Int. J. Morphol.,
40(5):1194-1201, 2022.

Mylohyoid Muscle Revisited: Anatomic Features with Clinical Implications in Dentistry

Revisión del Músculo Milohioideo: Características Anatómica con Implicaciones Clínicas en Odontología

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TRUONG, M. V.; KIM, S.; LEE, J.; LEE, W. & PARK, Y. S. Mylohyoid muscle revisited: Anatomic features with clinical implications in dentistry. *Int. J. Morphol., 40(5)*:1194-1201, 2022.

SUMMARY: The mylohyoid muscle, one of the suprahyoid group, forms the floor of the mouth. Its main function is swallowing. It is a margin between the sublingual and the submandibular spaces and is important in the pathway of oral and maxillofacial infection. In prosthodontics, it is one of anatomic landmarks that limits the lingual margin of the mandibular denture. Currently, the muscle receives much interest in the fields of maxillofacial reconstruction and rejuvenation. The hemorrhagic issue around the mandibular lingual region is usually involved with the mylohyoid especially in the dental implant installation. This review covers anatomic features of the mylohyoid muscle with diverse clinical implications.

KEY WORDS: Mylohyoid muscle; Denture; Hernia; Anatomy.

INTRODUCTION

Mylohyoid muscles are flat, paired muscles that belong to the suprahyoid group, which also includes the digastric, geniohyoid, and stylohyoid muscles (Fig. 1). It lies immediately superior to the anterior digastric muscle and forms the floor of the mouth, a region situated beneath the movable tongue and above the mylohyoid diaphragm. It functions mainly during swallowing, speech, and mouth opening. Anatomically, it constitutes a margin between the submandibular space and sublingual space. A myriad of pathologic conditions may involve the mouth floor region. Familiarity with the diagnostic imaging appearance of the mylohyoid is important for localizing disease (La'porte *et al*., 2011). The mylohyoid muscle is important not only in basic science but also in clinical medicine including dentistry. In this review, diverse features of the mylohyoid muscle published in the literature will be classified into general anatomy and clinical implications. The findings will be summarized and discussed to aid the current understanding of this unique muscle.

General Anatomy

Origin, insertion, and direction. The name "mylo" comes from the Greek word meaning "molar". The muscle lies superior to the digastric muscle's anterior belly. The origin of mylohyoid is the mylohyoid line of the mandible, which extends from around the symphysis menti to the molar teeth behind. Interestingly, the length of the line is known to be variable from individual to individual. The insertions are the anterior surface of the hyoid bone and the median raphe of the muscle, where two mylohyoid muscle fibers from each side unite (Fig. 2). Specifically, the fiber of the posterior portion of the mylohyoid runs in the medial and downward direction to the lower margin of hyoid bone anterior portion. The fibers of the anterior and middle portion decussate in the median fibrous raphe (Fehrenbach & Herring, 1996).

Microscopic structures of mylohyoid attachments. The mylohyoid line at the attachment is composed of bundle bone, which is actively remodeled. Sharpey's fibers in the bundle bone seemed to be able to adapt to the direction of tension (Shikano, 1996).

Anatomic relations. The geniohyoid muscle lies on top of the mylohyoid surface. The superior surface is also related to the hyoglossuss and styloglossus, the extrinsic group of tongue muscles. The sublingual gland, one of major salivary gland, is located on the muscle. The superficial lobe of the

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Received: 2022-06-05 Accepted: 2022-07-03

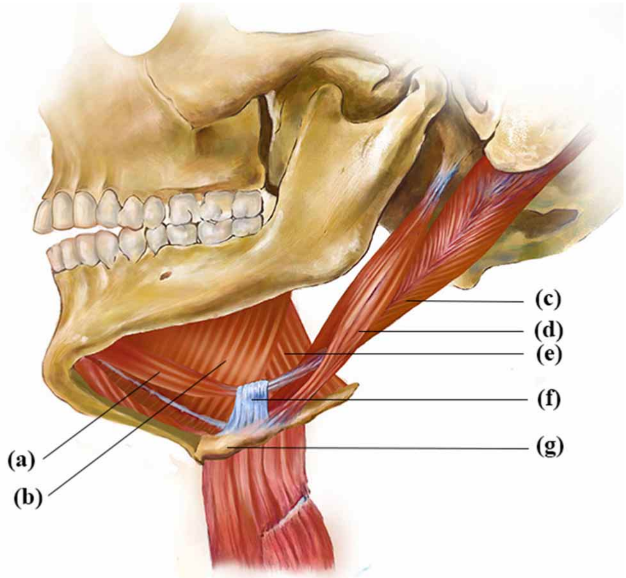

Fig. 1. Suprahyoid muscles. (A) anterior belly of digastric muscle, (B) mylohyoid muscle, (C) posterior belly of digastric muscle, (D) stylohyoid muscle, (E) hyoglossus muscle, (F) intermediate tendon, (G) hyoid bone.

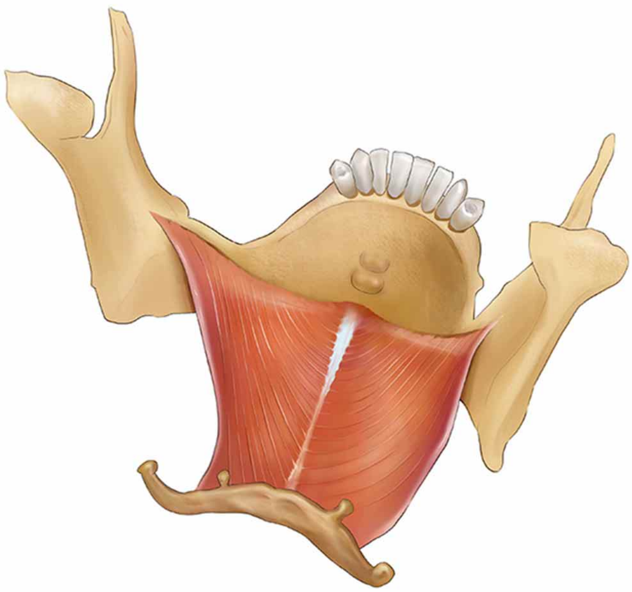

Fig. 2. Mylohyoid muscle.

submandibular gland, another major salivary gland, is located beneath the mylohyoid while the deep lobe and its duct are also located on the muscle (Saadeh *et al*., 2001). The lingual and sublingual vessels and the hypoglossal and lingual nerves run over the mylohyoid. The posterior part of the mucous membrane of the mouth floor lies directly upon the muscle. The crossing of the submandibular gland duct and the lingual nerve are consistently found in close vicinity to the posterior portion of the mylohyoid upper surface (Klepacek & Skulec, 1994).

The inferior surface is related to the platysma and the anterior belly of the digastric muscle. The superficial part of the submandibular gland is situated beneath the muscle. The facial, the submental and the mylohyoid vessels run under the mylohyoid. The mylohyoid nerve is also situated here.

Relationship to potential spaces around the mandible. There are many important potential spaces around the mylohyoid, both anatomically and clinically. The submental spaces exist in the suprahyoid region beneath the mylohyoid (Agarwal & Kanekar, 2012). The submental space is situated between the mylohyoid and the deep cervical fascia in the midline of the chin. Its lateral margins are the anterior bellies of the digastric muscle from each side. Posteriorly, the space communicates with the two submandibular spaces. The submandibular space is also located beneath the mylohyoid. Anteriorly, next to the submental space, the submandibular space starts from the digastric anterior belly. Posteriorly, it ends at the digastric posterior belly. It communicates with the sublingual space via a lateral gap between the mylohyoid and hyoglossus around the free posterior margin of the mylohyoid (Otonari-Yamamoto *et al*., 2010). In contrast to the submental and the submandibular space, the sublingual space is located above the mylohyoid and in the floor of the mouth. It is a continuous space across the midline that communicates with the submandibular space around the free posterior margin of the mylohyoid (Saadeh *et al*., 2001).

Relations to anterior triangle of the neck. The mylohyoid forms the floor of the digastric triangle with the hyoglossus and also forms the floor of the submental triangle. The former triangle is bounded above by the mandibular body and a line drawn from the mandibular angle to the mastoid process. It is bounded below by the anterior and the posterior bellies of the digastric muscle. The latter triangle is the region bounded posteriorly by the two anterior bellies of the digastric muscles and anteriorly by the midline of the neck. Its base is the hyoid bone body and its apex is the chin.

Development. The mylohyoid is mesodermal in embryogenic origin (Madhyastha *et al*., 2009). It develops from the muscle mass of the mandibular part for the first pharyngeal arch with the anterior belly of the digastric muscle, tensor veli palatini, tensor tympani, and four masticatory muscles. Meckel's cartilage was suggested to influence the development of the mylohyoid (Kishi *et al*., 2012). During the developmental period, the insertion lines of the mylohyoid were gradually transposed to the mandibular bony ridges, although the muscle originally inserted in Meckel's cartilage (Radlanski *et al*., 2001). The transposed muscles were known to influence mandibular movements, resulting in premature mandible dislocation (Wyganowska-Swiatkowska *et al*., 2012). The activity of the mylohyoid seems to influence later mandibular proclination as well as narrowing of the hemimandibles, resulting in anterior fusion of Meckel's cartilage (Kjaer, 1997). The length of the mylohyoid in the prenatal period increases proportionally to the increase in mandibular length, and its increase becomes evident beginning from the 16th week on (Szymanski & Wozniak, 1991). Not so surprisingly, the suprahyoid muscle group was observed to affect mandibular growth and orientation after birth (Spyropoulos *et al*., 2002). Interestingly, the mylohyoid is attached to the hyoid bone in a further developed state compared to other muscles attached to the hyoid bone (Sonoda & Tamatsu, 2008).

Arterial supply and innervation. The mylohyoid was supplied with arterial blood by several branches of the external carotid: the sublingual branch from the lingual artery, the submental branch from the facial artery, and the mylohyoid branch of the inferior alveolar artery from the maxillary artery. A recent study demonstrated that the submental branch of the facial artery is the main arterial supply of the mouth floor and lingual gingiva, despite what is widely described in classical anatomy textbooks (Bavitz *et al*., 1994). Therefore, the primary target of ligation is the submental branch or its parent facial artery in cases of severe hemorrhage in the mouth floor. The muscle is innervated by the mylohyoid branch of the inferior alveolar nerve, which supplies motor innervation (Drake *et al*., 2010).

Anatomy in variation. Infrequently, the median raphe of the mylohyoid is absent. In these cases, the two muscle straps from each side form a continuous sheet, or they can be fused with the digastric muscle. Accessory slips to other hyoid muscles are known to be frequent. A unilateral accessory mylohyoid muscle was reported (Sehirli & Cavdar, 1996). One case report suggested that an abnormal raphe of the mylohyoid provides attachment to muscle bundles from the anterior belly of the digastric muscle at its curved point (Fujimura *et al*., 2003). An uncommon variation of the mylohyoid being supplied by a hypoglossal nerve in addition to the mylohyoid nerve was reported (Madhyastha *et al*., 2009).

Mylohyoid ementiae and mylohyoid fossae, minor anatomic variations of the mandible, are sometimes found around the posterior mylohyoid line. The presence of a bony crest located above and distal to the mylohyoid lines has been reported. The crest was believed to serve as an attachment for the superior pharyngeal constrictor (Penhall & Townsend, 1994).

Herniation. In about one-third of subjects, though the rates vary by as much as 77 % of investigated subjects (White *et al*., 2001), a chasm or hiatus in the muscle has been reported (Fig. 3). Some researchers regard this variation as a common feature (Gaughran, 1963; Yang *et al*., 2016). The hiatus is a transverse fissure between the muscle fibers that otherwise have round or oval openings on a muscular sheet. There is sometimes herniation of fat tissue, blood vessels, or salivary glands, mainly the sublingual gland (Nathan & Luchansky, 1985). These variations can be mistaken for pathological abnormalities (Hopp *et al*., 2004; Kiesler *et al*., 2007). Inflammation is also often found (Engel *et al*., 1987). Sometimes, herniation was found without any contents (Windisch *et al*., 2004). The plunging ranula originates from the sublingual gland and may enter the neck through the hiatus. In this circumstance, sublingual sialadenectomy is the treatment of choice (Harrison *et al*., 2013). Most cases of plunging ranula have an anterior shortcut through the hiatus of the mylohyoid rather than through the posterior margin (Lee *et al*., 2016).

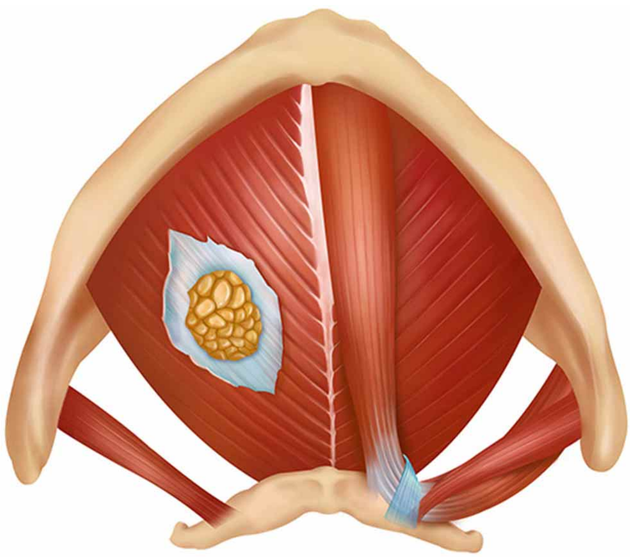

Fig. 3. Herniation of mylohyoid muscle.

Functions. The mylohyoid is the main muscle forming the floor of the mouth, along with the geniohyoid, which lies immediately above it. The mylohyoid may also supply functional support of the mouth floor (Sehirli & Cavdar, 1996). The floor is mainly occupied by the tongue in the oral cavity. When contracted, the mylohyoid can elevate the floor of the mouth and the hyoid bone (Okada *et al*., 2013). Its function is particularly important in deglutition and speech. During the first stage of deglutition, the mylohyoid is known to be contracted. When we swallow a food bolus, the mylohyoid contracts to complete tongue elevation with the styloglossus. The severity of postoperative swallowing problems is reported to be closely associated with removal of the mylohyoid (Hirano *et al*., 1992). In mouth opening, it helps to depress the mandible with other muscles to keep the hyoid bone fixed.

Additionally, the mylohyoid has a role in respiration (Furusawa *et al*., 1994). In this regard, the mylohyoids can be used as reliable indicators of respiratory muscle readiness for intubation after neuromuscular blockade (Lee *et al*., 2013).

In a study using Sihler's stain, the muscle demonstrated neuromuscular specialization of a segmental innervation pattern and predominant major/unusual myosin heavy chain (MHC) fiber types (Mu *et al*., 2004; Ren & Mu, 2005).

Mylohyoid muscular activity. There have been many studies using diverse technologies including electromyography (EMG) to analyze the integrated actions of orofacial muscles related to mandibular movements, and the mylohyoid is not an exception (Dillingham, 1999). The mylohyoid showed activity in deglutition, mastication, sucking, and blowing. The postero-lateral fibers showed more activity during tongue movements, while the anterior fibers were more active during mandibular movements (Lehr *et al*., 1971). Among others, swallowing, a highly complex adaptive motor activity, is a major issue related to the mylohyoid (Furusawa *et al*., 1994; Okada *et al*., 2013). In fact, mylohyoid activity is commonly recorded as an indicator of swallowing in studies of motor neuronal activity (Kitagawa *et al*., 2009). The muscle has also been investigated regarding its role in swallow-induced glottis closure associated with laryngeal elevation (Shaker *et al*., 1990; Spiro *et al*., 1994). The feasibility of dynamic open configuration magnetic resonance imaging (MRI) of swallowing was assessed in comparison with videofluorography and seemed to provide comparable results (Honda & Hata, 2007).

The mylohyoid is known to contract in the following movements: 1) mouth opening slowly and maximally, 2) mouth opening against resistance, 3) lateral movement without occlusal contacts keeping the jaw depressed and protruded slightly with other suprahyoid muscles, 4) protraction of the mandible without occlusal contact maintaining slight depression with other suprahyoid muscles, 5) protraction of the mandible against resistance, 6) retraction of the mandible in a weak manner, 7) swallowing saliva or water but sipping only in a negligible way, 8) chewing gum as an antagonist to masticatory muscles, and 9) tongue protraction (Vitti & Basmajian, 1977).

Dysphagia. Alteration of mylohyoid motor-evoked potentials in the affected hemisphere was closely associated with severity of chronic stroke dysphagia (Gallas *et al*. 2007). The mylohyoid is a main target muscle of neuromuscular electric stimulation (NMES) used to improve dysphagia in patients with brain injury (Toyama *et al*., 2014). The swallowing musculature of patients with dysphagia after chemoradiotherapy showed less structural deterioration after preventative behavioral intervention of a swallowing exercise program (Carnaby-Mann *et al*., 2012; Pearson Jr. *et al*., 2013).

Simulation model. In biomechanical modeling, jaw-opening muscles including the mylohyoid are better suited for producing velocity and displacement because they have a longer sarcomere (van Eijden *et al*., 1997). A mathematical model of the mylohyoid was developed to analyze its complex mechanics during mandibular movements (van Eijden & Koolstra, 1998). A motion simulator capable of recreating full mandibular motion was developed for intact temporomandibular joint and total joint prosthesis (Celebi *et al*., 2011).

Clinical Implications

Surgery

Mylohyoid in clinical infection. Since the mylohyoid line lies more superior in the posterior direction of the mandible, the root apices of mandibular molars are frequently below the mylohyoid attachment inside the mandibular body. Infections such as pericoronitis can penetrate the thin lingual plate close to the apex and directly drain into the submandibular tissue space. At the free posterior margin of the mylohyoid, the sublingual space communicates with the submandibular space to easily enter the sublingual space. Infection in this region may also spread into other posterior potential spaces such as the parapharyngeal and pterygoid spaces (Ariji *et al*., 2002). Sometimes, infection entering these spaces may spread down the neck into the mediastinum, which is an extremely dangerous situation. Ludwig's angina is a well-known example of life-threatening cellulitis of the mouth floor, and subsequent narrowing of the upper airway may lead to suffocation. In a computed tomography (CT) study on impacted third molars, the mylohyoids overlapped the crown at below or intermediate perpendicular positions, and most of them were involved in the infection through the submandibular space (Ohshima *et al*., 2004).

Hemorrhage. There have been many studies on a variety of vascular distributions around the floor of the mouth (Katsumi *et al*., 2013). In the anterior tooth lingual region of the mandible, sublingual and submental arteries run from the vicinity of the mylohyoid attachment along the bony surface in the anterosuperior direction. Most of these vessels were found to penetrate the alveolar mucosa and/or bone, which explains why many vascular injuries occur in this anterior lingual region during implant surgery (Fujita *et al*., 2012). According to another report, a large branch of the submental artery perforated the mylohyoid in 41 % of investigated samples, and the point of perforation was located an average of 31 mm posterior to the menton (Hofschneider *et al*., 1999). In the lingual side of the mandible, most vessels are located superior to the mylohoid in the intercanine area and beneath the mylohyoid in the premolar and molar areas. Horizontal distance from the lingual plate to these vessels was found as close as 2 mm around the canine and second molar area, so special caution should be taken to avoid lingual plate perforation during implant installation surgery (Mardinger *et al*., 2007).

The high presence of the lingual canal and its foramen, which contain the inferior alveolar artery, was observed inside the mental region in one CT and dry skull study (Yoshida *et al*., 2005; Morikage *et al*., 2017). The mental artery and incisive artery from the inferior alveolar artery were observed to run through the bony lingual canal and to anastomose with the submental artery in the mylohyoid or anterior digastric muscles. This observation is an important consideration for placement of dental implants (Kawai *et al*., 2006).

Maxillofacial Reconstruction. For reconstruction of oral composite resections, a mylohyoid flap can be used to close the anterior oral cavity. The procedure is used in many cases previously requiring closure by free flap. It has advantages of quick restoration of oral alimentation and minimal donor site morbidity (Sawhney *et al*., 2011). Indeed, the mylohyoid is frequently considered a useful structure for covering facial defects because of its good vascular supply (Faltaous & Yetman, 1996; Aszmann *et al*., 1998; Cheng & Bui, 2014; Zdilla, 2014). A myofascial flap using the mylohyoid is often used successfully for soft tissue reconstruction in patients with bisphosphonate-related osteonecrosis of the jaw (BRONJ) (Eckardt *et al*., 2011; Lemound *et al*., 2012).

Dysmorphic neck. Rejuvenation of the submental area is a current topic of interest in maxillofacial plastic surgery. Obtuse cervicomental angles are difficult to address. Submental lipectomy often gives suboptimal results and only addresses fat superficial to the platysma (Renaut *et al*., 1994). The mylohyoid creates a fat compartment with the platysma and digastric muscle (Rohrich & Pessa, 2010). Transection of three suprahyoid muscles, except the stylohyoid, at their attachment and relocation of the anterior hyoid posteriorly and superiorly was reported to be effective in improving the neck contour of patients with dysmorphic neck (Guyuron, 1992). The advantages and disadvantages of several cervicoplasty and rhytidectomy techniques involving the mylohyoid have been reported (Ramirez, 1997; Labbe *et al*., 2013; Langsdon *et al*., 2013).

Mylohyoid in denture fabrication. The mylohyoid muscle is a key determinant structure in limiting the posterior lingual margins of mandibular complete dentures. The posterior fibers of the mylohyoid affecting denture margins were reported to have an average inclination between 10 and 25 degrees (Jude, 1975), which can be used to guide fabrication of the lingual flange of dentures (Fig. 4).

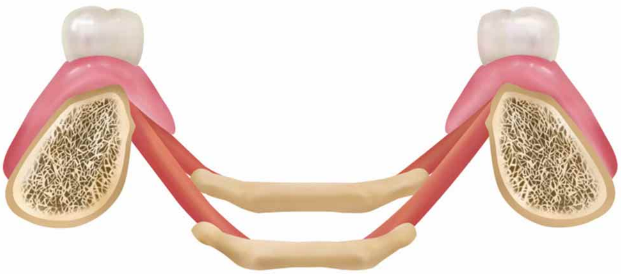

Fig. 4. Relation with the lingual flange of denture and contraction of mylohyoid muscle.

Although movement of the mylohyoid displaces overextended dentures, the mylohyoid itself and the buccinator affixed to buccal bony shelves seems to function as a kind of the barriers to the chronic bone resorption following edentulism, according to one macroscopic observational study on the dry mandible (Pietrokovski *et al*., 2007). In some patients with dentures, a small independent bundle of medial pterygoid may exist and be inserted into the fascia of the mylohyoid. In this case, the bundle looks as a streak-like structure that can possibly break the marginal sealing of mandibular dentures. Since the medial pterygoid is a closing muscle, the bundle may be more prominent during mouth closing, and it should be examined prior to making an impression (Abe *et al*., 1997). In one EMG study, the extensional flange of dentures demonstrated no significant interference on the buccinators and mylohyoid if it is properly designed. Preferably, they may even enhance retention of the denture (Wang, 1990).

To maximize retention and stability, the surgical techniques of Trauner and Caldwell are often used to lower mylohyoid attachments to the mandible in severely resorbed cases (Simmonds & Jones, 1975). The attachment is incised and then anchored more inferiorly on the mandible with sutures, resulting in deepening of the lingual sulcus. The procedure also results in lateralization of the lingual slope of the alveolar ridge. Consequentially, the lingual flange of the denture can be further extended inferiorly and laterally. The operation was reported to occur without impairing the physiology of the mylohyoid, according to a canine study (Courage & Huebsch, 1972).

The terminal lateral movement found in edentulous hemimandibulectomy patients is mainly caused by the mylohyoid, which introduces difficulty in complete denture fabrication for these patients. In these cases, the incorporation of ramps in the denture is recommended for a broader occlusal contact area (Curtis *et al*., 1975).

Miscellaneous. Focal myositis of the mylohyoid has been reported, and the differential diagnosis must include malignant neoplasm in these cases (McCluggage & Mirakhur, 1996). One case of proliferative myositis of the mylohyoid was reported in a girl, a very rare case in children (Choi & Myer 3rd, 1990).

A rare case of intramuscular hemangioma in the mylohyoid has been reported (Nair *et al*., 2010). Cysticercosis in the mylohyoid has been reported (Virk *et al*., 2009). One case presented with overfilling of endodontic obturation paste into the lingual plate and the mylohyoid insertion (Alantar *et al*., 1994). About 40 % of sialolithiasis within Wharton's duct was observed distal to the mylohyoid free margin, and 89 % of these cases had a single stone in the perihilar region (Zenk *et al*., 2001, 2005).

There has been a hypothesis that the mylohyoid groove can act as a path of least resistance in bilateral sagittal split osteotomy, making lingual fracture control difficult and causing "a bad split" (Mensink *et al*., 2014). Along with anesthetic and surgical measures, a nylon flexometallic tube through the mylohyoid was utilized to secure the airway in patients with multiple facial trauma in which anesthetic measure was performed at the same space with surgical measure (Gadre & Kushte, 1992). A modified mortised genioglossus advancement technique was reported to treat obstructive sleep apnea by demonstrating a great amount of muscular advancement including the mylohyoid (Hendler *et al*., 2001).

CONCLUSIONS

Anatomical and clinical literature on the mylohyoid muscle were reviewed here. The muscle is a flat sheet and is a main constituent of the mouth floor. Its function in swallowing and mandibular movements and its anatomic relation to adjacent structures require cardinal consideration by many clinicians and basic scientists. The clinical importance of the muscle is widely recognized, especially in the fields of denture prosthodontics and maxillofacial surgery.

ACKNOWLEDGMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2021R1I1A2048516).

TRUONG, M. V.; KIM, S.; LEE, J.; LEE, W. & PARK, Y. S. Revisión del músculo milohioideo: Características anatómicas con implicaciones clínicas en odontología. *Int. J. Morphol., 40(5)*:1194-1201, 2022.

RESUMEN: El músculo milohioideo es un músculo del grupo suprahioideo que forma el piso de la cavidad oral. Su función principal es la deglución. Es conocido como un límite entre los espacios sublingual y submandibular y es importante en la vía de infección oral y maxilofacial. En la prostodoncia, es uno de los hitos anatómicos que limita el margen lingual de la dentadura mandibular. Actualmente, el músculo recibe mucho interés en los campos de la reconstrucción y el rejuvenecimiento maxilofacial. El problema hemorrágico alrededor de la región lingual mandibular generalmente está relacionado con el músculo milohioideo, especialmente en la instalación de implantes dentales. Esta revisión cubre las características anatómicas del músculo milohioideo con diversas implicaciones clínicas.

PALABRAS CLAVE: Músculo milohioideo; Dentadura; Hernia; Anatomía.

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