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Detection methods for marginal mandibular branch of facial nerve: a literature review

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Running title : Detection method for marginal mandibular branch

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ABSTRACT

Detection methods for marginal mandibular branch of facial nerve: a literature review

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Purpose: After orofacial surgery, some patients' quality of life are lowered due to iatrogenic injury of the marginal mandibular branch (MMB). Therefore, methods that can localize and protect the MMB before or during orofacial surgery were reviewed through a literature review.

Material and Methods: Total of ten documents were sourced through a PubMed search. Depending on the methods that can navigate the MMB, the studies were categorized into landmarks' utilization, ultrasound scanning techniques, nerve stimulators, and fluorescent dye techniques.

Results: In the cases of using landmarks, there were methods that used a layer with facial artery and facial vein. Also, the location of MMB inferred by making the triangle based on mouth commissure, sternocleidomastoid muscle, mandibular groove, mastoid, and mastoid apophysis. There was also a technique for visualizing an MMB via ultrasound scanning. The portable and disposable nerve simulator enabled an accurate MMB identification. Moreover, MMB mapping using a stimulator could help in the security and protection of the nerve during surgery. Finally, using a fluorescent dye (which is currently limited to animal study) could make visualization of MMB and micro branches.

Conclusion: Most orofacial surgeries still rely on landmarks to search for the MMB. However, it is believed that damage to the MMB can be reduced by using the various techniques identified in this review paper in clinical practice.

Key words : Facial nerve, Marginal mandibular branch, Anatomic landmark, Intraoperative monitoring, Diagnostic imaging, Ultrasonography, Fluorescent dyes

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Ⅰ. Introduction

The facial nerve is the seventh cranial nerve[1], which mostly acts as a motor nerve responsible for facial muscle movement. Furthermore, in some parts, such as the front of the tongue, it is a special sensory nerve that is responsible for gustation. The facial nerve, which originates from the pons of the brainstem, passes through the stylomastoid foramen and parotid gland. It is divided into five branches: temporal, zygomatic, buccal, marginal mandibular branch (MMB), and cervical[2]. Compared to other cranial nerves, it can easily be damaged by surgery, trauma, or infection[3]. The higher propensity of damage to the facial nerve is due to the long distance traversed by it. Moreover, it passes through the narrow bone canal within the temporal bone. In particular, iatrogenic injury is a predominant cause of facial nerve injury, which can result from a variety of facial surgeries, such as superficial or total parotidectomy, submandibular gland extirpation, neck dissection, marginal or segmental mandibulectomy, and cervicofacial facelift[4,5].

Among the branches of the facial nerve, the MMB is clinically important. When the action of the depressor anguli oris muscle and depressor labii interferioris muscle is reduced by MMB paralysis, not only labial asymmetry[6] but also lower lip immobility can occur. Furthermore, the reduced activity of these muscles makes it difficult to talk or eat. In addition, the MMB has a higher frequency of damage than other branches during surgery[5,7,8]. This is because many facial surgeries use submandibular approaches and MMB has anatomically thin nerve diameter. Moreover, the location of the branch varies with age, and it is difficult to find the layer in which the nerve is placed[7].

A clinical study reported that facial surgery was performed in 2,354 patients. Among them, MMB injury took place in 165 patients (7%) with submandibular gland excision, 235 patients (10%) with mandibular fracture fixation, 259 patients (11%) with parotidectomy, and 471 patients (20%) with cervical lymph node dissection in submandibular triangle[2]. The damage rate of MMB was approximately 30% of the total surgery, which suggests that clinicians have the burden of the possibility of damage during relevant facial surgery[2].

Traditionally, the process of finding an MMB using the surgical approach has relied on anatomical methods attributed to the depth of the facial artery and vein. Surgical approaches based on anatomical landmarks are still employed[5,7,9,10]. However, in addition to anatomic method, some studies reported the other methods that find the MMB using devices and tools[11,12]. Through this study, we intended to review the methods to find the MMB using various detection tools. Moreover, this review also aims to suggest directions for reducing nerve damage.

Ⅱ. Material and Methods

In the present study, PubMed, a medical thesis research database built by the National Library of Medicine, was used to find research papers. With the keywords 'facial nerve', 'marginal' and 'detection', total 52 papers were found. Among them, we excluded clinical studies that studied postoperative prognosis, review papers, and papers whose original text could not be retrieved as they were published a long time ago. Only clinical and preclinical studies related to the detection of MMB were included in the paper. Finally, ten studies were included in this review.

Ⅲ. Results

The searched papers were classified into four categories according to the methodology: landmark, ultrasound, nerve stimulator, and fluorescent dye (Table 1).

1. Landmarks

There have been studies to detect MMB through known surrounding anatomical landmarks. Arvinder P. et al.[13] studied the variation of MMB (Fig. 1). In 44 cases (88%) of 50 cadavers, the MMB was single branch at the origin. However, in 42 cases (84%), two or more branches were divided at the termination. This shows that the branch gets divided as it moves towards the nerve endings. Additionally, MMB was located in the superficial layer of the facial artery and facial vein in all cases (100%). The MMB was merged with 28% of the mental nerve and 12% of the buccal branch of facial nerve. In 32% of cases, it passed below the inferior border of mandible, and the maximum distance between the MMB and the inferior border was 1.6 cm. Therefore, it was suggested that the submandibular incision should be marked more than 1.6 cm downward from the inferior border of the mandible. The study also mentioned that facial artery pulsation is an important guide for distinguishing the MMB.

In Percy P. et al.'s study[14], the danger zone was mentioned using landmarks to determine the location of the MMB (Fig. 2). This zone exists between the lower area of the mouth corner and the anterior area of the anterior margin of the sternocleidomastoid muscle. Four reference points were identified: mastoid apophysis, lateral commissure of the mouth, mandibular groove, and anterior border of the sternocleidomastoid muscle (SCM). The danger zone should be carefully dissected during facial surgeries. The 64 hemifaces in 32 cadavers (25 males, 7 females) were analyzed about the triangular regions. MMB was identified in 100% of cases in the anterior segment of the facial artery. It was reported that MMB is located on the inside of platysma and on the superficial layer of the superficial muscular aponeurotic system (SMAS).

Kun H. et al.[15] used landmarks on 11 cadavers to evaluate the location of the MMB according to the neck position. The border-nerve distance (BND) from the MMB to the mandibular border was measured at three points (1. Gonion, mandibular angle (Go point); 2. Intersections of the facial artery and MMB (FA point); 3. 1/4 point line from the gonion to the menton (1/4 point)) using a caliper. The difference in BND for each point according to the neck

Table 1. Summary of review literature

Category	Published Year	Author	Study Design	Study Subjects	Landmarks or Device	Discriminable whether nerve damage or not	Success Rate (%)
Find anatomic landmarks	2010	Arvinder P. et al.	Cadaver	50	Facial artery and facial vain	Relationship with the angle and inferior border of the mandible, with facial artery, with facial vein and other surrounding structures	–
	2015	Percy R. et al.	Cadaver	32	Marginal branch triangle	Sternocleidomastoid muscle with a line intersects the lateral commissure of the mouth and the mandibular groove	–
	2012	Kun H. et al.	Cadaver	11	Skin windows	Distance from the mandibular border to the mandibular branch of the facial nerve	–
	2007	Syed M. et al.	Clinical Study	20	Simple nerve dissecting technique	Horizontal component of the standard neck incision is made 4 cm below the lower margin of the mandible	19/20 (95%)
Ultrasound scanning technique	2021	Riccardo P. et al.	Cadaver specimens	3	Red latex infusion & ultrasound	Injecting latex under ultrasound guidance	–
			Clinical Study	20	Ultrasound probe	Standardized scanning protocol	3/20 (15%)
Nerve stimulator	2006	Babak S. et al.	Clinical Study	25	Disposable nerve block needle	Using low-current nerve stimulation to localize MMB	25/25 (100%)
	2015	Bo L. et al.	Clinical Study	40	Needle electrodes	Thresholds of the needle electrode on the mapping path or below 0.5 mA	39/40 (97.5%)
	2015	Kei I. et al.	Clinical Study	5	Nerve stimulator bipolar probe	Electrical stimulation to identify by movement of lower lip and MMB location marked on the skin	5/5 (100%)
Fluorescent dye	2016	Giulianno M. et al.	Animal Study	40	Probe dye (Carbocyanine)	Measuring time for localization and facility of localization and nerve function	40/40 (100%)
	2017	Timon H. et al.	Animal Study	28	Probe dye (FAM-NP41)	Measuring nerve function by automated whisker tracking	9/13 (69%)

position (neutral position, full flexion (15°), extension (15°), and left and right rotation (30°)) was analyzed. At the Go point and FA point, no significant differences in BND were verified according to the neck position. However, in the case of 1/4 point, BND decreased about 1 mm when rotated to the ipsilateral side and BND increased about 0.7 mm when rotated to the contralateral side.

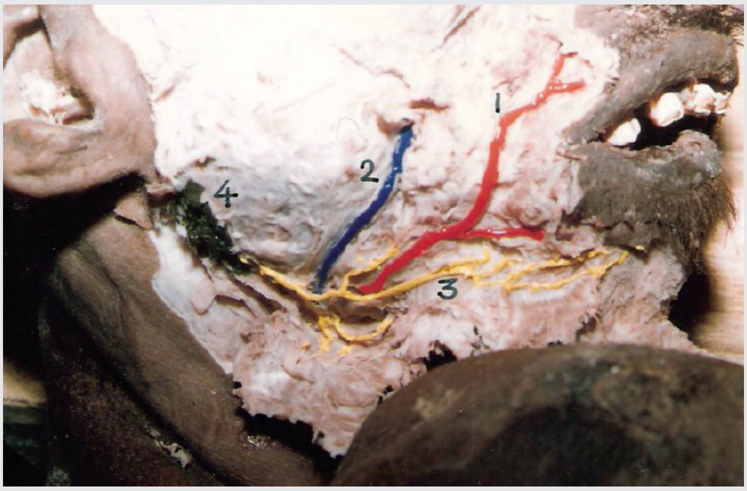

Figure 1. Marginal mandibular branch (MMB) of the facial nerve in the cadaver. (1. Facial artery, 2. Facial vein, 3. MMB of the facial nerve, and 4. Parotid gland) (Cited from Arvinder P, Anupama M, Karunesh G. Marginal mandibular branch of the facial nerve: An anatomical study. Indian J Plast Surg 2010;43(1):60–4.[13])

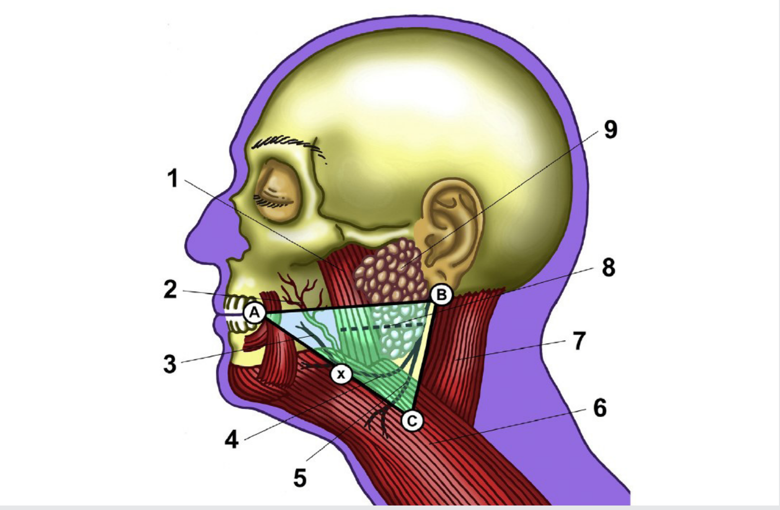

Figure 2. The marginal branch triangle. 1: Masseter muscle. 2: Facial artery. 3: Terminal branches of marginal nerve. 4: Marginal branch of facial nerve. 5: Cervical branch of facial nerve. 6: Platysma muscle. 7: Extracellular matrix muscle. 8: Facial distribution of facial nerve. 9: Parotid gland. (A: Lateral commissure of the mouth B: Base of mastoid apophysis C: Anterior border of the ECM muscle. X: Mandibular groove). (Cited from Percy P. The marginal branch triangle: Anatomic reference for its location and preservation during cosmetic surgery. J Plast Reconstr Aesthet Surg 2016;69(3):387–94.[14])

Another study[16] on landmarks presented a nerve-avoiding technique to lift the common facial vein. This method was based on the fact that if the entire surface layer is lifted after vein ligation, the MMB also gets included and lifted. In addition, the authors presented a method for avoiding MMB damage using the cervical branches. The cervical branch of the superficial layer of the deep cervical fascia was identified by performing a deep retrograde dissection to the subcutaneous adipose tissue in front of the SCM. The cervical branch was lifted and the MMB was dissected with minimal handling.

2. Ultrasound

Localization of MMB through the use of ultrasound was attempted. Riccardo P. et al.[3] reported the use of ultrasonic waves for tracking MMB routes in cadavers and clinical studies. First, diluted colored latex was injected into the presumed MMB position using three cadavers. Subsequently, the MMB could be dissected through direct real-time ultrasound visualization with colored latex. Besides cadaver, the facial artery and vein were found in 20 healthy volunteers, and it was confirmed that the hypoechoic structure of the MMB was located between the facial artery and platysma. The MMB traveled to the inferior fibers of the platysma and interposed in the depressor anguli oris and depressor labii inferior muscles. The distance between the facial artery and MMB was 0.69±0.07 mm, and the distance from the gonion to the MMB was 3.3±0.6 on the ultrasound. For observation of damaged MMB, three patients was evaluated using ultrasound. No proximal end of the damaged MMB was observed and it was occupied by soft tissue. The peripheral muscles around the MMB showed severe atrophic changes, with a decrease in volume and echogenicity (Fig. 3).

3. Nerve stimulator

There have been studies of preoperative or real-time tracking of the location of MMB through a nerve stimulator. Babak S. et al.[17] reported a method of tracking the MMB using a portable disposable plexus block nerve stimulator through facial contraction of a patient when in direct contact with nerve tissue during surgery. A plexus block nerve stimulator was used during skin flap elevation. The nerve stimulator had minimally invasive electrical stimulation at 1.00 mA frequency and 1 Hz which was connected to a conductive, disposable sterile monopolar electrode to a hand-held generator (Fig. 4A). It was used for neck dissection and flap operation in 25 patients where it showed 100% success rate for MMB identification (Fig. 4B). Moreover, postoperative paralysis was not reported.

In another study[18], mapping was performed before surgery using a stimulator. Electromyography surface electrodes were placed above and below the orbicularis oris muscle and ground electrodes were placed on the forearm. Electrical stimulation was performed using a bipolar probe. The bipolar probe was placed 30 mm apart between the two tips and provided a tingling sensation at 1-2 Hz frequency and 5.0-5.5 mA. Clear compound muscle action po-

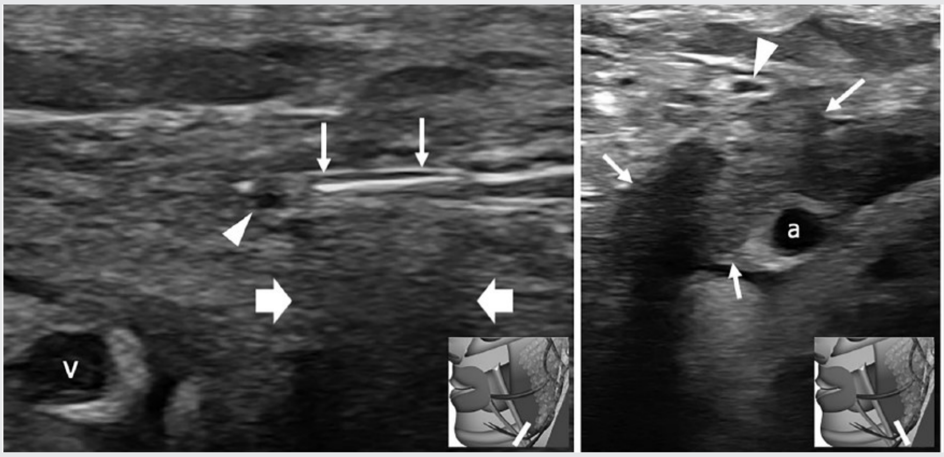

Figure 3. Marginal mandibular branch (MMB) detection using ultrasound. MMB transection in a patient with previous right type-1 modified radical neck dissection and extended superficial parotidectomy. The inserts on the right bottom side of each image illustrates the respective probe position. (a: facial artery, v: facial vein, Arrowheads: Marginal mandibular branch, Arrows: metallic vascular clip (left), postsurgical fibrosis (right)) (Cited from Riccardo P, Federio Z, Federico P. High-resolution ultrasound of the marginal mandibular branch of the facial nerve: Normal appearance and pathological findings in a postsurgical case series. Head Neck 2021;43(9):2571-79.[3])

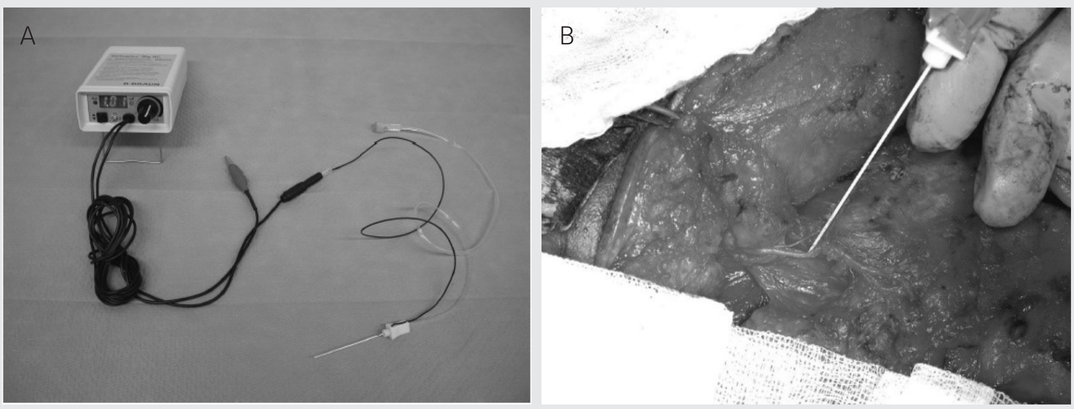

Figure 4. The correct identification of the Marginal mandibular branch using nerve stimulator. A: nerve stimulator, B: Correct position identified. (Cited from Babak S, Stephane H, et al. Preservation of the marginal mandibular branch of the facial nerve using a plexus block nerve stimulator. Laryngoscope 2006;116(9):1713-6.[17])

tential (CMAP) was recorded. If the MMB below the soft tissue was located between the two tips, CMAP lead contraction of the orbicularis oris muscle. Dots were marked at the maximal CMAP position, and the pathways of the MMB were matched with a line connecting the dots. Incision line was drawn 5-20 mm below the connecting line (Fig. 5).

A nerve stimulator was used to identify the presumed MMB of the neck dissection area in five cases[19]. Electrical stimulation was performed at 5.0 mA with an interval of 4.0 ms Bipolar electrode was placed in the same position as the surgical position while the patient was awake, and the movement of the lower lip was marked with a felt pen. The total time did not exceed ten minutes. To find the MMB, the stimulation site was set above the facial vein. Two MMBs were identified in four out of five patients. Moreover, an additional branch was found in one case below the mandibular border. Paralysis in lower lip was not detected in all cases using the nerve stimulator.

4. Fluorescent dye

Although limited to animal experiments, there have been studies that visualize the location of MMB by injecting fluorescent dyes. In the paper by Giulianno M. et al.[20], peripheral nerve tissue was stained with Cy5-NP41, an intravenous fluorescent dye, in mice (Fig. 6). Nerve pathways were then observed under a microscope with polarized light. In 40 mice, 0.1 mL of saline solution was injected into ten mice which were designated as the control group, and 0.1 mL the fluorescent dye carbocyanine (FastDio) was injected into the remaining 30 mice. The injection site was set shallow and parallel to the facial muscles. The injection site was the point where the facial muscle met the bifurcation at the angle between the nasal dorsum and the nasolabial folds at 2 cm anterior to the tragus and 1/3 of the line from the tragus to the oral rhyme. Vibrissae movement score was used to confirm the function of the MMB. The higher vibrissae movement score , the more similar the positioning of MMB. After the injection of the dye, parotidectomy was performed. The day of the first injection was designated as day 0, surgery was performed on day 1, and the scores were measured on days 2, 7, 14, and 28. When the nerve detection time was compared between the two groups, the test group was approximately two minutes faster. Analysis of the total scores revealed that the test group had a higher score than the control group. On day 2, the Vibrissae movement score score decreased significantly in both the groups. However, the score quickly recovered to the normal value on days 7, 14, and 28 in the test group.

Timon H. et al.[21] stained nerve tissue by systemic injection of carboxyfluorescein called FAM-NP41 through the mouse's tail vein. A total of 28 Swiss-Webster female mice were used, and Luc2-positive SCA-9 cells were injected into the glands to induce parotid gland tumors. After culturing the tumors for seven days, the mice were divided into two groups, FAM-NP41 aided tumor removal surgery (n=13, test group) and non-dye using group (n=15, control group). Tumor removal was performed after

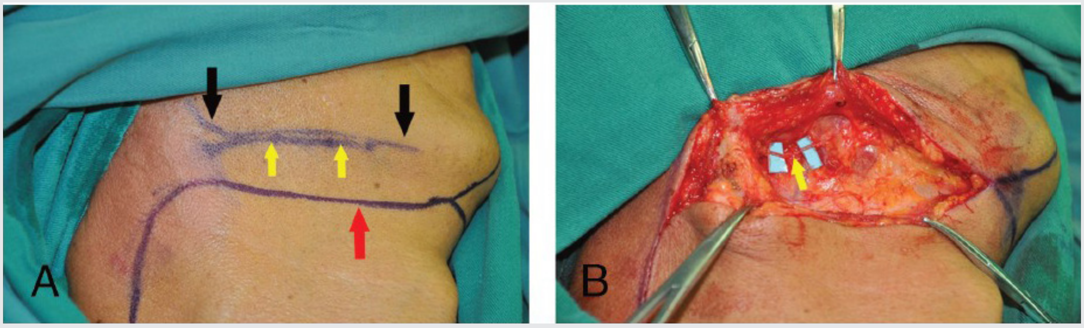

Figure 5. Preoperative mapping using nerve stimulator of Marginal mandibular branch (MMB). Course of the underlying MMB and placement of the incision line were mapped (black arrows: marginal border of the mandible; yellow arrows: the course of MMB; red arrow: incision of neck dissection.). (Cited from Xuguang L, Xiaofeng S, Lei Z, Zhigang C. Preoperative percutaneous nerve mapping of the mandibular marginal branch of the facial nerve. J Craniofac Surg 2015;26(2):411–4.[18])

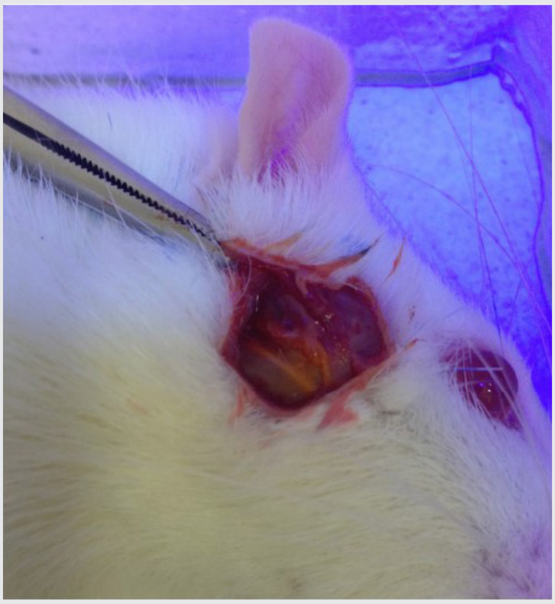

Figure 6. The dissection with the mandibular and buccal fluorescent-colored branches of the facial nerve. (Cited from Giulianno M, Onivaldo C, et al. Facial nerve identification with fluorescent dye in rats. Acta Cir Bras 2016;31(2):92–102.[20])

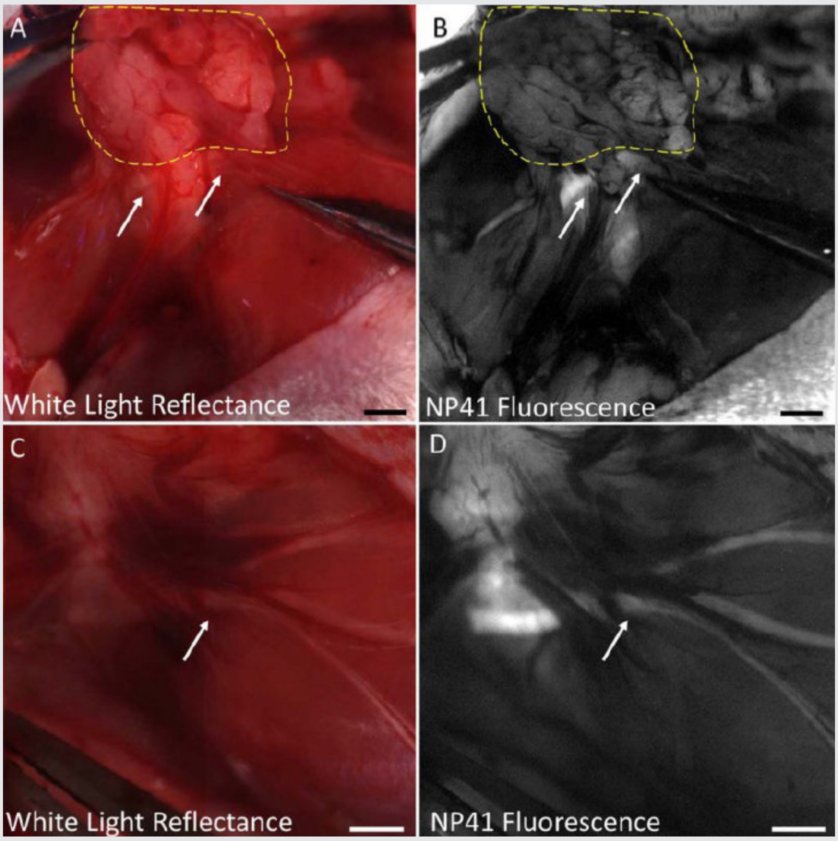

Figure 7. Intraoperative nerve visualization by fluorescence during parotid gland cancer surgery. Prior to tumor removal (stippled line indicating tumor extent), the main branch of the facial nerve is covered by tissue and barely distinguishable under white light (A, arrows pointing to nerve). Fluorescent labeling improves nerve visualization (B). After tumor removal by using fluorescence guidance, the intact nerve is shown under white light (C) and fluorescence (D). (Cited from Timon H, Linda TN, Michael W, Honathan H, Quyen TN. Improved facial nerve identification during parotidectomy with fluorescently labeled peptide. Laryngoscope 2016;126(12):2711–17[21]).

2.5 hours' injection of the probe dye. Two days after tumor removal, whisker movement was measured using pixel planar images (360X250) at 250 Hz for 10 s. This motion image was amplified and divided to one of three groups: 0% to 33%, 34% to 66%, and 67% to 100% movement compared to normal grade. In the test group injected with FAM-NP41, more mice showed higher recovery than in the control group (Fig. 7). Furthermore, the contrast of the facial nerve branch increased 2.86 times compared to the control group.

Ⅳ. Discussion

Among several branches of the facial nerve, the MMB intervenes with the depressor labii inferioris, depressor anguli oris, and mentalis muscles, which move the anterior inferior labrum. After the facial nerve passes through the stylomastoid foramen, it is divided into temporofacial and cervicofacial divisions within the parotid gland. The MMB is the second branch of the cervicofacial division among the buccal, marginal, and cervical branches. When performing surgery such as neck dissection and parotidectomy in the oral and maxillofacial regions, the MMB can be easily damaged. This could cause the complication of a change in facial appearance due to sagging of the lower labia. Therefore, oral and maxillofacial surgeons should take good care not to damage this branch by using very sensitive techniques. The present study reviewed the effectiveness of various MMB detection methods.

The method of finding an MMB using a landmark is the most common and traditional way[22]. Moreover, most surgeons tend to operate relying on the landmark. Anatomically, the MMB was mostly located outside the facial artery and vein. Focusing on the fact that the layers on each structure are different, the technique of protecting the MMB by elevating the layer including the facial vein is the norm currently. Although this method is not affected by obesity or gender, it is difficult to employ in cases of re-operation. In addition, it can be greatly influenced by proficiency of the surgeon. For these reasons, numerous studies on auxiliary methods for finding MMB have been conducted.

Ultrasound is the least invasive, user-friendly, and real-time confirmation method[3]. It can identify not only nerves but also other important appendages, which could be highly supportive during surgery. MMB is usually located on the surface layer of the mandible and ultrasound is easy to apply, regardless of the limitation that it does not pass through the bone. However, nerves are difficult to distinguish compared to blood vessels and are very sensitive to operators because two-dimensional screen information must be interpreted as three-dimensional in clinical applications. Moreover, it may be affected by the position of the patient. In re-operative cases, the anatomical deformation could lead to difficulty in interpreting the results. Nevertheless, the potential usefulness of ultrasound in the maxillofacial area is substantial. It is thought to play an auxiliary role in the MMB search along with the method of using landmarks.

Using the nerve stimulator during surgery, direct current stimulation make enable to identify MMB by facial contractions. This method is the most widely used for beginners in surgery. Through repeated improvements in equipment, portable and lightweight devices can now be used. However, it is possible to cause misprinting because electrical stimulation affects the vicinity of the MMB, causing misprinting. Additionally, the nerve stimulator has a disadvantage because the action potential is higher in the surface layer. It means that the distinction of MMB becomes vague as it goes to the deeper layer. If the mapping technique is used additionally, the error of the equipment can be somewhat reduced by comparing the position of the MMB with the pre-tracked map.

The study using FAM-NP41 dye and fluorescent dye

(FastDio dye) confirmed the increase in the convenience of the surgery and reduction in the nerve damage. The fluorescent dye provides the direct location of the MMB to the surgeon through visualization. However, this method is invasive by blind injection and its long-term safety has not yet been proven. If the other peripheral nerves in the cutaneous layer are stained, surgical confusion can occur. Esthetic problems can also occur. Therefore, it is thought that more research is needed for the use of dye in humans.

Among the dyes used in the study, FAM-NP41 dye is synthesized by covalently binding fluorescein-5(6)-carbonyl to C-terminal lysinamide using NP41, a code that is repeatedly observed during phage isolation, to myelin basic protein[23]. In particular, FAM-NP41 can be clearly identified even under white light by staining the peripheral nerves. In contrast, FastDio dye was developed by reconstructing the molecular structure of fluorescent carbocyanine dye with 3,3'-dilinoleyloxacarbocyanine perchlorate[23]. The basic characteristic of carbocyanine is that it incorporates into the cell membrane and spreads through the lipid bilayer for staining[24]. Thus, peripheral nerves are distinguished from other tissues because only nerve fibers are stained. Furthermore, it has the advantages of long duration, and low cell toxicity[24].

V. Conclusions

In the present literature review, we established that many studies were performed to localize and protect the MMB. All techniques have their own pros and cons, but using several techniques at the same time to compensate for these shortcomings can reduce the damage to the MMB.

List of Abbreviations

MMB: Marginal mandibular branch, SCM: Sternocleidomastoid muscle, SMAS: Superficial muscular aponeurotic system, BND: Border-nerve distance, CMAP: Clear compound muscle action potential,

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

The Materials are available from the corresponding author on reasonable request.

Conflict of interest

The authors declare no conflicting interests.

Author' Contributions

Conceptualization: H.-J.K., H.-K.L.; Methodology: H.-J.K., H.-K.L.; Validation, M.-K.K.; Formal analysis, H.-J.K., M.-K.K.; Investigation: H.-J.K., M.-K.K.; Resources: H.-J.K., D.-H.K.; Data curation: H.-J.K., D.-H.K.; Writing original draft: H.-J.K.; Writing review and editing: H.-K.L., I.-S.S.; Supervision: H.-K.L., E.-S.L.; Project administration: H.-K.L. All authors have read and approved the final manuscript.

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