PRACTICAL APPLICATION OF ANATOMY FOR THE DENTAL IMPLANTS.

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Abstract

A proficient knowledge of oral anatomy is needed to provide effective implant dentistry. This article addresses basic anatomic structures relevant to the dental implantologist. Pertinent muscles, blood supply, foramen, and nerve innervations that may be encountered during implant procedures are reviewed. Caution must be exercised when performing surgery in certain regions of the mouth. Furthermore, numerous suggestions are provided regarding the practical application of anatomy to facilitate successful implant therapy.

Keywords - Dental implants, Anatomy, Maxillary sinus, Nerve injury.

Introduction

The study of anatomy familiarizes the implant surgeon with normal and atypical oral structures. Knowledge of oral structures and ordinary anatomic variations, which usually differ with respect to size and shape, enhances patient evaluation and facilitates precise surgical procedures. A thorough understanding of anatomy provides the implant surgeon with the confidence to resect or augment tissues in an attempt to restore form, function, esthetics, and health. This article reviews practical application of basic anatomy of the structures routinely encountered, which are critically important to planning and executing dental implant surgery.

Discussion:

MANDIBULAR STRUCTURES:

Mandibular Foramen- The location of the mandibular foramen may vary based on race and ethnicity, and this can affect the success ofblockinjections.[1,2] Among adult cadaveric mandibles, the foramen was found inferior to the occlusal plane, at its level, or above it 75%, 22.5%, and 2.5% of the time, respectively. In another study,[2] the figures were 29.4%, 47.1%, and 23.5%, respectively. Therefore, according to these investigations, 2.5% to 23.5% of block injections given at the level of occlusion would be ineffective. Accordingly, it is advisable to inject patients 6 to 10 mm superior to theocclusal plane,[3] which usually accounts for anatomic variations. The distance to the mandibular foramen assessed on cadavers revealed that it is within the reach of a short needle (needle length = 21 mm).[4] Therefore, short needles can be used to attain anesthesia in the mandible. If there are symptoms of a good block injection, but the patient is still symptomatic, infiltrate the

lingual aspect of the molar teeth, because there may be additional innervation from C2 and C3 (cutaneous coli nerve of the cervical plexus).

Inferior Alveolar Canal- The trigeminal nerve, the fifth cranial nerve, has three main branches: ophthalmic, maxillary, and mandibular. The mandibular nerve gives rise to the inferior alveolar nerve (IAN). It enters the mandibular canal on the medial surface of the ramus by the lingula. The canal is 3.4 mm wide, and the nerve is 2.2 mm thick. Within the canal there is a nerve, an artery, a vein and lymphatic vessels. The artery lies parallel to the nerve as it traverses anteriorly, but its position varies with respect to being superior or inferior to the nerve within the mandibular canal. Therefore, it is possible to inadvertently penetrate into the mandibular canal and induce neurologic damage without provoking hemorrhaging and vice versa. When developing an osteotomy over the mandibular canal, corticalbone is penetrated first, and the preparation terminates within softer cancellous bone.

The mandibular canal usually has cortical bone around it, which may provide some resistance to drilling. However, clinicians should not rely on tactile feedback to signal the that canal is about to be penetrated, because a twist drill can enter the canal with little warning. Conversely, when traversing from more to less mineralized regions of the posterior mandible during osteotomy development, a sudden decrease in resistance may give an erroneous impression that the canal has been breached. Accordingly, there is no substitute for precise radiometrics, safety devices (e.g., drill stops), and a plan for attaining specific implant lengths in this region of the mouth. The IAN may present in different anatomic configurations. The nerve may lower gently as it proceeds anteriorly, or there can be a sharp decline or the nerve can drape downward in catenary fashion (curled as hangingbetweentwopoints). TheIANcrossesfromthelingual to the buccalsideofthemandibleandoften,bythe first molar it is located midway between the buccal and lingual cortical plates of bone.

Usually, the IAN divides into the mental and incisive nerves in the pre molar region. The mental nerve emerges from the mental canal, and anterior to the mental foramen the mandibular canal is referred to as the incisive canal.[11] Implant placement buccal or lingual to the IAN is a risky maneuver and should not be attempted without the aid of computed tomography (CT).

The mandibular canal bifurcates in the inferior– superior or medial–lateral plane in 1% of patients. Abifurcatedcanalmaymanifestmorethanonemental foramen andthe bifurcation may not be seen on panoramic or periapicalfilms. The undetectedpresenceof a bifurcated mandibular canal can result in an incorrect estimation of available bone superior to the mandibular canal. Denio et al evaluated cadavers to determine how closetheIANwastotheapicesofmandibularposterior teeth.Themeandistanceto these molars,firstmolar and premolars was 3.7, 6.9, and 4.7 mm, respectively. Similarly, Littneret al.[14] reported that upper border of the mandibular canal was located 3.5 to 5.4 mm below the root apices of first and second molars. Other investigators15 found that the canal was often close tothe inferiorborderofthe mandible. It isalso possible for the mandibular canal to be adjacent to the apex of the mandibular molar. Therefore, with regard to developing osteotomies over the inferior alveolar nerve, it should be recognized that mean distances between apices of teeth and the nerve canal reported in articles may not apply to any

particular patient. Hence, to avoid untoward sequelae in the posterior mandible, the location of the nerve needs to be verified before an osteotomy is created. With regard to radiographs, Denioet al.[13] reported that in 28% of patients the mandibular canal could not be clearly identified in the second premolar and first molar regions on periapical radiographs. Therefore, if the inferior alveolar canal cannot be seen on a periapical film, it is recommended to obtain a panoramic film and adjust distances for radiographic distortion. If it still cannot be detected, a CT scan is needed. Osteotomies should not be developed in the posterior mandibleuntilthepositionoftheinferioralveolarcanal is established. Several additional facts about radiographs should be considered. The angulation of the periapical film can affect the perceived location of the canal with respect to the bone crest.

For instance, if the x-ray beam is perpendicular to the canal, but not the film, elongation occurs, and the canal appears further from the crest than it really is. Conversely, when the x-ray beam is perpendicular to the film, but is not parallel to the canal, foreshortening happens.

Mental Foramen and Nerve

Commonly, three nerve branches of the mental nerve emerge from the mental foramen (each 1 mm in diameter). They supply innervation to the skin of the mental foraminal area, the lower lip, chin, mucous membranes, and the gingiva until the second premolar. Occasionally, the mental nerve emerges from the buccal plate of bone and re-enters the alveolar bone to provide innervation for the incisor teeth.Thelocationofthemental nerve differsinthehorizontal and vertical planes, and these variations may be related to race. For example, horizontally the foramen is often found flanked by the apices of premolars in white individuals and next to the apex of the second mandibular premolar among Chinese subjects.Atypically, the foramen may be situated by the canine or the first molar.

In these situations, theincisivecanalstartswherethementalnerveemerges from the mandible. Thepositionoftheforaminalsovariesinthevertical plane. Pertinently,itwas reported that inthefirstpremolar area of 936 patients, the foramen was situated coronal to the apex in 38.6% of cases, at the apex in 15.4% of cases, and apical to the apex in 46.0% of cases.

The mental nerve comes out of the mental canal, which is angled upward at 50 (range, 11 to 70) from the mandibular canal. Therefore, it should be noted that the inferior alveolar nerve is lateral and apical to the mental foramen. If it is desired to place an implant, which is larger than the safety distance determined above, anterior tothementalforamen,aCTscan is necessarytodetermine whether an anterior loop is present, or it is necessary to probe within the foramen to ascertain if there is an anterior loop. In this regard, a curved probe (e.g., Naber's 2N probe) can be gently placed into the foramentoassessifitsdistalaspect isopen.Ifitisnotopen, then the nerve entered on the mesial side, and this denotes that an anterior loop is present. The mesial side of the foramen is consistently patent, because at this site the anterior loop emerges from the bone or the incisal nerve proceeds anteriorly.

Note that the patency on the mesial aspect of the foramen leading to the incisal region and an anterior loop feel similar, and itisnotpossibletodistinguishbetweenthesetwostructures. It must be emphasized that probing into the mental foramen should be done very gently; otherwise, neurologic damage can be done to the nerve. Furthermore, even if the presence of an anterior loop is

corroborated by probing, its length is still unknown. Therefore, as a general guideline, if there is an anterior loop of the mental foramen and a CT scan is not available to determine its dimensions, and it is desired to place an implant deeper than the safety measurement on the mesial aspect of the foramen, it is prudent to place the distal aspect of the implant 6 mm anterior to the mental foramen to avoid damaging the loop when drilling the osteotomy.

Mandibular Incisive Canal

Numerous investigations reported that there is a ''true'' incisive canal mesial to the mental foramen, which is a continuation of the mandibular canal. It has also been noted that the incisive canal may appear as a maze of intertrabecular spaces, which include neurovascular bundles. The incisive nerve supplies innervation to teeth (first bicuspid, canine, lateral and central incisors). The incisive canal is typically found in the middle third of the mandible (in 86% of cases). It usually narrows as it approaches the midline and only reaches the midline18%ofthetime.Thenerveusuallyterminates apical to the lateral incisor and sometimes apical to the central incisor. The incisive canal's width is 1.8 – 0.5 mm, and it was found in 96% of assessed cadavers. However, when the appearance of the incisive canal on panoramic radiographs was evaluated, Jacobs et al. reported that it was seen only on 15% of the films (n = 545). In contrast, it was observed on 93% of CT scans. In the interforaminal area, as long as the mental foramen and the anterior loop of the mental foramen (if present) are avoided, implants can usually be inserted without too much thought given to the presence of the incisive canal. However, if there is an unusually large incisive nerve canal, a patient can experience discomfort during osteotomy development precluding implant placement35 or experience postoperative pain requiring implant removal.36 Consequently, consideration should be given to the size of the incisive canal before placing implants deeply in the interforaminal area.

The Long Buccal Nerve

The buccal nerve is a branch of the mandibular nerve that is derived from the trigeminal nerve, and it begins high in the infratemporal fossa. It transmits sensory innervation to the buccal gingiva and mucosa of the cheek from the retromolar area to the second premolar.It courses between the two heads ofthelateral pterygoidmuscle,underneaththetendonofthetemporalis muscle, and then under the masseter muscle to connect with the buccal branches of the facial nerve on thesurfaceofthebuccinatormuscle.Ananatomicvariation of the long buccal nerve, called Turner's variation, consists of the nerve emerging from a foramen in the retromolar fossa. When this variation exists, trauma in this region can cause paresthesia to the adjacent gingiva and mucosa. Muscles Attached to the Mandible. There are 26 muscles attached to the mandible. There are two single muscles (orbicularis oris and platysma) and 12 pairs of bilateral muscles, which arelistedinalphabeticorder:anteriorbellyofdigastric, buccinator, depressor angulioris, depressor labiiinferioris, genioglossus, geniohyoid, masseter, mentalis, mylohyoid, lateral pterygoid, medial pterygoid, and temporalis. Several of these muscles are of particular concern to the implant surgeon. Mentalis Muscle Thementalismuscleisapaired small musclethatoriginates in the incisive fossa of the mandible and inserts into the integument of the chin.

The muscle fibers pass in an inferior direction, and upon contraction, they elevate the lower lip. When a flap is raised in this region, the entire mentalis muscle should not be released off from the mental protuberances, because the muscle may fail to reattach well. This can result in an appearance referred to as a witch's chin (double chin). Full-thickness replaced flaps, which do not reachtheinferiorborder,usuallydonotaffectfacialappearance. However, vestibular incisions that sharply dissect this muscle require special suturing (i.e., the muscle layer and then the overlying soft tissues). Mylohyoid Muscle Two flat mylohyoid muscles form a sling inferior to the tongue, supporting the floor of the mouth. Their origin is the mylohyoid line on the medial aspect of the mandible, which extends from the symphysis to the last molar.

They insert on the body of the hyoid bone andoverliethe digastrics muscles.Thismuscleisanimportantan atomicbarrier separatingthesublingualand submandibular spaces. The submandibular fossa is below the mylohyoid muscle, and the sublingual fossa is superior to the muscle. Manipulation of the muscle should be performed only to fulfil clearly defined objectives. In this regard, sometimes there are situations, such as guided bone. The Long Buccal Nerve The buccal nerve is a branch of the mandibular nerve that is derived from the trigeminal nerve, and it begins high in the infratemporal fossa. It transmits sensory innervation to the buccal gingiva and mucosa of the cheek from the retromolar area to the second premolar.

MAXILLARY STRUCTURES

Thickness of the Gingiva and Palatal Mucosa The thickness of the gingival and palatal epithelium is 0.3 mm.65 The gingiva is supported by a lamina propria (firm connective tissue), whereas palatal epithelium is sustained by a lamina propria and submucosa. Average gingival thickness ranges from 0.53 to 2.62 mm (mean, 1.56 mm), and palatal width varies from 2.0 to 3.7 mm, with a mean of 2.8 mm.

The best location for harvesting a connective tissue graft is in the maxillary canine–premolar region.Thingrafts may be garnered several millimeters away fromthe gingival margin,andthickergraftscanbeharvestedfurtherawayfromthegingivalmarginwherethe submucosa is wider. The thickest grafts can be obtainedinthetuberosityregion(i.e. 5mm).Thewidth of the palatal tissue can be estimated by sounding the bone with a periodontal probe or a needle that has an endodontic stopper. Graft height is limited by the position of the greater palatine artery, whose location is subsequently discussed.

Nasopalatine Foramen The nasopalatine foramen is also referred to as the incisive foramen Upon flap reflection within the foramen, two lateral canals are noticeable, which are called incisive canals or foramina of Stenson. They transmit the anterior branches of the descending palatine vessels and the nasopalatine nerves. Occasionally, one to four canals may be present. The nasopalatine foramen is 4.6 mm wide and is located 7.4 mm from the labial surface of an unresorbed ridge. The nasopalatine canal (mean length, 8.1 mm) exits the incisive foramen. A large incisive canal maybeanobstacletoimplant placement inthe central incisor region. When a large canal was present, Artzi et al. displaced its contents (moved it over without elimination) and placed an implant. In contrast, Rosenquist and Nystrom enucleated the canal, inserted a bone graft, and subsequently

placed an implant. It is also often possible to angle an implant and avoid the canal. When performing surgery in the nasopalatine area, some clinicians create a crestal incision labially around the incisive papilla to avoid transecting the contents of the nasopalatine canal. An incision through the canal region does not usually have a detrimental affect; however, it occasionally results in some numbness of the anterior palatal tissue. Infraorbital Foramen The infraorbital nerve and blood vessels emerge from the infraorbital foramen.

The foramen is usually located directly under the pupil of the eye on the inferior portion of the infraorbital ridge, and it can be palpated through the skin of the cheek. The infraorbital nerve is found5mmbelowtheinferiorportionoftheinfraorbital ridge, and it can be injured during surgery. It is a significant landmark, and intraoral flap elevation should cease several millimeters inferior to it.

 The average height of the maxillary sinus is 36 to 45 mm; therefore, a lateral window extending 15 mm from the alveolar ridge crest usually avoids encroaching on the infraorbital nerve. However, if advanced resorption of the maxilla transpired, vigilance needs to be exercised when elevating a flap to avoid damaging the infraorbital nerve.

Greater Palatine Foramen

The posterior maxilla needs to be treated cautiously in the region of the greater palatine foramen. The greater palatine artery and nerve emerge from the foramen and traverse the palate anteriorly.

The foramen was found opposite the third molar in 86% of cases, between the second and third molar in 13% of cases, and opposite the second molar in 1% of cases. Other investigators noted that the foramen was detected by the third molar in 55% of cases, between the second and third molar in 19% of cases, opposite the second molar in 12% of cases, and distal to the third molar in 14% of cases. The foramenislocated halfway betweenthe osseous crest and the median raphe. Wang et al. reported a mean distance of 16 mm from the center of the greater palatine foramen to the mid-sagittal plane of the hard palate. Severing the palatal artery close to the foramen can present a problem, because it can retract into the bone, which precludes ligating it. The precise location ofthe foramencanbedetermined prior toflapelevation by sounding the bone with an anesthetic needle.

Blood Supply in the Maxilla

The internal maxillary artery (maxillary artery) arises from the external carotid artery behind the neck of the mandible and provides branches to several regions of the face: mandibular, pterygoid, and pterygopalatine.Surgery in the maxilla can involve arteries in the pterygopalatine region: descending palatine artery, sphenopalatine artery terminal branch, infraorbital artery, posterior superior alveolar artery, and the artery of pterygoid canal.

GREATER PALATINE ARTERY

The descending palatine artery emerges from the greater palatine foramen and traverses anteriorly in a groove on the medial side of the hard palate to the incisive canal. The end branch of the artery enters the incisive canal to anastomose with the nasopalatine branch of the sphenopalatine artery.

Monnet-Corti et al.80 reported that the distance from the gingival margin to the greater palatine artery ranged from 12.07 – 2.9 mm in the canine area to 14.7 – 2.9 mm at the mid-palatal aspect of the second molar level. With regard to the greater palatine artery, it is prudent to assess the height of the palatal vault to establish the extent to which a surgical procedure can be performed(e.g.harvestingaconnectivetissuegraft)without damaging the artery. It is advantageous to leave 2 mm between the artery and the end of the surgical incision.81 Based upon the shape of the palatal vault, it is possible to estimate how far the palatine artery is from the cemento-enamel junction: low vault (flat) = 7 mm, average palate = 12 mm, and high vault (U-shaped) = 17 mm.81.

The mean palatal vault height for males and females is 14.9 and 12.7 mm, respectively. When performing a connective tissue graft, a splitthickness palatal flap, and so forth, the surgeon should be ready to manage accidental injury to the greater palatine artery. If the artery is deemed to be close to the site of surgery, it may be advantageous to place ''deep'' sutures to lasso and ligate the greater palatine artery distal to the surgical site prior to initiating therapy. If the artery is damaged, this step may preclude hemorrhaging. To manage bleeding from a damaged blood vessel, apply pressure, and clamp the palatal flap where the incision was made with a hemostat. If the bleeding vessel is visible, ligate it, or apply electric cautery. Additional deep sutures are needed if the bleeding vessel is not visible.

INFRAORBITAL AND POSTERIOR SUPERIOR ALVEOLAR ARTERY

The infraorbital artery provides branches to the anterior part of the sinus. These vessels anastomose with vessels of the posterior superior alveolar artery within the buccal plate of bone (intraosseous artery) and in the buccal tissues (extraosseous artery). The intraosseous artery is hemorrhaging blood vessel. On occasion, it is necessary to continue preparing the window, despite the bleeding, until the membrane is elevated and the bone can be clamped. The assistant should hold the suction tipnexttothebleedingsitetopreservegoodvisibility. When the intraosseous artery is severed on the mesial aspect of the lateral window, it probably is also injured on the distal aspect. Therefore, the clinician may need to deal with bleeding on both sides of the lateral window. If a CT scan reveals the presence of an intraosseousarterybeforestartingthe lateral window,and itispossibleto circumvent it,developthelateralwindow inferior to the artery, and elevate the membrane internally in a superior direction. However, reasonable access must be achieved, because a poorly located lateral window can lead to a non-optimal sinus lift outcome. Anothertechniquethatcanbeusedtoisolatethe artery and not injure it during creation of the lateral window uses a piezosurgery unit (ultrasonic).

Anterior Nasal Spine

Under the nose, in the midline, at the lower margin of the anterior aperture, there is a sharp bony process formed by the forward elongation of the maxillae that is referred to as the anteriornasal spine. It is used as a landmark when elevating a large flap in the premaxilla in preparation for flap advancement. Care must be exercised when extending flap elevation beyond this point because the tissue is thin, and it is possible to penetrate through the tissue into the nose. The bony rim of the

nares is referred to as the piriform rim. Maxillary Sinus The maxillary sinus (antrum of Highmore) is pyramidal in shape and is the largest paranasal sinus.

Typical averagedimensionsofthesinusareheight,36to45mm, width, 25 to 35 mm, and length, 38 to 45 mm. The ostium is the opening from the sinus to the middle meatus of the nose. It is situated on the superior aspect of the medial wall of the maxillary sinus above the first molar. The mean distance from the most inferior point of the antral floor to the ostium is 28.5 mm. Thus, when performing a sinus lift, the sinus should not be overfilled with graft material beyond 15 mm to avoid potentially blocking the ostium and causing sinusitis.

The maxillary sinus is surrounded by six walls. 1) The anterior wall contains the infraorbital nerve and blood vessels to the anterior teeth. The infraorbital artery gives off the anterior superior alveolar arteries that supply the sinus mucosa in the anterior section of the sinus. 2) The superior wall is very thin and makes up the orbital floor. A bony ridge contains the infraorbital canal with the nerve and blood vessels. 3) The posterior wall corresponds to the pterygomaxillary region, which separates the antrum from the pterygopalatine fossa. It contains the posterior superior alveolar nerve and blood vessels, including the pterygoid plexus of veins and internal maxillary artery. 4) The medial wall separates the sinus from the nasal fossa. The maxillary ostium (around first molar area) drains into the middle meatus of the nasal cavity. 5) The sinus floor may extend between the roots of the maxillary molars. The floor may be 10 mm below the floor of the nasal cavity. 6) The lateral wall forms the posterior maxillary and zygomatic process. This wall provides access for the sinus graft procedure. The medial wall derives its arterial supply from nasal mucosal vasculature. This comes from branches of the sphenopalatine artery: posterior lateral nasal and posterior septal branches. The frontal, lateral, and inferior walls derive their arterial supply from the osseous vasculature (infraorbital, facial, and palatine arteries). The medial sinus wall drains through the sphenopalatine vein. All other veins drain through the pterygomaxillary plexus. Innervation is provided by nasal mucosa nerves and the superior alveolar and infraorbital nerves. Septa (Underwood's clefts) have been located in 31.7% of the maxillary sinuses in the premolar area, and they usually do not compartmentalize the antrum.
 However, they frequently get larger as they proceed medially. Therefore, during a sinus lift, membrane elevation over partial septa should proceed lateralto medial, because elevation attempted anterior to posterior is more prone to create a perforation. To accommodate large or multiple septa during a sinus lift, more than one lateral window can be created as part of the antral opening. In addition, septa are a concern if an osteotome sinus floor elevation procedure is planned. There are several other issues of interest regarding the managementofthemaxillarysinusarea.

Nerve Innervations in the Maxilla

The sensory nerves of the palate are branches of the maxillary nerve. The greater palatine nerve innervates the gingiva, mucous membranes, and most of the glands of the hard palate. The nasopalatine nerve supplies the mucous membranes of the anterior hard palate. The lesser palatine nerves supply the soft palate. The infraorbital nerve innervates the mucosa of the maxillary sinus; the maxillary incisors, canine, and premolars; the maxillary gingiva; the inferior eyelid and

conjunctiva; part of the nose; and the superior lip. The posterior superior alveolar nerve supplies the gingiva and mucous membranes in the posterior maxilla, sinus, and molar teeth.

Conclusion

Familiarity with the anatomic structures pertaining to dental implantology is critically important. Preplanning and review of anatomy before surgical procedures can help to avoid problems. However, certain anatomic structures may be problematic with respect to treatment planning. In this regard, many of the shortcomings of two-dimensional radiography for treatment planning can be eliminated with the use of three-dimensional imaging. In particular, if the mandibular or mental nerve's position is not clear or if it is unclear how much bone is present for implant placement, a CT scan should be ordered. Similarly, CT scans are an important diagnostic aid in predetermining the dimensions of the maxillary sinus and the presence of unexpected findings (e.g., septa, tumors, and intraosseous arteries). A general rule to follow is, if you are wondering if you need a CT scan, order one. Most significantly, proper training should be obtained to provide advanced surgical procedures.

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