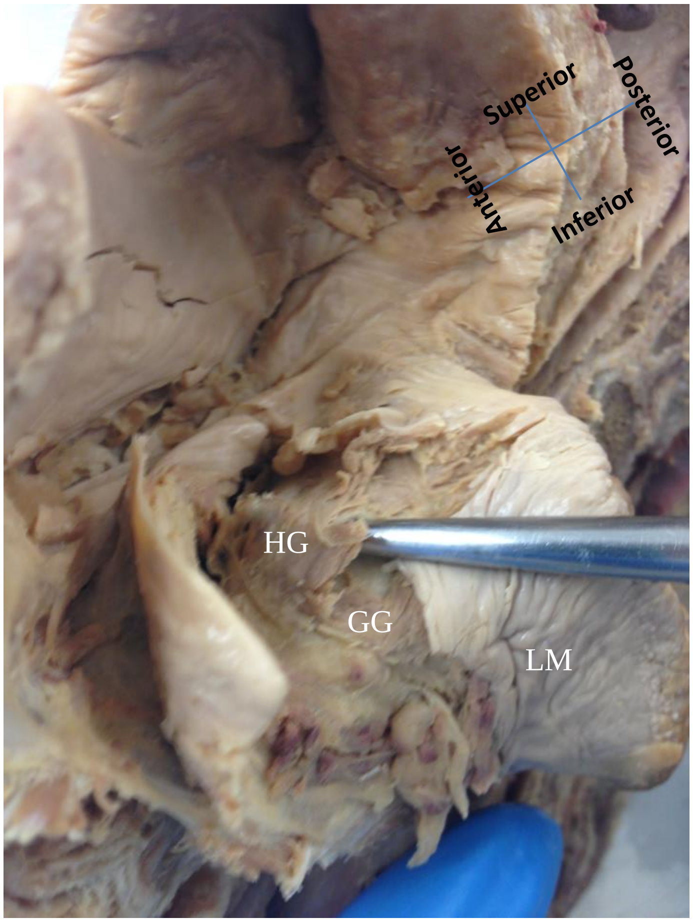


Figure 3.2.1 A probe is being inserted into the space between the hyoglossus (HG) and genioglossus (GG). The lingual mucosa (LM) had to be removed before this region could be accessed. The hyoglossus will be cut superior to the probe and reflected to access the lingual artery deep to it.

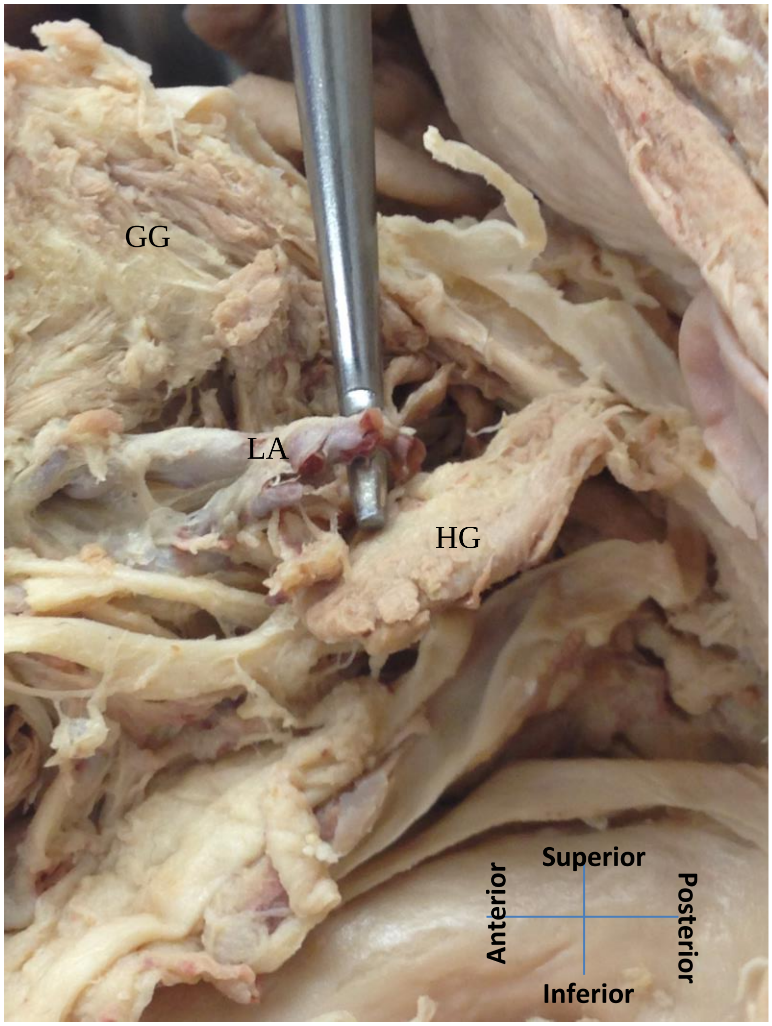


Figure 3.2.2 The hyoglossus (HG) has been reflected laterally to expose the lingual artery (LA) underneath.

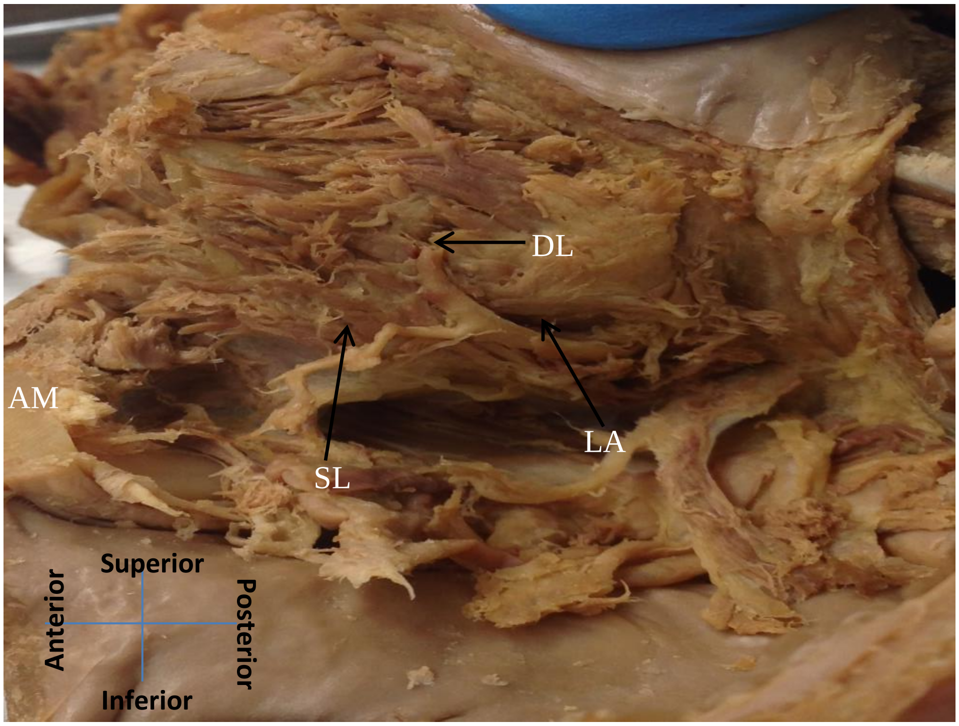


Figure 3.2.3 A full dissection of the sublingual artery (SA) travelling to the lingual foramen in the anterior mandible. The deep lingual (DL) artery can also be seen supplying the tongue (top). Note that the genioglossus has been stripped away from the mandible to expose the foramen. The primary lingual artery (LA) as well as the anterior mandible (AM) have also been labelled.

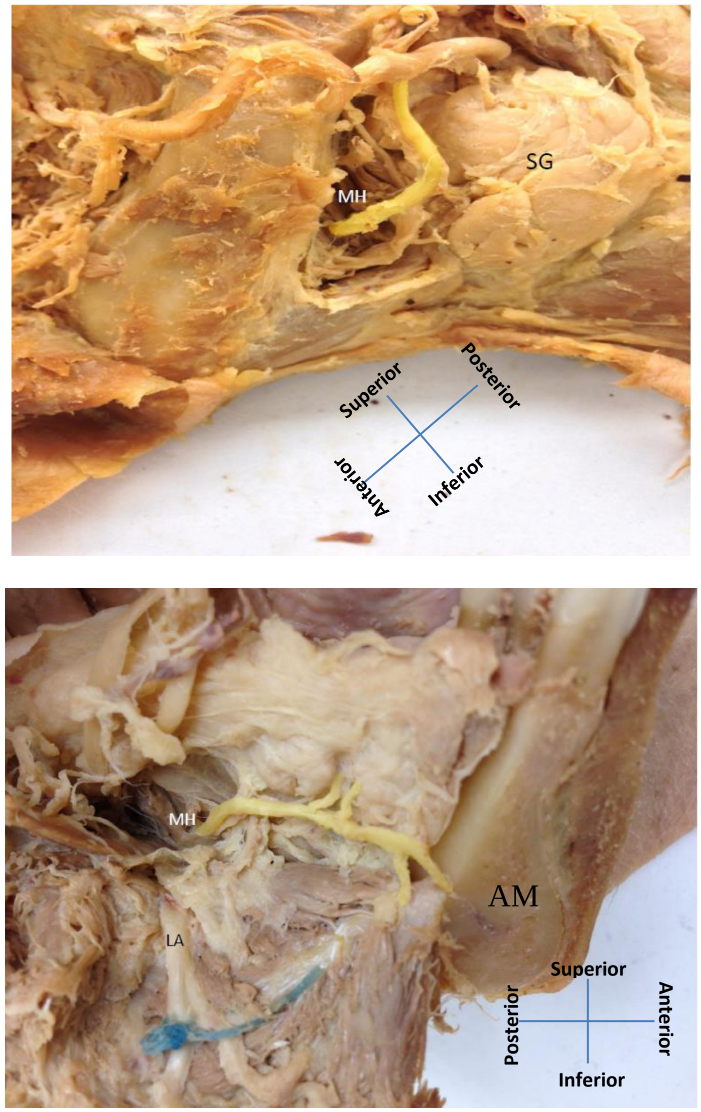


Figure 3.2.4 An enlarged submental artery (indicated in yellow) taking the place of the sublingual artery and entering the lingual foramen. The sublingual gland (SG), mylohyoid muscle (MH) and anterior mandible (AM) are all labeled for orientation purposes.

3.2.3 Study of the Submental and Sublingual Arteries – Whole Heads

For this portion of the study, an inferior approach was taken to identify the sublingual artery. An incision was made just below the mandible inferior to the ear on either side of the specimen and continued medially, with the two incisions coming together at the mandibular midline. An incision was then made inferiorly down the midline of the neck, and the skin was removed to expose the underlying musculature and fascia. The fascia was removed, along with the anterior bellies of the digastric muscles, The mylohyoid was examined for evidence of a penetrating submental artery before being carefully removed. The interior mandible was then examined for evidence of a sublingual artery branch on either side (Figure 3.2.5).

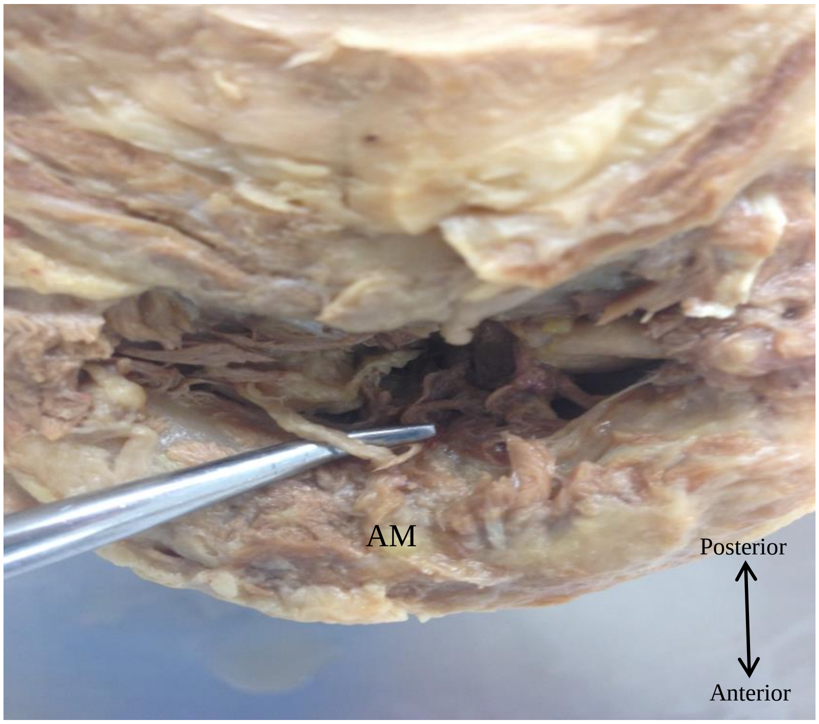


Figure 3.2.5 An inferior view of the mandible in which the skin, fascia, and musculature has been removed. A Sublingual Artery can be seen travelling towards the anterior mandible (AM)

Chapter 4

4 Results

4.1 Interrater Reliability

The interrater reliability was measured using the intraclass correlation coefficient in order to determine whether the values of both raters agreed with one another using IBM SPSS statistics version 23. The 95% confidence interval was 0.938-0.984, indicating a high degree of agreement between raters.

4.2 Lingual Foramen Characterization

Of the 43 mandibles examined, four were excluded from this portion due to the lack of any apparent lingual foramen, resulting in a lingual foramen prevalence of 90.7%. First, the distance from the superior alveolar surface of the lingual side of the mandibular bone (henceforth known as D1) was measured in millimeters and recorded as a histogram in order to identify patterns among the foramina and their positions (figure 4.2.1).

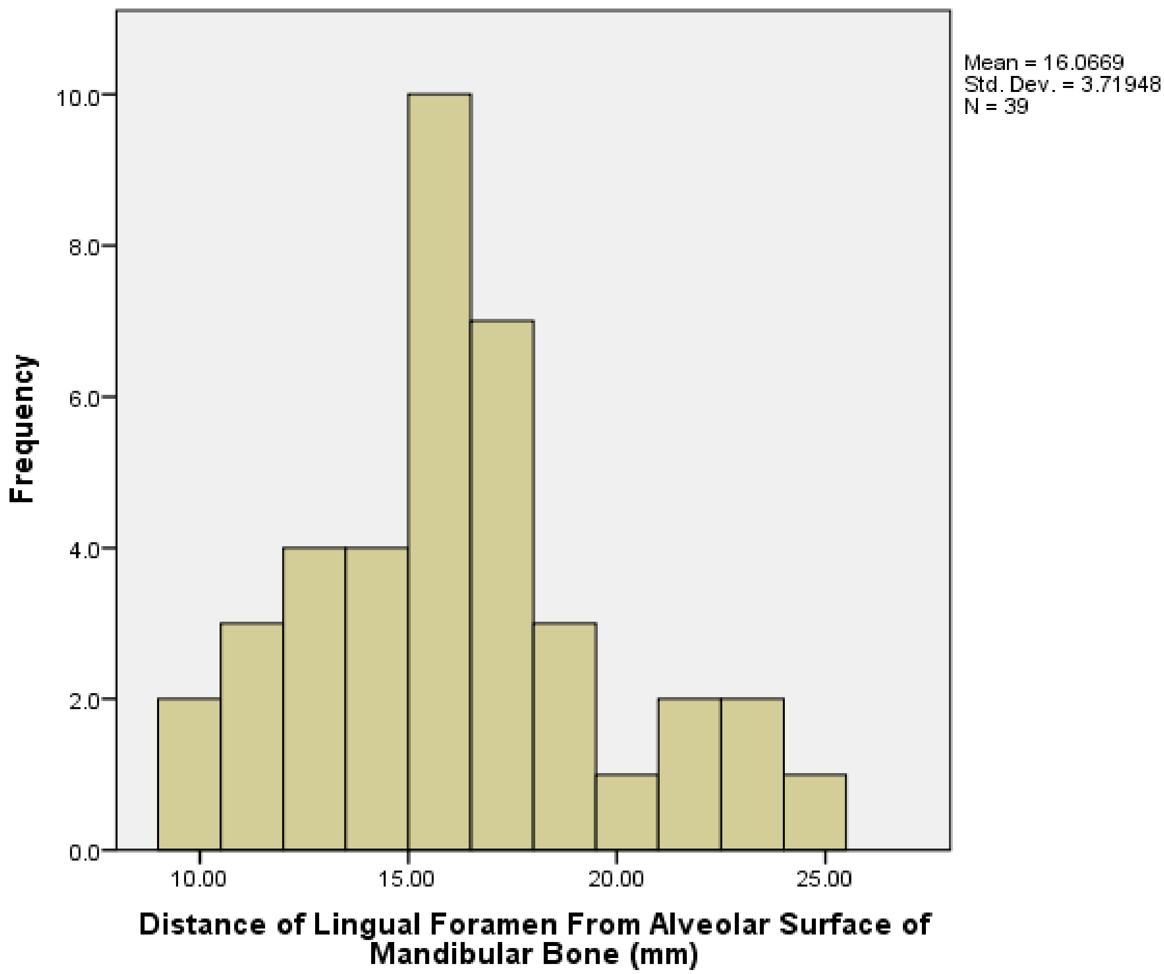


Figure 4.2.1 Histogram depicting the variation in positioning of the lingual foramen along the lingual surface of the mandible in relation to the alveolar surface of the bone. 39 specimens were measured with the mean distance from the alveolar surface being 16.17 ± 3.72 mm with a range of 9.27 mm – 24.33 mm.

The distance of the lingual foramen from the mental surface of the lingual aspect of the mandible was also measured (henceforth known as D2) and expressed in a fashion similar to figure 4.2.1 (Figure 4.2.2).

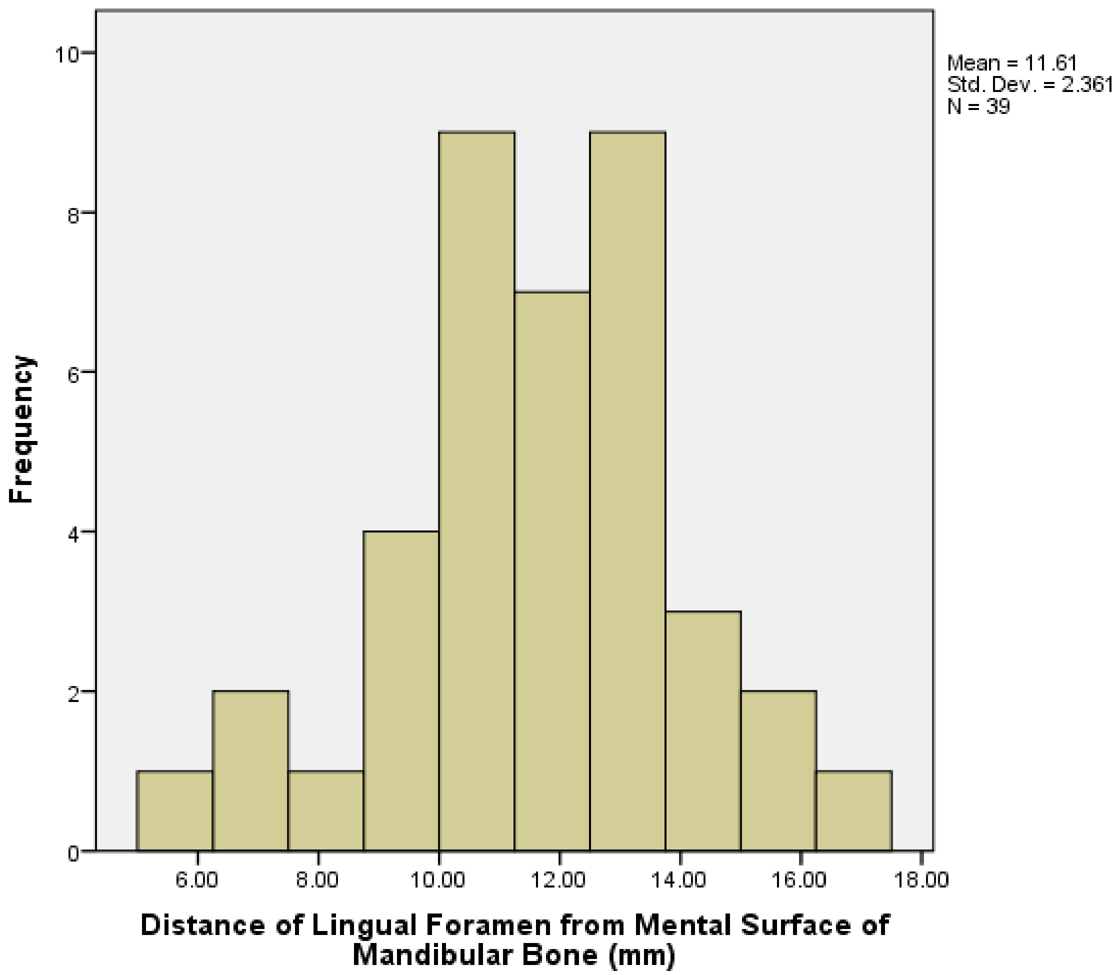
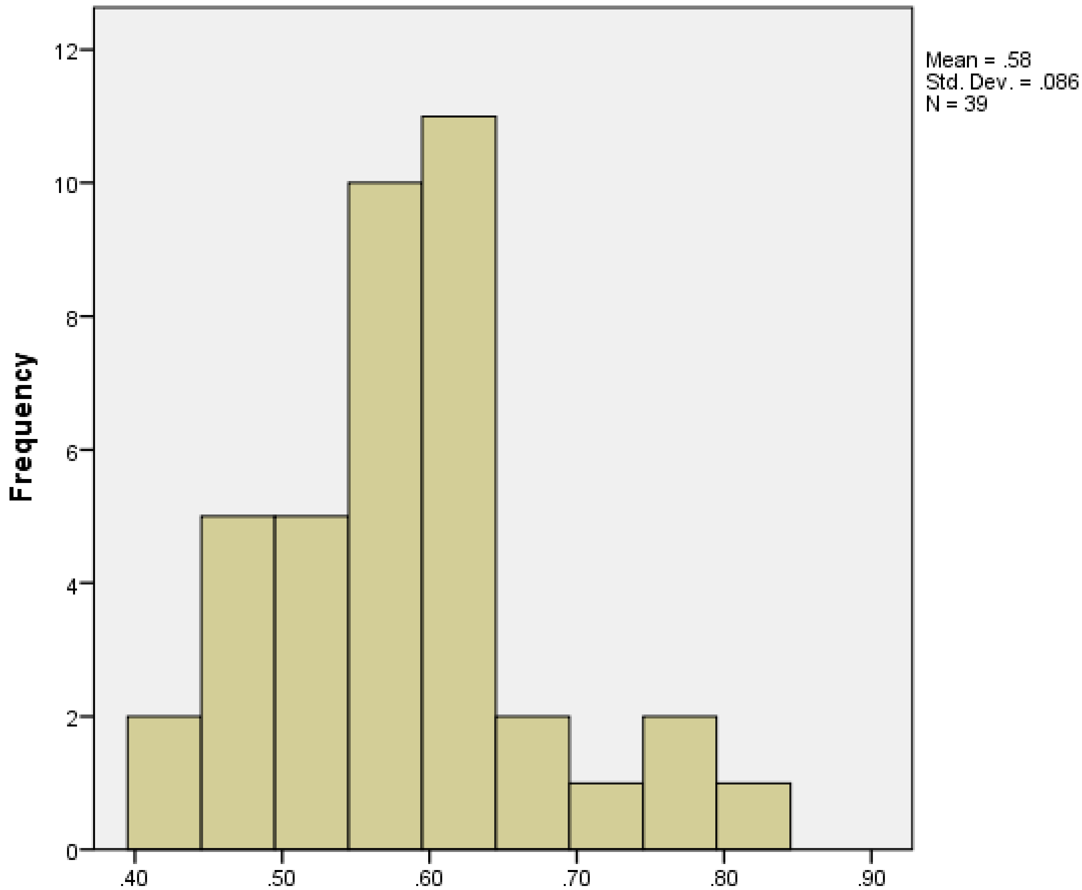


Figure 4.2.2 Histogram depicting the variation in positioning of the lingual foramen along the lingual surface of the mandible in relation to the mental surface of the bone. 39 specimens were measured with the mean distance from the mental surface being 11.61 ± 2.36 mm with a range of 5.22 mm – 15.62 mm.

The position of the lingual foramen was then measured as a ratio using the following formula:

$$\frac{D1}{Total\ Height\ of\ the\ Internal\ Interforaminal\ Surface\ of\ the\ Mandible\ (D1 + D2)}$$

This was done in order to account for differences in bone morphology such as sex, race, and age, and the results can be seen in figure 4.2.3



$$\frac{D1}{Total\ Height\ of\ Internal\ Interforaminal\ Surface\ of\ the\ Mandible}$$

Figure 4.2.3 Histogram depicting the position of the lingual foramen on the lingual surface of the mandible as a ratio between D1 and the total height of the mandible at its lingual surface. 39 specimens were measured with the mean distance from the superior alveolar surface being 0.58 ± 0.09 with a range of 0.42 – 0.81.

The diameter of the lingual foramen was measured in all specimens and the mean diameter was found to be 0.946mm ± 0.287mm with a range of 0.44 mm – 1.75 mm. We then wanted to see if the position of the lingual foramen affected its diameter, since this has been suggested in past literature. To do this, the specimens were split based on their position on the mandible, with group 1 including those specimens that were found at a point equal to or greater than the mean D1/total height ratio of 0.58 and group two including those found at a point below this ratio. The mean diameter of foramina in group 1 was 0.933mm ± 0.256mm. The mean diameter of foramina in group two was 0.980mm ± 0.346mm. An Independent Samples t-test was performed on these two groups, and no significant difference was found between the diameters of lingual foramina when accounting for their height on the lingual mandibular surface (P=0.243).

4.3 Accessory Lingual Foramina Characterization

The positioning of the accessory lingual foramina (ALF) on the mandible was examined similarly to how the primary lingual foramen's position was evaluated. It was found that the dry mandibles had, on average, 1.91 ± 0.84 accessory foramina directly surrounding the lingual foramen. Of the 43 mandibles; 2/43 (5%) had no foramina, 11/43 (25.6%) had one foramen, 19/43 (44.2%) had two foramina, and 11/43 (25.6%) had three foramina. None of the mandibles examined had more than three foramina that were identifiable. A right lingual foramen was found in 22/43 (51.2%) of specimens, a left lingual foramen was found in 24/43 (55.8%) of specimens, a superior lingual foramen was found in 5/43 (11.6%) of specimens, and an inferior lingual foramen was found in 31/43 (72.1%) of specimens.

The primary statistics of interest for the different foramina were their distances from the alveolar and mental surfaces of the mandibular bone. The average distance from both the alveolar and mental surfaces of each accessory foramen was obtained, documented in Table 4.3.1, and plotted on a graph against the primary lingual foramen, as seen in figure 4.3.1.

Table 4.3.1 Mean distances (mm) of the primary and accessory lingual foramina from the alveolar and mental surfaces of the mandible

A one-way ANOVA test was done to compare the mandibular location of all four

	Distance from Alveolar Surface (mm)	Distance From Mental Surface (mm)
Lingual Foramen	16.13 ± 3.58	11.61 ± 2.36
Right Lingual Foramen	21.38 ± 4.18	6.63 ± 2.39
Left Lingual Foramen	19.58 ± 4.42	7.75 ± 2.42
Superior Lingual Foramen	13.44 ± 3.84	14.33 ± 1.78
Inferior Lingual Foramen	24.21 ± 4.02	4.40 ± 2.26

types of accessory foramina to each other as well as to the primary lingual foramen. It was found that there was no significant difference between the lingual foramen and the superior lingual foramen ($P=0.619$), however there was a significant difference in the position of the lingual foramen and the inferior lingual foramen ($P>0.0001$), the right lingual foramen ($P=0.000026$), and the left lingual foramen ($P=0.010$). There was an expected difference between the overall positions of the superior lingual foramen and inferior lingual foramen ($P=0.000001$). However, there was no significant difference between the positions of the left and right lingual foramina ($P=0.546$). Both of these foramina were typically found below the level of the primary lingual foramen, with the left lingual foramen’s height being a mean distance of 3.46 ± 1.06 mm below the lingual foramen, and the right lingual foramen’s height being a mean distance of 5.26 ± 1.26 mm below the lingual foramen. The right lingual foramen was the only foramen that didn’t have a significantly different position from the inferior lingual foramen ($P=0.089$), with the right lingual foramen on average being 2.83 ± 1.11 mm above the inferior lingual foramen.

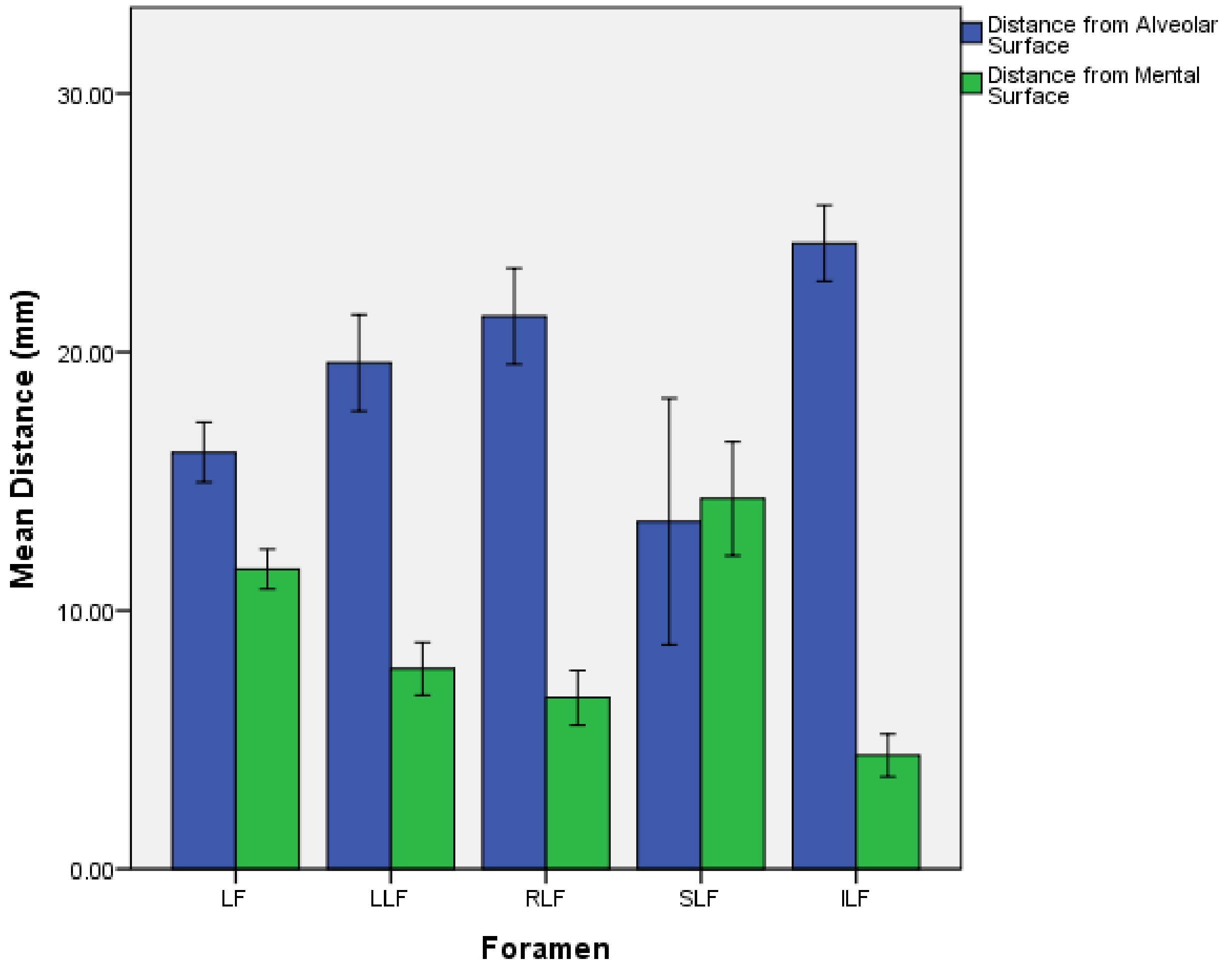


Figure 4.3.1 Mean distances of various accessory lingual foramina plotted against the primary lingual foramen (LF). The accessory foramina examined were the left lingual foramen (LLF), right lingual foramen (RLF), superior lingual foramen (SLF), and inferior lingual foramen (ILF). Error bars represent a 95% Confidence Interval

Chapter 5

5 Discussion

5.1 Anatomical and Clinical Significance

The prevalence of lingual foramen in the dry mandibles was found to be 39/44 (90.7%). In the literature, the prevalence of this foramen has been fairly consistent, with values such as 96% (Salinas-Goodier et al., 2015), 99% (McDonnell et al., 1994), and 100% (Sheikhi, Mosavat, & Ahmadi, 2012) being reported. The value that was found was slightly lower than these reported values. This could be due to our lower sample size, with some studies such as Mcdonnell et al examining 314 mandibles. Unfortunately, more mandibles were not able to be measured due to a lack of resources. Another possible reason for this decreased foraminal prevalence is a difference in race between the specimens. A study done in an Indian population did a gross examination of the lingual foramen in a manner similar to our study and found a prevalence of only 72.45% (Nagar et al., 2001). This is significantly lower than the studies listed above, which tested mandibles without factoring in race. One drawback to our study is the loss of any identifying information on the mandible specimens, and therefore it is not possible to look at the data based on factors such as race and sex.

The mean distance of the lingual foramen from the mental surface of the mandible was found to be 11.61mm ± 2.36. There are a couple of papers in the literature that have also examined the lingual foramen's mean distance from the inferior surface of the mandible. These distances include 12.5 ± 2.1 mm (Rosano, Taschieri, Gaudy, Testori, & Del Fabbro, 2009) and 19 ± 4.29 mm (Kilic et al., 2014). Our measurements agree with the former paper but differ from the latter by 3.13 standard deviations. One difference is that our study and the Rosano study used gross observation, whereas the Kilic study used CT examination to determine their measurements. However, nothing was found in the literature to suggest that a different method of measurement would result in changes in the foraminal height.

The mean distance of the lingual foramen from the alveolar surface of the mandible was found to be 16.17 ± 3.72 mm, with a range of 9.27 mm – 24.33 mm. Because dental implants are inserted superiorly from the alveolar surface, it was felt this was a very important distance to interpret in order to determine why dental implants will damage the sublingual artery. Most hemorrhaging incidents in this region occur due to the implant or implant drill perforating the bone near the site of the lingual foramen, resulting in injury to the sublingual or accessory submental artery and heavy bleeding. Therefore, it seemed important to determine the depth at which surgeons are inserting these drills and see how it relates to the average height of the foramen found in our study. A study done in 2010 looked to determine the length and diameter of implants surgeons use and their typical failure rates. This was done by looking at 1,649 patients who received implants over an 8 year period – from 1996-2004. The study showed that of all the combinations of length and positioning of implants possible, short implants placed in the anterior mandible had the greatest chance of early failure (Olate, Lyrio, de Moraes, Mazzonetto, & Moreira, 2010). The fact that there were significantly fewer short implants placed overall (10.7%) compared to medium and long implants (43.4% and 45.9% respectively) implies that surgeons understand this increased failure rate in shorter implants and try to avoid them when possible. However, there seems to be a lack of discrimination between the medium and long implants, likely due to their similar failure rates of 3.0% and 3.4% respectively. It is worth noting that short implants were defined as those ranging from 6-9mm, medium from 10-12mm, and long from 13-18mm. In our study, only 5/39 (12.8%) lingual foramina were found at a height of 12mm or less from the superior alveolar border, with the other 34/39 (87.2%) being found at a distance greater than this. Due to the work done by Olate et al, combined with the data found in this project, it may be stated that dental surgeons should prioritize using medium length implants over long ones, since they have a similar rate of success but are much less likely to come in close proximity to the lingual foramen in most patients.

Another factor that would affect the rate and severity of hemorrhaging during dental implant surgery would be the size of the lingual foramen. The mean vertical diameter of the lingual foramen in our study was found to be 0.946 ± 0.287mm with a range of 0.44 mm – 1.75 mm. This value is in agreement with studies done by Ogawa et al, 2016, (0.9 ± 0.4 mm) and Wang, Ju, Pan, & Chan, 2015, (0.61 ± 0.33 mm).

It has been found that the diameter of the lingual foramen directly relates to the size of the vessel entering it (Kilic et al., 2014), and therefore a larger foramen should carry a larger vessel, implying a greater severity of hemorrhage if damaged. Past literature has shown that as a lingual foramen gets closer to the base of the mandible, it is more likely to contain the primary sublingual artery. Inversely, a higher lingual foramen is more likely to simply contain branches of the sublingual artery (Bernardi, Rastelli, Leuter, Gatto, & Continenza, 2014). This research would imply that as the lingual foramen travels inferiorly down the lingual mandibular surface, it would get larger. This was tested this by splitting our sample into two groups at the mean lingual foraminal distance ratio (0.58), and conducted a t-test to see if there was a difference in diameter. Interestingly, a significant difference was found between the diameters of the lingual foramina and their positions on the mandible (P=0.243).

A literature review of various sublingual hemorrhages found a large variance in when these hemorrhages are detected, ranging from immediately during implant surgery up to 7 hours after (Tomljenovic et al., 2015). Unfortunately, the artery that was damaged and its corresponding foramen’s location were not often classified in these case reports. Therefore, it is difficult to say whether the more severe and immediate bleeds were due to a larger artery and foramen or other factors such as degree of damage to the vessel. That being said, our research implies that more severe bleeds do not necessarily correspond to a deeper artery, since no connection was found between foraminal depth and diameter.

The final aspect of the dry mandibles that was examined to determine potential causes of sublingual hemorrhaging was the frequency and symmetry of the Accessory Lingual Foramina. The only named foramina on the mandible are the mandibular, lingual, and mental foramina, with all other foramina being considered "accessory" (Gupta, Singh, & Soni, 2013). While there is a substantial amount of information in the literature on the accessory foramina surrounding the mental and mandibular foramina, the lingual accessory foramina remain relatively unstudied. (Gupta et al., 2013) looked at 50 dry mandibles of Indian descent and classified the accessory foramina, but only a numerical count of these foramina was done without any measurements of their distance from any mandibular landmark. Their study found that 94% of mandibles had at least one accessory foramen on the interforaminal region of the lingual surface, thus agreeing with our study's accessory foramina prevalence of 95%. These results are corroborated by studies done by (Murlimanju et al., 2012) and (Salinas-Goodier et al., 2015), who counted accessory lingual foramina prevalence rates of 96% and 100% respectively.

The fact that only 0-5% of mandibles do not have any accessory lingual foramina, as shown in our study as well as past studies, shows the importance of these foramina and their associated structures. However, beyond characterizing the quantity of these foramina on the lingual surface of the mandible, the literature is sparse with detail about where these foramina are specifically located. Therefore, the heights of the accessory lingual foramina along the lingual surface of the mandible were characterized similar to the primary lingual foramen. The primary motivation for doing this was to evaluate whether the branches of the sublingual artery that enter these accessory foramina were also at risk of damage during dental implant surgery.

Normally, the superior lingual foramen would be considered most at risk of damage due to its close proximity to the alveolar surface of the mandible, where dental implants are placed. However, due to its relatively low rate of occurrence (11.6%), it is not likely to pose a significant problem for dental surgeons doing surgery in the mandible. Looking at the superior lingual foramen, it has a mean distance of 24.21 ± 4.02 mm from the alveolar surface. As discussed before, the mean length of even "long" implants is only 13-18 mm (Olate et al., 2010), and therefore it is not likely that the vascular contents of the superior lingual foramen would be at risk of damage during dental implant surgery.

The right and left lingual foramina were compared to one another to examine whether or not the lateral branches of the sublingual artery travel to the same relative location on the lingual surface of the mandible. It was found that the average distance of the left lingual foramen from the alveolar surface of the mandible was 19.58 ± 4.42, and the average distance of the right lingual foramen from the same surface was 21.38 ± 4.18. A Tukey Post Hoc test was performed and the two distances were found to not be statistically different from one another (P=0.546). Interestingly, there was a significant difference between the distances of the left lingual foramen and superior lingual foramen (P=0.000394), but not between the right lingual foramen and superior lingual foramen (P=0.089). This implies that on average, the right lingual foramen will be found slightly lower than the left lingual foramen, making it less likely to be damaged by a dental implant.

The symmetry of the accessory foramina was evaluated to determine relative vascularization of the left and right halves of the interforaminal region. The left half of the interforaminal region was found to have a greater number of foramina on average than the right half (P=0.021). This implies a greater level of vasculature on the left half of the mandible. This data, combined with the closer proximity of the left lingual foramen to the alveolar surface of the mandible, implies that the left half of the anterior mandible is riskier to operate on, and surgeons should take care when placing implants in this region.

A final observation made about the accessory foramina was their relation to the age of the mandible specimens. It has been shown that there is a positive correlation between hypertension (which is correlated to age) and the number of accessory lingual foramina found in patients (Yilmaz, Akgül, Akgül, Dagistanli, & Çakur, 2003). As stated previously, the age of our dry mandible specimens was not readily available, but past literature has shown that mandibular age can be approximated within two-three years by looking at the number of dental facets (Kim, Kho, & Lee, 2000). By using this paper, along with the guidance of a Periodontist and Endodontist (Dr. Khadry Galil and Dr.

Hiran Perinpanayagam respectively), the relative age of these specimens was estimated based on the level of dental attrition, the presence of furcation involvements (bone loss where the tooth root branches), visibility of cementum, and rounded mandibular condyles which imply significant wear over time (figure 5.1.1). Combining these factors, it is believed that all mandibles involved in this study had a minimum age of 50 years old, with many specimens being as old as 70 years of age.

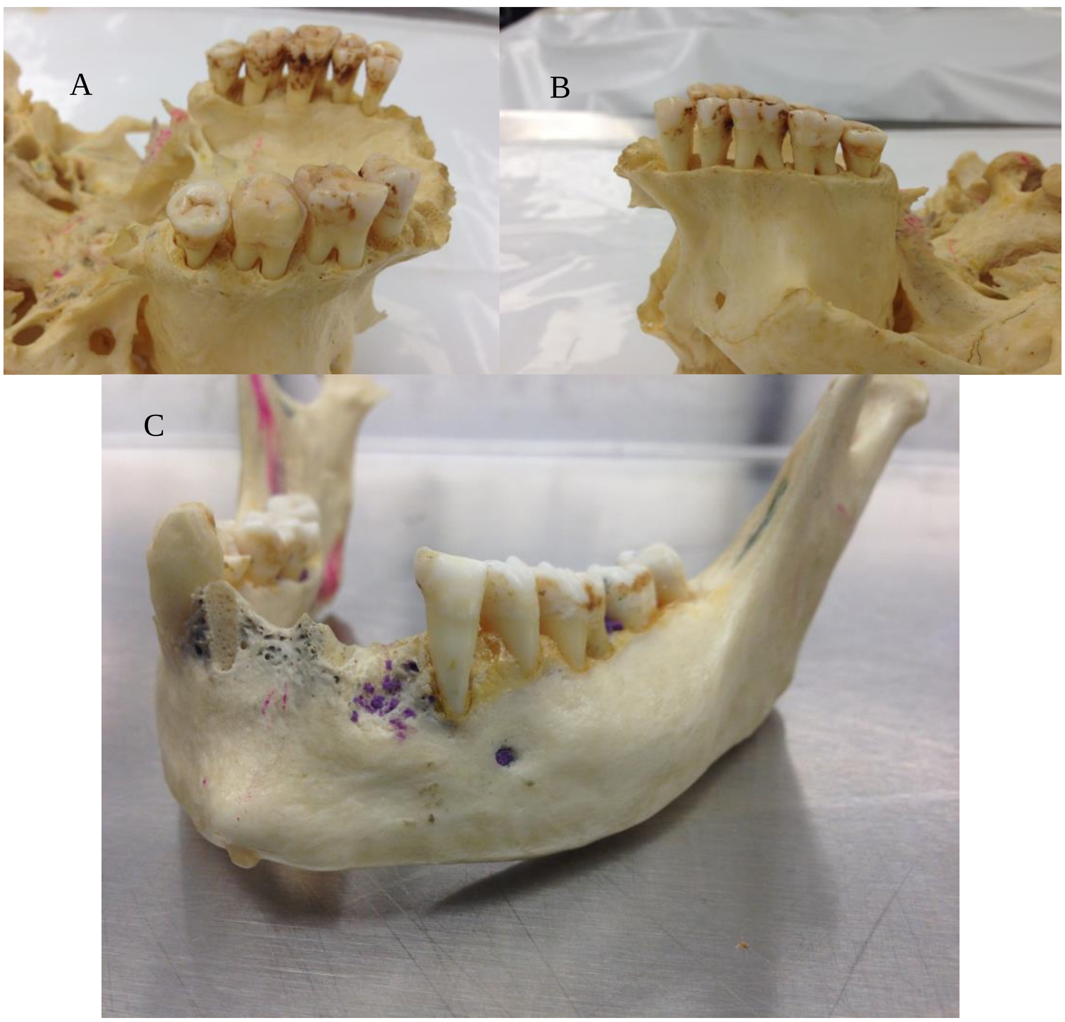


Figure 0.1 Images from three different mandibular specimens showing presence of dental facets on the surface of teeth (A), furcation involvement (B), and severe bone loss around anterior teeth (C). These factors are typically present in older populations.

This study found 4.23 ±1.84 foramina per mandible, and our population seems to have an average age above 50 years old. Future studies may wish to examine younger specimens and attempt to determine the difference in prevalence of foramina between our two groups.

5.2 Future Considerations

Future studies can aim to use this information and apply it to live patients. Studies have been done to investigate different methods of imaging and how they can be used to visualize the lingual foramina (Lustig, London, Dor, & Yanko, 2003). CBCT has been shown to be the only adequate imaging technique for seeing this foramen, and future studies may aim to see if variations in foramina in live patients with CBCT imaging match those seen in this study. In addition, future studies may wish to use imaging to observe the canals in the mandible and follow them to see if there is a pattern in their pathway, and how this pathway may affect damage of the contained vessels via dental implants.

In addition, future studies may wish to take a look at the sublingual artery in whole heads. Due to the bisected nature of our specimens, an adequate number of sublingual branches were not observed, leading to a lack of results for that portion of the study. The size and branching pattern of this artery should be examined in order to better understand how to avoid damaging it. In addition, the sublingual artery's size should be compared to the accessory submental branch that replaces it in its absence, in order to determine if there is a significant difference, and a subsequent change in hemorrhage risk based on which vessel is present in a patient.

5.3 Limitations of the Study

One major limitation of this study was the low number of cadaveric specimens for dissection. Western University's body bequeathal program allows individuals to donate their body for various purposes including research and education. However, because these donors are limited and they have various purposes, only a limited number were obtained for the purposes of this study. In addition, because these specimens were initially used as an educational resource for those students enrolled in the Schulich School of medicine and dental surgery, they were bisected. This became an issue when the sublingual artery and lingual foramina were examined on these specimens, since they are located on the midline of the anterior mandible, and were therefore mostly damaged.

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Appendix A

Appendix B – Permissions

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Appendix C - Raw Data

Table C1. Descriptive statistics for the Lingual and Accessory Lingual Foramina's distance from the alveolar mandibular surface – One way ANOVA

Descriptives

Distance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
RLF	22	21.3845	4.18337	.89190	19.5297	23.2393	13.90	28.72
LLF	24	19.5838	4.42116	.90247	17.7169	21.4506	11.94	30.70
LF	39	16.1263	3.58403	.57390	14.9645	17.2881	9.27	24.33
SLF	5	13.4420	3.84169	1.71806	8.6719	18.2121	10.28	18.09
ILF	31	24.2097	4.01821	.72169	22.7358	25.6836	15.35	31.54
Total	121	19.7281	5.19265	.47206	18.7935	20.6628	9.27	31.54

Table C2. Post Hoc test for significance for the Lingual and Accessory Lingual Foramina's distance from the alveolar mandibular surface – One way ANOVA

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Distance
Tukey HSD

(I) Foramen	(J) Foramen	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
RLF	LLF	1.80080	1.17830	.546	-1.4645	5.0661
	LF	5.25826*	1.06443	.000	2.3086	8.2080
	SLF	7.94255*	1.97779	.001	2.4618	13.4233
	ILF	-2.82513	1.11286	.089	-5.9090	.2588
LLF	RLF	-1.80080	1.17830	.546	-5.0661	1.4645
	LF	3.45747*	1.03568	.010	.5874	6.3275
	SLF	6.14175*	1.96247	.018	.7034	11.5801
	ILF	-4.62593*	1.08540	.000	-7.6337	-1.6181
LF	RLF	-5.25826*	1.06443	.000	-8.2080	-2.3086
	LLF	-3.45747*	1.03568	.010	-6.3275	-.5874
	SLF	2.68428	1.89629	.619	-2.5706	7.9392
	ILF	-8.08340*	.96057	.000	-10.7453	-5.4215
SLF	RLF	-7.94255*	1.97779	.001	-13.4233	-2.4618
	LLF	-6.14175*	1.96247	.018	-11.5801	-.7034
	LF	-2.68428	1.89629	.619	-7.9392	2.5706
	ILF	-10.76768*	1.92389	.000	-16.0991	-5.4363
ILF	RLF	2.82513	1.11286	.089	-.2588	5.9090
	LLF	4.62593*	1.08540	.000	1.6181	7.6337
	LF	8.08340*	.96057	.000	5.4215	10.7453
	SLF	10.76768*	1.92389	.000	5.4363	16.0991

Table C3. Descriptive statistics for the Lingual and Accessory Lingual Foramina's distance from the mental mandibular surface – One way ANOVA

Descriptives

Distance_Mental

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
LF	39	11.6050	2.36120	.37809	10.8396	12.3704	5.22	16.76
LLF	24	7.7454	2.42493	.49499	6.7215	8.7694	4.26	12.95
RLF	22	6.6268	2.39340	.51027	5.5656	7.6880	3.17	13.79
SLF	5	14.3300	1.78227	.79706	12.1170	16.5430	11.64	16.57
ILF	31	4.4048	2.26144	.40617	3.5753	5.2343	1.15	9.55
Total	121	8.2023	3.85086	.35008	7.5091	8.8954	1.15	16.76

Table C4. Post Hoc test for significance for the Lingual and Accessory Lingual Foramina's distance from the mental mandibular surface – One way ANOVA

Multiple Comparisons

Dependent Variable: Distance_Mental

Tukey HSD

(I) Foramen	(J) Foramen	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
RLF	LLF	-1.11860	.68979	.487	-3.0301	.7929
	LF	-4.97818*	.62313	.000	-6.7050	-3.2514
	SLF	-7.70318*	1.15782	.000	-10.9117	-4.4947
	ILF	2.22198*	.65148	.008	.4166	4.0273
LLF	RLF	1.11860	.68979	.487	-.7929	3.0301
	LF	-3.85958*	.60630	.000	-5.5397	-2.1794
	SLF	-6.58458*	1.14885	.000	-9.7682	-3.4009
	ILF	3.34058*	.63540	.000	1.5798	5.1014
LF	RLF	4.97818*	.62313	.000	3.2514	6.7050
	LLF	3.85958*	.60630	.000	2.1794	5.5397
	SLF	-2.72500	1.11011	.108	-5.8013	.3513
	ILF	7.20016*	.56233	.000	5.6419	8.7585
SLF	RLF	7.70318*	1.15782	.000	4.4947	10.9117
	LLF	6.58458*	1.14885	.000	3.4009	9.7682
	LF	2.72500	1.11011	.108	-.3513	5.8013
	ILF	9.92516*	1.12627	.000	6.8041	13.0462
ILF	RLF	-2.22198*	.65148	.008	-4.0273	-.4166
	LLF	-3.34058*	.63540	.000	-5.1014	-1.5798
	LF	-7.20016*	.56233	.000	-8.7585	-5.6419
	SLF	-9.92516*	1.12627	.000	-13.0462	-6.8041

*. The mean difference is significant at the 0.05 level.

Table C5. Description of Subjects (n=12)

Dissection Status	Sex	Age	Cause of Death
Bisected			
1776	Female	90	Myocardial Infarction, Atrial Fibrillation
1807	Male	78	Interstitial Lung Disease
1741	Female	92	Myocardial Infarction
1758	Female	90	Multi organ failure, Anemia, Thrombocytopenia.
1765	Female	75	Breast Cancer
1754	Female	85	Metastatic Adenocarcinom of lung
1770	Male	72	Metastatic esophageal cancer
1766	Female	77	Cerebrovascular accident
1793	Male	90	Carcinoma with a primary unknown origin, Atrial Fibrillation
Whole Heads			
1656	Male	80	Arrythmia, C.A.D, COPD, Dementia
1717	Female	84	Myocardial Infarction, Stroke

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Education

- **Western University (2010-2014)**
  - Bachelor of Medical Sciences (BMSc.)
    - Honors double major in Medical Science and Pharmacology
  - Dean's Honor List 2012, 2013, 2014
  - Transcript available upon request
- **Western University (2014-2016)**
  - Masters of Science (M.Sc) in Clinical Anatomy
  - 2 year masters with one year of courses based on learning advanced principles of anatomy, histology, and teaching and a one year research project

Research Experience

- **Undergraduate Research Project**
  - Worked in a genetic ecology lab examining genetic factors behind the migration pattern of a species of swamp fly
  - Learned how to manage my time effectively due to balancing this research with my coursework at the time

- **Graduate Research Project**
  - Did a one year project looking at blood supply to the anterior mandible and its anatomical variation
  - Developed skills such as team work and problem solving as I worked with a supervisory committee to complete this project
  - Successfully defended April 29th 2016

Teaching Experience

Guest Lectures

ANATCELL 3309 – Histology of the heart and cardiovascular system guest lab talk

- Led 2 lab talks on the histology of the cardiovascular system to approximately 200 3rd year undergraduate students
- Discussed the abovementioned system as it relates to its physiology, using relevant clinical examples when possible
- Spent the remaining 2 hour lab session assisting students in conducting the lab itself

Graduate Teaching Assistant

Anatomy for Medical Students (September 2015-April 2016)

- Facilitated 4 groups of 6 first and second year medical students through their weekly anatomy labs
- Used clinical cases to appeal to their passion for medical education in an effort to help them learn anatomy effectively

DENTISTRY 5160 – Systemic Anatomy and Histology (September 2015 – December 2015)
- Led small groups of 15 first year dental students through various systems of the human body using pre-dissected prosections
- Used microscope slides to relate the anatomical function of the body to its histological appearance
- Helped create and administer bell-ringers and exams to evaluate the students' progress throughout the year

DENTISTRY 5185 – Core Biology (September 2015 – November 2015)
- Introduced first year dental students to basic anatomical and biological concepts through the use of prosections
- Guided them by asking questions, facilitating discussion, and allowing them to explore specimens at their own pace

DENTISTRY 5186 – Head and Neck Anatomy (October 2015 – February 2016)
- Led small groups of 10 first year dental students through an extensive head and neck anatomy course
- Taught them anatomy using prosections and related the anatomy to various clinical cases that they are likely to see throughout their dental careers

ANATCELL 3309 – Mammalian Histology (face to face) (September 2014 - December 2014)
- Facilitated students as they observed histological specimens under a microscope and completed assignments related to what they saw
- Marked quizzes and assignments, proctored examinations, and provided feedback to students in an effort to better their understanding of the field of histology

HEALTSCI 2330B – Anatomy for Nursing students (January 2015 – April 2015)
- Created and led tutorial sessions for students to build upon the content they learned in lecture
- Combined anatomical information with clinically relevant cases that they will see throughout their career as nurses
- Marked exams and assignments, providing constructive criticism where necessary to improve their anatomical skills

ANATCELL 3309 – Mammalian Histology (online) (May 2015 – August 2015)
- Created and led online tutorial sessions to help students expand the histological knowledge they learned in lecture
- Employed the use of online tools such as interactive quizzes and online forums as a way to keep the students engaged
- Marked exams and assignments, providing feedback to students in order to expand their knowledge in the field of anatomy