 DOI: 10.21608/adjalexu.2025.374472.1618

3D GUIDED BOTULINUM TOXIN INJECTION IN LATERAL PTERYGOID MUSCLE FOR MANAGEMENT OF PATIENTS WITH DISC DISPLACEMENT WITH REDUCTION

Nourhan Raafa [1]*BDS, Lydia Melek [2]PhD, Hesham Zoheir [3]MSc, Eman Mansour[4]PhD, Aya Sakr[5]PhD

ABSTRACT

INTRODUCTION: Temporomandibular disorder is one of the most prevalent health disorders affecting psychological and physiological abilities of those affected, with disc displacement being one of its most common types. Lateral pterygoid muscle (LPM) injection with botulinum toxin (BTX) is a promising management modality for disc displacement with reduction (DDWR). However, its deep location and its surrounding structures necessitate use of guidance technique during its injection. In this study, a new guidance technique has been introduced using LPM segmentation for 3d guided injection.

OBJECTIVE: To evaluate the effectiveness of LPM segmentation for 3D guided botulinum toxin injection.

METHODOLOGY: This study included 10 patients suffering from DDWR. Evaluations were done after 1,3 and 6 months for maximum interincisal opening (MIO), temporomandibular joint (TMJ) and LPM tenderness, and TMJ clicking and for disc position after 3 months.

RESULT: Maximum interincisal opening (MIO) showed insignificant reduction after 1 month. However, significant increase in MIO was detected at 3-and 6-month post injection. For disc position, improvement was detected at 3-month post injection. Significant improvement in TMJ and LPM tenderness and disappearance of TMJ clicking were also detected at 1-, 3-and 6-month post injection.

CONCLUSION: The findings suggest that muscle segmentation technique for LPM is a reproducible and effective guidance modality for accurately targeting LPM for BTX injection in the management of DDWR.

KEYWORDS: Temporomandibular joint, Lateral pterygoid muscle, Disc displacement with reduction, Computed Tomography.

ABBREVIATION: TMJ: Temporomandibular joint; BTX: Botulinum toxin; DDWR: Disc displacement with reduction; LPM: **LATERAL PTERYGOID MUSCLE;** MIO: Maximum interincisal opening.

1 Clinical instructor, Department of Oral and Maxillofacial surgery, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
2 Professor, Department of Oral and Maxillofacial surgery, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
3 Consultant of Diagnostic and Interventional Radiology, Faculty of Medicine, Alexandria University, Alexandria, Egypt.
4 Lecturer, Department of Rheumatology, Rehabilitation and physical medicine, Faculty of Medicine, Alexandria University, Alexandria, Egypt.
5 Lecturer, Department of Oral and Maxillofacial surgery, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.

*** Corresponding Author:**
E-mail: n.soliman164366.na@alexu.edu.eg

INTRODUCTION

Temporomandibular disorders (TMDs), being one of the most prevalent health disorders affecting individual psychological and physiological abilities, include several disorders that may involve muscles of mastication, temporomandibular joint (TMJ) or its adjoining structures (1-5). Myofascial pain, arthralgia, disc displacement and dislocation are some of the most common types of TMDs (2, 3). Disc displacement, one of the most common causes of TMJ sounds, has been classified by diagnostic criteria of temporomandibular disorders (DC/TMD) into 4 types: disc displacement with reduction (DDWR), DDWR with intermittent locking, disc displacement without reduction (DDWoR) with limited opening
and DDWoR without limited opening (3, 6). In disc displacement with reduction, the articular disc is slightly displaced anteriorly during jaw closure, and it returns to its normal position in TMJ during jaw opening (3,7, 8). A lot of modalities, such as oral appliances, pharmacological therapy, cognitive behavior therapy, arthrocentesis, lateral pterygoid muscle injection with Botulinum toxin (BTX) and TMJ arthroscopy, have been used for management of DDWR, as the main complaints of these patients are ongoing pain and TMJ clicking that do not improve with time (8-11). Botulinum toxin (BTX) is a toxin produced through the fermentation of Clostridium botulinum bacteria, with Botulinum toxin type A (BTX-A) being the most widely used due to its duration and effectiveness. This toxin induces muscle relaxation by inhibiting acetylcholine release at the presynaptic neuron in the neuromuscular junction (12, 13). Also, BTX can manage chronic pain conditions by producing anti-inflammatory and analgesic effect (14, 15). Administration of BTX-A into LPM was introduced by Bakke et al. and Emara et al. as a treatment

modality for DDWR. That modality depends on the theory of LPM hyperactivity role in displacing the articular disc anteriorly to counteract action of retrodiscal tissues (8, 11). Lateral pterygoid muscle is a deeply located muscle, surrounded with multiple vital structures such as pharyngeal muscles and shows also interindividual anatomical variations (16-18). Therefore, guided BTX injection in LPM is mandatory as dysphonia and dysphagia may be accompanied with its blind injection(17, 18). Recently, advancements in computer aided design, computer aided manufacturing (CAD/CAM) technology and virtual planning have enhanced several oral and maxillofacial procedures such as implantology and orthognathic surgeries (19, 20). This study depends on these technologies to introduce a new guidance technique for BTX injection in LPM based on LPM segmentation technique for 3d visualizing muscle location and depth.

In this study, a novel guidance technique for BTX injection into LPM is introduce to enhance the precision and safety of the procedure in patients with DDWR. The aim of the study is to evaluate the effectiveness of muscle segmentation technique in accurately targeting the LPM for BTX injection.

MATERIALS AND METHODS

10 patients were enrolled in the study and informed consent were obtained before participating. This study followed Helsinki principles (21).

Study design:

This study is approved by the Research Ethics Committee, Faculty of Dentistry, Alexandria University, Egypt (IRB No.001056 - IORG 0008839, ethics committee number:0837-01/2024).

Study setting

Participants were recruited from the outpatient clinic at Oral and Maxillofacial Department, Faculty of Dentistry, Alexandria University, Egypt.

Eligibility criteria:

10 patients from both sexes were enrolled after fulfilling the inclusion criteria which were:

1- Age range 20 to 45 years old.
2- Angle class I maxillo-mandibular relation.
3- Diagnosed with DDWR according to DC/TMD criteria.

While the exclusion criteria were:

1- No BTX-A sensitivity.
2- No previous TMJ intervention.
3- No musculoskeletal disorders.
4- Not contraindicated to MRI examination.

Sample size calculation:

Sample size was calculated based on the primary outcome, which is the change in MIO, assuming a 5% alpha error and 80% study power, based on previous studies (22, 23). A minimum of 9 patients was required and increased to 10 patients to account for potential loss to follow-up. The calculation was performed using Rosner's method (24) with G*Power software version 3.1.9.7 (25).

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0**. (**Armonk, NY: IBM Corp**)** Qualitative data were described using number and percent. The Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range (IQR). Significance of the obtained results was judged at the 5% level.

Assessment:

Maximum interincisal opening, TMJ clicking, LPM tenderness were evaluated at 1-,3-and 6- month follow-up. Articular disc position was only evaluated after 3-month post injection.

Maximum interincisal opening

Maximum interincisal opening was measured in millimeters between incisal edges of upper and lower central incisors.

TMJ clicking and TMJ tenderness:

Bilateral palpation in front of ear tragus by index finger and patient was asked to open and close the mouth several times. Then, TMJ clicking was recorded as present or absent and TMJ tenderness was recorded according to visual analogue scale (VAS) with rating 0 (no pain) and 10 (the severest pain).

LPM tenderness:

Intraoral palpation by index finger behind tuberosity was done to record LPM tenderness with rating 0 (no pain) and 10 (the severest pain) according to VAS.

For Articular disc position:

Disc position was evaluated on MRI according to the Kruita et al. method (26). 3 points were drawn on MRI: point (T) at the lowest point of articular eminence; point (P) at the highest point of the external auditory canal; point (D) at the intersection between tangent between point (T) and (P) and posterior point of the articular disc.

Intervention:

Preparation of 3d virtual model:

Computed tomography (CT) scan with soft tissue window (slice width 0.5 mm) with patient biting on a bite block preventing inter-arch teeth contact between posterior teeth and saved as Digital Imaging and Communication in Medicine (DICOM) format.

An intraoral scan for the upper jaw using intraoral scanner (CEREC Omnicam AC; Dentsply Sirona) and saved as standard tessellation language file (STL).

After that, DICOM file of CT was imported to Mimics software system (Mimics innovation suite; Materialise) and segmentation to skull bone was done first followed by manual segmentation to targeted LPM with lasso tool in the axial cuts showing LPM. A 3d model was created by merging

the segmented skull bone and segmented LPM and exported as STL. **Figure.1,2**

Preparation of customized needle insertion guide:

DICOM file and STL file of jaw scan and segmented 3d model were imported to blue sky plan software (Blue sky plan V 4.7; Blue Sky Bio). Needle direction and insertion point into the midpoint of the muscle was planned using custom implant as the injection needle with a hole diameter of 1.5 mm, from 15-20 mm height and zero offset guide tube. Then, the guide was printed using manufactured resin (Esun standard resin; Esun). **Figure.3**

Botulinum toxin injection:

25 Units of BTX-A (Botox; Allergan) was prepared according to manufacture instruction. Then, the customized needle insertion guide was inserted inside the patient mouth while biting on the same bite block used during CT scan. Injection of BTX-A was injected using 22-gauge cannula needle prepared according to the planned length after negative aspiration. After that, mandible manipulation was started by opening and closing multiple times. **Figure.4**

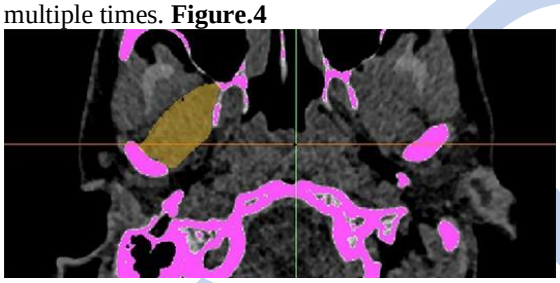

Figure.1: Axial cut of CT scan showing segmentation of lateral pterygoid muscle.

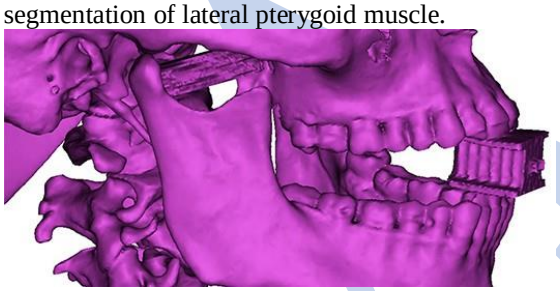

Figure.2: Showing 3D model of skull with lateral pterygoid muscle in its actual position.

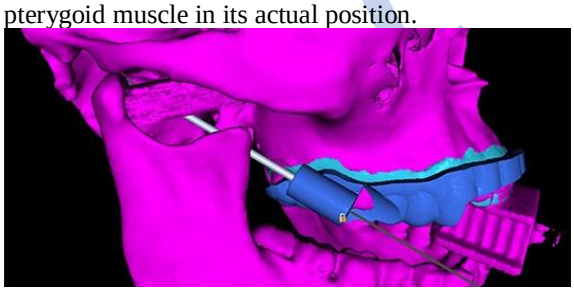

Figure.3: Showing customized needle insertion guide.

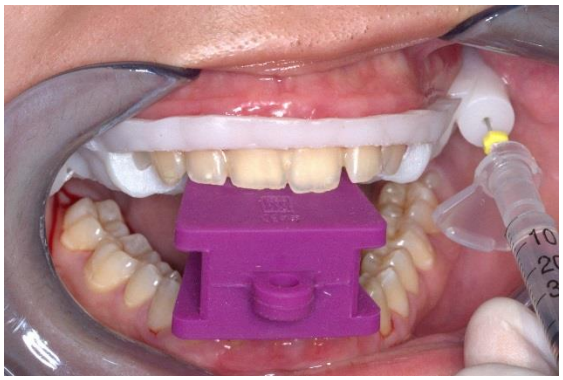

Figure.4: Showing needle insertion guide with patient biting on the same readymade bite block.

RESULTS:

Participants' baseline data:

Nine female patients and one male patient with mean age 27.30 ± 5.36 years were enrolled in this study based on the previous inclusion and exclusion criteria without any drop out.

Outcomes:

Maximum interincisal opening:

The mean MIO preoperatively was 35.60 ± 2.37. at 1-month follow-up. The mean MIO decreased insignificantly to be 31.30 ± 4.81 mm (p=0.163). Then at 3-and 6- month follow-up, it increased significantly to be 41.20 ± 3.74 mm and 41.40 ± 3.47 mm respectively. ($p < 0.001^{*}$)

Clicking:

100% of patients had TMJ clicking preoperatively. After 1 month, 100% of patients lost their clicking. At 3-month follow-up, only 10% of patients (n=1) regained clicking till the end of the study.

Measurement of articular disc position

A statistically significant increase in mean of TD/TP from 0.40 ± 0.00 to be 0.48 ± 0.04 ($P<0.001^{*}$) at 3-month post injection. **Figure.5A, B**

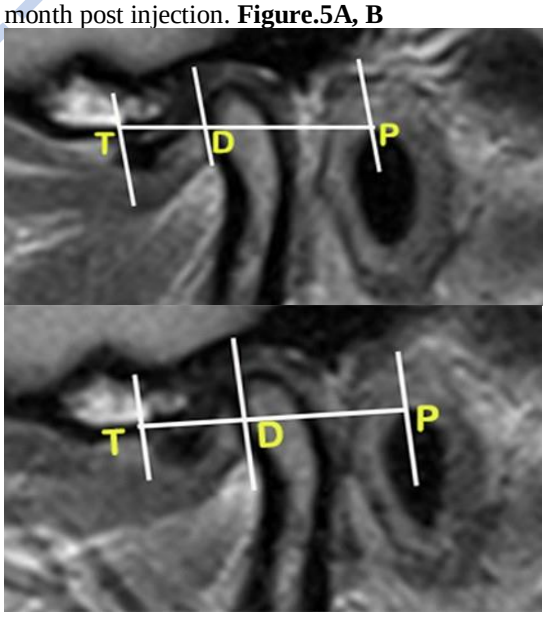

Figure.5: **A**, disc position in preoperative MRI. **B**, improvement in disc position in post operative MRI.

Temporomandibular joint tenderness

Temporomandibular joint tenderness decreased significantly from a median of 6.50(5.0 – 7.0) to a median of 0.0(0.0 – 0.0) at 1-,3-and 6- month follow-up.

Lateral pterygoid muscle tenderness

Lateral pterygoid muscle tenderness decreased significantly from a median of 10.0(10.0 – 10.0) to a median of 0.0 (0.0 – 0.0), 0.0(0.0 – 1.0) and0.0(0.0 – 2.0) respectively at 1-,3-and 6- month follow-up.

DISCUSSION

Botulinum toxin administration into LPM has been considered as an effective modality for the management of oromandibular dystonia, DDWR and TMJ dislocation (11,18, 27-29). Lateral pterygoid muscle injection remains challengeable due to the unintentional complications of the blind injection. Therefore, guided injection is necessary. Several guidance modalities for LPM injection have been introduced such as electromyography (EMG), ultrasonography and MRI guided navigation (17, 18, 30). Although EMG is the most commonly used, it does not prevent out target injection as it is a functional guidance that depends on operator skills for estimation of the muscle location(17, 18). For MRI guided navigation, it is still not widely used in clinical practice due to its special equipment and operator skills(17, 23). Ultrasonography is a real time image, however, the surrounding bony structures around the muscle hinder easily visualizing the muscle and make it different to reproduce the procedure(17,30,31).

In this study, fully guided BTX injection in LPM is introduced using muscle segmentation technique for LPM based on CT with soft tissue window which is considered an actual viewing and measuring method for the muscles (32). After that, a 3D virtual model is created that mimics skeletal and dental structures of the patient together with the segmented LPMs in it with its actual location and depth. Virtual planning to determine needle insertion, direction and depth performed on this virtual 3D model and a customized needle insertion guide is fabricated using CAD/CAM technology.

In the present study, although MIO decreased insignificantly after 1 month post injection, it increased significantly at 3-month follow-up and till the end of the study. These results come in accordance with Altaweel et al. using EMG and pons et al using MRI navigation, while are in disagreement with Emara et al. who detected not significant decrease in MIO till 4 months post injection(11,17,33).

For TMJ clicking, all the patients lost clicking at 1-month follow-up and only one patient regained clicking after 3 months post injection till the end of the study without any repeatable injection. These results are in agreement with Taema et al., Bakke et al. and Emara et al. who explained regaining of clicking in some patients by disappearing effect of BTX-A using EMG in guidance(8, 11, 28).

This fully guided technique for LPM using muscle segmentation technique showed significant improvement in disc position. This is in agreement with previous studies that confirmed the theory of LPM hyperactivity role in displacing the disc anteriorly to counteract retrodiscal tissues(11, 28).

Significant reduction in TMJ and LPM tenderness was detected at 1-,3-and 6-month follow-up. These results come in accordance with Altaweel et al who recorded TMJ and LPM reduction using EMG (33).

At 1-and 3-month follow-up, relief of symptoms can be explained by the effect of BTX on the muscle while the prolonged relief after 3-month can be explained by muscle deprogramming after BTX effect (33).

This newly introduced technique of the fully guided BTX injection in LPM using muscle segmentation technique has showed significant effect in MIO, TMJ clicking, disc position and TMJ and LPM tenderness. This technique differs from previous studies that introduced needle insertion guide based on estimation of the muscle location rather than true visualization of the muscles by getting rid of EMG that was essential for determining muscle location in these studies (18, 34).

CONCLUSION

The findings of this study suggest that muscle segmentation technique for LPM is a reproducible and effective guidance modality for accurately targeting LPM for BTX injection in the management of DDWR. By creating 3D environment that mimics patient's skeletal anatomy.

Declaration

Ethical approval: The study was approved by the Research Ethics Committee, Faculty of Dentistry, Alexandria University, Egypt (IRB No.001056 - IORG 0008839, ethics committee number:0837-01/2024).

Informed consent: Written informed consent was obtained from all patients.

Conflict of Interest: The authors declare that they have no conflict of interest.

REFERENCES

1. De Leeuw R, Klasser GD. Orofacial pain: guidelines for assessment, diagnosis, and management. Am J Orthod Dentofacial Orthop. 2008;134:171.
2. Rongo R, Ekberg E, Nilsson IM, Al-Khotani A, Alstergren P, Conti PCR, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for children and adolescents: An international Delphi study-Part 1-Development of Axis I. J Oral Rehabil.2021;48:836-45.
3. Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP, et al. Diagnostic Criteria

for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: recommendations of the International RDC/TMD Consortium Network* and Orofacial Pain Special Interest Group†. J Oral Facial Pain Headache.2014;28:6-27.
4.List T, Wahlund K, Larsson B. Psychosocial functioning and dental factors in adolescents with temporomandibular disorders: a case-control study. J Orofac Pain.2001;15:218-27.
5-Suvinen TI, Reade PC, Kemppainen P, Könönen M, Dworkin SF. Review of aetiological concepts of temporomandibular pain disorders: towards a biopsychosocial model for integration of physical disorder factors with psychological and psychosocial illness impact factors. Eur J Pain.2005;9:613-33.
6.Elfving L, Helkimo M, Magnusson T. Prevalence of different temporomandibular joint sounds, with emphasis on disc-displacement, in patients with temporomandibular disorders and controls. Swed Dent J. 2002;26:9-19.
7-Ingawalé S, Goswami T. Temporomandibular joint: disorders, treatments, and biomechanics. Ann Biomed Eng. 2009;37:976-96.
8.Bakke M, Møller E, Werdelin LM, Dalager T, Kitai N, Kreiborg S. Treatment of severe temporomandibular joint clicking with botulinum toxin in the lateral pterygoid muscle in two cases of anterior disc displacement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;100:693-700.
9.Ghoneim NI, Mansour NA, Elmaghraby SA, Abdelsameaa SE. Treatment of temporomandibular joint disc displacement using arthrocentesis combined with injectable platelet rich fibrin versus arthrocentesis alone. J Dent Sci. 2022;17:468-75.
10.Castaño-Joaqui OG, Cano-Sánchez J, Campo-Trapero J, Muñoz-Guerra MF. TMJ arthroscopy with hyaluronic acid: A 12-month randomized clinical trial. Oral Dis.2021;27:301-11.
11.Emara AS, Faramawey MI, Hassaan MA, Hakam MM. Botulinum toxin injection for management of temporomandibular joint clicking. Int J Oral Maxillofac Surg. 2013;42:759-64.
12. Aoki KR, Guyer B. Botulinum toxin type A and other botulinum toxin serotypes: a comparative review of biochemical and pharmacological actions. Eur J Neurol. 2001;8:21–9.
13. Shabaan AA, Kassem I, Aboulmagd I, Amer IA, Shaaban A, Abd-El-Ghafour M, et al. Effectiveness of intra-oral botulinum toxin injection in comparison to the extra-oral approach on pain and quality of life in patients with myofascial pain: a randomized clinical trial. Clin Oral Investig. 2024;29:18.http://dx.doi.org/10.1007/s00784-024-06051-0
14. Kim Y-M, Son J-Y, Ahn D-K. Botulinum toxin type A is a potential therapeutic drug for chronic orofacial pain. J Oral Biosci. 2024;66:496–503.
15- Rahmatipour H, Shabestari SM, Benisi SZ, Samadikhah H. Pioneering Pain Management with Botulinum Toxin Type A: From Anti-Inflammation to Regenerative Therapies. Heliyon. 2025.
16- Stöckle M, Fanghänel J, Knüttel H, Alamanos C, Behr M. The morphological variations of the lateral pterygoid muscle: A systematic review. Ann Anat. 2019;222:79–87.
17- Pons M, Meyer C, Euvrard E, Weber E, Sigaux N, Louvrier A. MR-guided navigation for botulinum toxin injection in the lateral pterygoid muscle. First results in the treatment of temporomandibular joint disorders. J Stomatol Oral Maxillofac Surg. 2019;120:188–95.http://dx.doi.org/10.1016/j.jormas.2018.11.002
18- Yoshida K. Computer-aided design/computer-assisted manufacture-derived needle guide for injection of botulinum toxin into the lateral pterygoid muscle in patients with oromandibular dystonia. J Oral Facial Pain Headache. 2018;32:e13–21.
19. Kwon H-B, Park Y-S, Han J-S. Augmented reality in dentistry: a current perspective. Acta Odontol Scand. 2018;76:497–503.
20. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. BMC Oral Health. 2019;19:238. http://dx.doi.org/10.1186/s12903-019-0937-8
21.World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. J Am Coll Dent. 2014;81:14-8.
22.Montes-Carmona JF, Gonzalez-Perez LM, Infante-Cossio P. Treatment of Localized and Referred Masticatory Myofascial Pain with Botulinum Toxin Injection. Toxins. 2020;13.
23.Martenot A, Devoti JF, Pons M, Meyer C, Brumpt E, Louvrier A, et al. Persistent myogenic temporomandibular disorders: Are navigation-guided botulinum toxin-A injections into the lateral pterygoid muscles effective? J Stomatol Oral Maxillofac Surg 2024;125:101715.
24. Sample Inference. In: Fundamentals of biostatistics. 7th ed. Boston:Brooks/Cole. Nelson Education. 2015;269-301
25.Universität Düsseldorf. G*Power.2019. http://www.gpower.hhu.de/
26. Kurita H, Kurashina K, Ohtsuka A, Kotani A. Change of position of the temporomandibular joint disk with insertion of a disk-repositioning appliance. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998;85:142–5.

27.Rady NA, Bahgat MM, Abdel-Hamid AM. Promising minimally invasive treatment modalities for symptomatic temporomandibular joint disc displacement with reduction: a randomized controlled clinical trial. BMC oral health. 2022;22:547.
28.Taema M, Nabi NA, Ibrahim S, Kamal HA, Emara A. Assessment of anterior positioning splint in conjunction with lateral pterygoid BTX injection to treat TMJ disc displacement with reduction - a preliminary report. Maxillofac Plast Reconstr Surg.2021;43:33.
29.Martínez-Pérez D, García Ruiz-Espiga P. Recurrent temporomandibular joint dislocation treated with botulinum toxin: report of 3 cases. J Oral Maxillofac Surg. 2004;62:244-6.
30.Lee ST, Kim D, Park JH, Kwon TG. Ultrasound-guided intraoral botulinum toxin injection into the lateral pterygoid muscle for chronic temporomandibular joint dislocation. J Korean Assoc Oral Maxillofac Surg. 2024;50:41-8.
31. Rodríguez-Gimillo P, Valverde-Navarro A, Margaix-Muñoz M, Poveda-Roda R, Delgado-Navarro C, Puig-Bernabeu J. Lateral pterygoid muscle ultrasound-guided injection: A technical note. J Stomatol Oral Maxillofac Surg.2024;125:101547.
32-Yao N, Li X, Wang L, Cheng X, Yu A, Li C, et al. Deep learning for automatic segmentation of paraspinal muscle on computed tomography. Acta Radiol. 2023;64:596–604.
33-Altaweel AA, Elsayed SA, Baiomy A, Abdelsadek SE, Hyder AA. Extraoral Versus Intraoral Botulinum Toxin Type A Injection for Management of Temporomandibular Joint Disc Displacement With Reduction. J Craniofac Surg.2019;30:2149-53.
34. Casatuto T, Gosselin M, Lerhe B, Vandersteen C, Ehrmann E, Savoldelli C. In-house tooth-supported guide for the injection of botulinum toxin into the lateral pterygoid muscle using Blue Sky Plan software: A technical note. J Stomatol Oral Maxillofac Surg. 2021;122:e77-e80