Mandibular Regional Anatomical Landmarks and Clinical Implications for Ridge Augmentation

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Mandibular ridge augmentation via guided bone regeneration in the atrophic mandible is considered one of the most challenging scenarios for implant-supported oral rehabilitation. Uneventful wound healing has clearly demonstrated its impact on the final regenerative outcome. Soft tissue management must be precise and adequate to attain flap-free wound closure. Accordingly, it demands exhaustive insight and expertise to avoid damaging the neighboring structures. The cadaver study described herein discusses the mandibular morphologic landmarks (ie, musculature, vascularization, innervation, and salivary glands) necessary to safely perform regenerative procedures in the atrophic mandibular ridge, such as vertical ridge augmentation and dental implant surgery. The potential intraoperative complications are presented, as well as clinical implications of which the clinician must be aware to prevent adverse surgical events during regenerative surgery and implant placement in this anatomical region. Int J Periodontics Restorative Dent 2017;37:347–353. doi: 10.11607/prd.3199

Vertical and horizontal ridge augmentation of the severely atrophic posterior and anterior mandible is considered the most challenging scenario for implant-supported oral rehabilitation in implant dentistry. Due to the presence of the inferior alveolar neurovascular bundle and the submandibular fossa, this region is remarkable for its high risk during implant placement.1–3 Complications in this zone include but are not limited to sensory disturbances or trauma of the sublingual and submental arteries with consequential hematoma in the submandibular and sublingual spaces.4 A comprehensive and precise understanding of such anatomical structures is necessary to avoid potential complications that could ultimately jeopardize the treatment outcome.

Furthermore, ridge augmentation in the posterior mandibular region has been classified as an unpredictable therapy due to the complexity of the approach.5 A variety of treatment modalities have been proposed, such as onlay/inlay block grafting6,7 and guided bone regeneration (GBR) by means of a barrier membrane.8–12 Although early findings conceived of autogenous block grafts as the gold standard, recent data seem to demonstrate the feasibility of combining biomaterials with autogenous bone particles. Combined with a nonresorbable

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membrane, these may offer comparable bone gain with less morbidity, fewer postsurgical complications, and better stability of the peri-implant bone level in the long term. Nevertheless, adequate hard and soft tissue management and fulfillment of the biologic principles (ie, primary wound closure, angiogenesis, stability of the clot, and space creation) are the most relevant factors for successful GBR. In this sense, it is worth noting that wound dehiscence may be detrimental to the bone augmentation outcome as flap tension plays a primary role in postoperative closure, and thus in undisturbed wound healing. As such, closing forces of > 0.1 N may substantially increase the rate of wound dehiscence (≥ 40%). To coronally advance and achieve tension-free flap closure, vertical and periosteal releasing incisions combined with flap repositioning are recommended.

Management of soft tissues in this region demands exhaustive insight and expertise to avoid damaging the neighboring structures. For instance, the first step in releasing the lingual flap to obtain elasticity is to raise the mylohyoid muscle that extends toward the origin of the hyoglossus muscle. It is important to protect this anatomical area since the lingual nerve, the branches of the lingual artery, and the sublingual gland could be damaged, requiring emergency care to stop bleeding. These unfortunate events could result in hematoma followed by swelling, which has occasionally been reported as life-threatening due to respiratory obstruction. Therefore, descriptions of the anatomical features of the posterior mandibular region (ie, musculature, vascularization, innervation, and salivary glands) necessary to safely perform regenerative procedures such as vertical ridge augmentation and dental implant surgery in the atrophic mandibular ridges are included here.

Musculature of the Floor of the Mouth and the Tongue

The key muscle of this region is the mylohyoid, which creates the diaphragm of the mouth—diaphragma oris. This muscle originates from the mylohyoid line of the inner surface of the mandible, and its line is oblique, running more superior at the molar region and starting deeper at the first premolar and anterior. The muscle inserts into the body of the hyoid bone and anteriorly into a connective tissue raphe located in the middle (Fig 1). It functions in swallowing and mouth opening and creates a separation for the floor of the mouth.

Several muscles are involved in movement of the tongue, including the genioglossus muscle, the hyoglossus and styloglossus muscles, and the palatoglossus muscle (Fig 2). The groove between the mylohyoid and the hyoglossus muscles is called the lateral lingual groove—sulcus lateralis linguae.

The digastric muscle has an anterior and a posterior belly connected by an intermediate tendon, which is held to the hyoid bone. The stylohyoideus muscle originates from the styloid process and inserts into the hyoid bone, usually with a lateral and medial tendon that surrounds the posterior belly and the intermediate tendon of the digastric muscle. The posterior belly arises from the mastoid notch of the temporal bone, and the anterior belly arises from the digastric notch at the mandibular symphysis. The digastric muscle and the body of the mandible form the submandibular

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Materials and Methods

A total of 10 embalmed cadaver heads including mandibles with associated intact soft tissue were used for this study. The cadaver heads were provided by the Department of Anatomy, Histology, and Embryology, Semmelweis University, Budapest, Hungary. Postmortem time ranged from 0 to 5 days. In 5 of the cadaver heads, both common carotid and vertebral arteries were cannulated and irrigated with cold saline (500–1,000 mL), followed by perfusion with Thiel solution. After a second irrigation of the vessels with cold saline (50 mL) they were injected with red-colored Creato Latexmilch (Zitzmann Zentrale). Specimens were then immersed in Thiel solution for at least 1 year.

The remaining 5 cadavers were fixed in a 10% neutral formalin solution. The heads were sectioned such that the mandibular alveolar arches were preserved along with the surrounding soft tissue. An experienced surgeon and dissection assistant reflected the soft tissues, vessels, nerves, and glands to display the regional anatomical features carefully. Experienced anatomists assisted with the interpretation and allocation of the structures.

The International Journal of Periodontics & Restorative Dentistry

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triangle. The digastric muscle functions in mouth opening and lowering the mandible. When the lower jaw is stabilized, it elevates the hyoid bone. Other muscles of the neck are not of clinical relevance for mandibular bone graft surgery and are not described in detail herein.

Vascular Supply

Severe bleeding and hematoma have been reported related to implant surgery in the mandible. Anatomical knowledge of the vascularization of the floor of the mouth is critical when the clinician is performing regenerative therapy in the posterior and anterior mandible. Branches of the external carotid artery provide the arterial supply. The two main anterior branches of the artery are the lingual and facial arteries, which are the second and third branches arising from the carotid. It is not uncommon for these arteries to arise from the common lingual-facial trunk.

Lingual Artery

The lingual artery commonly arises from the carotid artery slightly superior to the hyoid bone, as the second anterior branch of the external carotid. It then runs anteriorly between the space of hyoglossus and middle pharyngeal constrictor, and anterior to genioglossus muscles. This is also called the medial lingual groove.

Passing the body of the hyoid bone anteriorly, the lingual artery starts to run superiorly, branching into the hyoid and the dorsal lingual arteries. Running anteriorly, it bifurcates and becomes the deep lingual artery and the sublingual artery (Figs 3 and 4). The sublingual artery runs between the mylohyoid and the genioglossus muscle, which is the anterior part of the lateral lingual groove (Fig 5). It provides branches to the sublingual gland, muscles, and gingiva, and in most cases creates an anastomosis with the submental artery anteriorly. Additionally, some terminal branches penetrate the cortical bone.

Facial Artery

The facial artery arises as the third anterior branch of the external carotid (Fig 3). It runs anteriorly and curves superiorly, medial to the digastric and stylohyoid muscles, and reaches the base of the mandible superior to the submandibular gland. Before reaching the mandible, it branches into the submental artery, which runs toward the chin and, in 29% of the cases, gives rise to a branch that perforates the...
mylohyoid muscle and anastomoses with the sublingual artery (Figs 6 and 7). The facial artery then curves up to the face in front of the masseter muscle, running toward the medial corner of the eye. It provides branches to the face throughout its course.

Anatomical Variations in Mandibular Vascularization

Studies investigating the anatomical variations of the floor of the mouth have recently been published. In a study investigating 27 cadavers, four types of variations were found. The most common anatomical variation (63%) is the sublingual artery supplying the sublingual space (Figs 5 to 7). In 29.6% of the cases, the sublingual artery did not exist and the sublingual space was supplied by a branch of the submental artery. In this situation, a branch of the submental artery perforates the mylohyoid muscle and enters the lingual space. The lingual artery supplies the tongue, and the submental artery supplies the floor of the mouth. Rarely (in 1.8% of the cases), the sublingual and the deep lingual artery are missing from the lingual artery and the floor of the mouth, and the tongue is supplied by the submental artery arising from the facial artery.

Innervation

There are two major nerves to be aware of when performing these surgeries: the lingual and the hypoglossal. Surgically, the most remarkable is the lingual nerve, a branch of the mandibular nerve (cranial nerve V/III). The lingual nerve starts...
just after the mandibular nerve exits the foramen ovale of the skull. Running downward between the medial and lateral pterygoid muscles, it reaches the ramus of the mandible. Around the wisdom tooth area, it turns anteriorly and runs into the lateral lingual groove. It has been reported that 75% turn toward the lingual site at the first and second molar. The distances are 9.6 mm, 13 mm, and 14.8 mm at the second molar, first molar, and second premolar, respectively. The lingual nerve innervates the anterior two-thirds of the tongue. Before entering the lateral lingual groove, the chorda tympani, a branch of the facial nerve (cranial nerve VII) connects to the lingual nerve. This nerve is responsible for taste sensation in the anterior two-thirds of the tongue and the salivary production of the sublingual and submandibular glands.

The hypoglossal nerve (cranial nerve XII) is responsible for the motor function of the tongue. Exiting the skull, it runs between the internal carotid artery and the internal jugular vein. Running anteriorly and downward, it enters deep into the lateral lingual groove and reaches the lateral border of the hyoglossus muscle, where it breaks up into its terminal branches.

Salivary Glands

There are two salivary glands in this area: the submandibular and the sublingual. The submandibular gland is the major component of the posterior part of the submandibular trigone. It protrudes into the lateral lingual groove with its uncinate process and occasionally merges with the sublingual gland (Figs 3, 5, 6, and 7).

The excretory duct of the submandibular gland is the submandibular duct, also known as Wharton duct. This runs into the lateral lingual groove, is crossed by the lingual nerve inferiorly from outside,
and opens into the sublingual caruncle. The sublingual gland is located in the anterior portion of the lateral lingual groove. It is covered directly by the oral mucosa and protrudes laterally from the lingual frenulum into the oral cavity as the sublingual fold. The posterior lobes open with numerous short ducts (ductus sublinguales minores), and the anterior lobe opens with the major sublingual duct (of Bartholin) into the Wharton duct.

**Connective Tissue**

It was noted throughout this investigation that all the key anatomical landmarks, such as the lingual nerve, sublingual artery, sublingual gland, and Wharton duct, were imbedded in a dense, thick, supportive connective tissue (CT) layer. The fibers forming such a dense CT are thick and more numerous than those found in loose CT—for instance, in adipose CT—with ground substance that occupies relatively little space. Collagen fibers dominate this dense, irregular CT beside the fibroblasts and ground substance.²¹

**Potential Intraoperative Complications**

The most common surgical complications are hemorrhage, nerve damage, and accidental injury to neighboring anatomical structures. While these may result from inadequate implant therapy planning, the clinician must be prepared for any adverse complication. Potential complications resulting from anatomical variations should be explored presurgically to foresee any potential risk. Due to the proximity to nerves and blood vessels in the mandible, especially the posterior region, this area must be thoroughly understood. At implant drilling/placement, due to the morphology of the posterior mandible (ie, presence of concavity—U type ridge ~ 70%),²² lingual cortical plate perforation is possible (occurrence ~ 1%).²³ Knowing that the vascularization to the inner aspect of the mandible is supplied by the facial artery and its branch, the submental artery, and the lingual artery and its branch, the sublingual artery, is critical as penetrating the mandibular lingual plate may trigger excessive hemorrhage that, if not controlled by compression or ligation, may result in a life-threatening episode.²⁴ It has been reported that the most common presentation (92%) is the artery running medial to the sublingual gland, while in 45% of cases the artery lies further from the lingual plate.²⁰ Since anatomical variations occur, caution must be exercised when placing implants in the posterior mandible or reflecting the lingual flap for ridge augmentation procedures.

In addition, neurosensory disturbances could manifest during the immediate postoperative period as hypoesthesia, paresthesia, or dyesthesia. Disregarding damage to the inferior alveolar nerve due to inadequate implant selection or poor presurgical planning (ie, assisted by three-dimensional diagnostic tools such as cone beam computed tomography), lingual nerve damage can occur when the lingual flap is raised carelessly in ridge augmentation procedures. Trauma may also occur from the injection needle. When anesthetizing the inferior alveolar nerve, the lingual nerve is held within the interpterygoid fascia; the lingual nerve fibers might be damaged, causing transient paresthesia.²⁵ Moreover, the anterior mandible is not exempt from neurosensory and vascular complications originating from the end portion of the lingual, sublingual, and submental arteries.²⁶

**Clinical Implications for Ridge Augmentation**

Several methods have been proposed for advancing the lingual flap without injuring the surrounding vital structures. Blunt dissection with a dull instrument (ie, 90-degree rotated blade or dull periosteotome instruments) or application of manual/compression forces to detach the mylohyoid muscle from the mandible or the mucosa overlaying the floor of the mouth have been advocated.¹²,²⁷ In the anterior atrophic mandible, when the lingual flap is reflected to access/advance, nerves and vessels (branches of the lingual artery and nerve) that approach the genial spinal foramina might be injured. To prevent hemorrhagic/neurosensory alteration events, cautious and gentle reflection assisted by a dull elevator must be performed and must never extend beyond the genial foramina. However, as was found in the present morphologic study, dense/
thick, supportive fibrous connective tissue forms a protective compartment around such anatomical structures that may prevent irreversible deep injury.

Conclusions

An understanding of and knowledge about the key anatomical landmarks of the mandibular region is imperative to safely perform ridge augmentation when releasing the lingual flap to attain tension-free closure and consequently undisturbed wound healing. Dense connective tissue may play an important role in protecting the key elements of the sublingual space during lingual flap management.

Acknowledgments

The authors would like to thank Viktor Pankovics for his assistance in the preparation of the specimens shown in this manuscript. The authors reported no conflicts of interest related to this study.

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