Review Article

Masticatory Muscle Responses to Orthodontic Bite-raising Appliances

Passakorn Wasinwasukul[1], **Udom Thongudomporn**[1]

[1]Department of preventive dentistry, Prince of Songkla University, Songkhla, Thailand

Abstract

A variety of bite-raising appliances are involved in contemporary orthodontic treatment depending on an individual's malocclusion and the objectives of treatment. The appliances can affect the dentoskeletal and neuromuscular system over the short and long terms. Most of the bite-raising appliances do not change the immediate muscle response at rest, but temporarily decreases the activity during maximum clenching. The activity returns to the previous state after a period of treatment in long-term observation.

The purpose of this article is to compare similarities and contrast differences between various types of orthodontic bite-raising appliances, both in the short and long term. Factors affecting the masticatory muscle responses included vertical dimension, number of occlusal contacts, jaw relocation, material, and wearing duration. Moreover, suggestions for further studies are also discussed.

Keywords: Bite-raising appliance, Masticatory muscles, Muscle activity

Received Date: Jan 24, 2022 **Revised Date:** Feb 21, 2022 **Accepted Date:** Apr 18, 2022
doi: 10.14456/jdat.2022.43

Correspondence to:
Passakorn Wasinwasukul, Orthodontic section, Department of preventive dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla, Thailand, 90110 Telephone: +66804410048 E-mail: passakorn.ws@gmail.com

Introduction

During dental treatment it is often necessary to raise the patient's bite for therapeutic purposes or for assisting the main treatment purpose. Bite-raising can be temporary such as during use of bite raising appliances in orthodontic treatment, or permanent when patients who need full mouth rehabilitation require an increase in the vertical dimension. Some studies have suggested that bite-raising inevitably affects the craniofacial neuromuscular system including masticatory muscles[1] and temporomandibular joints (TMJ).[2,3]

Orthodontically, bite-raising has been applied to several situations. Examples include the use of anterior bite-raising appliances to alleviate a deep bite, the application of posterior bite-raising appliances to assist the correction of a crossbite or to intrude posterior teeth, the use of splint-like bite-raising appliances to re-program masticatory muscles in cases with jaw deviation due to prolonged dental interference, and the use of functional appliances to accelerate the forward growth of the mandible in combination with an increase in the skeletal vertical dimension. Since knowledge about the responses of the craniofacial neuromuscular system to bite-raising in orthodontic treatment is scattered around the world, this article aims to collect and review the evidence of previous studies concerning these masticatory muscle responses to several methods of orthodontic bite-raising. Suggestions for further studies are discussed.

Immediate responses

Normally, at the physiologic rest position, the masticatory muscles are in a state of minimal contraction[4]. When a bite-raising appliance is inserted, there is an insignificant change of muscle activity at rest throughout the treatment.[1,5] However, masticatory muscle activity is significantly reduced when functioning with a bite-raising appliance. This is because the forced jaw-opening reduces signal sending from perioral-mechanoreceptors to the central nervous system and activation area in the brain, called neuroplasticity.[6] The reduction of proprioceptive signaling down-regulates the activity of the masseter and temporalis muscles. Hence, muscle activity decreases during maximum clenching. The objective and subjective masticatory functions and efficiency also decrease when forced bite-opening is applied.[7,8] It can be concluded that the limited forced bite-opening of 2-4 mm within the freeway space does not change the muscle activity at rest but decreases the activity of the masseter and temporalis muscles when there is maximal clenching.

Adaptive responses

After bite-opening, the stomatognathic system accommodates the new oral environment and reestablishes the normal function.[9] A study in rats found that the responsiveness of the masseter muscle spindle afferent to the mesencephalic trigeminal nucleus decreased during two to four weeks of continuous bite-raising appliance wearing and returned to normal after six weeks of appliance wearing.[10] In another study, similarly to neuroplasticity, the muscle activity temporally decreased, but reverted to the previous condition after two years of follow-up.[11] Unlike bite-raising for prosthodontics or treatment for temporomandibular disorders (TMDs), bite-raising during orthodontic treatment is usually temporary, ranging from a few weeks to a few months. Studies found that the muscle activity was insignificantly different from the start of treatment to after six months with a removable bite plane[12] or eight months with a fixed appliance.[1] This suggests that orthodontic bite-raising appliances also cause immediate and adaptive responses similar to other appliances that raise the bite.

Reduction of muscle size correlates with muscle activity[13]. Human studies found a reduction of muscle thickness after a long-term forced bite opening.[14,15] If that is the case, long-term wearing of interocclusal appliances to treat myogenous TMDs and bruxism may be a permanent cure. However, a study reported an insignificant difference in muscle thickness and activity in TMD patients compared to a control group.[16] A decrease in muscle thickness and activity was also found in patients with bruxism after treatment with interocclusal appliances.[17] More evidence may be needed to support these findings.

Individual anatomical and physiological responses, intensity, and duration of the stimulus affect the adaptation.[18] Sometimes adaptive responses do not occur, leading to physio-pathological conditions of the stomatognathic system. In the short term, muscle tenderness, mastication or phonetic problems occur, but these problems often disappear quickly and therefore go unreported.[12,19]

Factors affecting masticatory muscle responses

Orthodontic bite-raising appliances, basically, modify the oral environment then distress the masticatory muscle responses. The vertical dimensional change, the number of occlusal contacts, the materials of the appliance, relocation of the mandible, and wearing duration are all together confounding factors that affect the outcomes as shown in Figure 1.

The amount of vertical dimensional change

The amount of jaw opening relates with the muscle stretching and its activity. A previous experiment showed a progressive decrease of the anterior temporalis and masseter muscle activity whilst there was an increase of intermolar distance.[20] It can be explained by the stretching of the masticatory muscles, which was observed in previous animal studies.[10,21] The activity reaches the minimum anterior interocclusal distance at 15-20 mm where the highest cross-bridge between thick and thin sarcomere myofilaments was established, then excitation can occur easily.[22,23] Overstretching of a muscle beyond its optimum length could reduce the tension of the muscle according to the stretch reflex of the muscle.[22] A previous experiment showed increasing muscle activity after opening to the maximum mouth opening.[22]

Number of occlusal contacts

Bite raising appliances for orthodontic purposes, on either the anterior or posterior bite plane, allow only a few teeth to occlude on the appliance. Therefore, the effect on the cranio-neuromuscular system may be somewhat different from the use of a full coverage splint. Higher muscle activity of masseter and anterior temporalis muscles was observed in patients wearing a splint than those with an anterior bite plane[5], but there was no significant change in both rest positions and maximum clenching after six months of treatment with an hard occlusal splint compared to those without the appliance.[12] The greater muscle activity was expected by the higher number of occlusal contacts on the occlusal splint compared to those with an anterior bite plane, which only occluded at the anterior teeth. A higher diversity of mechanoreceptors might be expected in the full coverage occlusal splint administration.

It might be concluded that appliances which open the jaw but reduce the number of occlusal contacts, such as for anterior bite-raising, posterior bite-raising and some type of functional appliances, affect the muscle responses in the same way. It temporarily decreases the masticatory muscle activity during maximum clenching. In contrast, the muscle activity is not different nor does it increase after treatment with occlusal splints. The significant point is that it is due to the number of tooth contact areas and mechanoreceptors, which are found to have higher responsiveness in the stomatognathic system. Once the number of occluded teeth are decreased due to the intentionally applied appliances, it causes unstable occlusion[24] and reduces the sensory input of receptors in masticatory muscles and results in the immediate change of neuromuscular responses.[14] Thus, the masticatory performance was reduced because of the direct relationship between muscle activity and its performance.[25] However, after a certain amount of time given, the muscles then regain their activity at the new position as a result of treatment. Remarkably, a number of earlier long-term studies found no statistically significant difference between pre and post treatment.[11,26]

The effect of the number of occlusal contacts on muscle response is likely to be more than the vertical dimension. In some situations, bite-raising appliances both increases the vertical dimension but still performs a great number of occlusal contacts such as occlusal splints showing no significant difference between having or not having an appliance or among those with three and six millimeters of interocclusal distance.[27] However, another study presented a gradual decrease in masseter muscle activity as the vertical interocclusal distances increased.[28] This effect may be advantageous to treat TMDs. An interocclusal appliance has been shown to relieve almost all symptoms in patients with joint sound and muscle soreness within two weeks of treatment.[3]

Appliance's materials

The types of materials used for bite-raising may affect the responses. The muscle activity decreased more with the use of hard occlusal appliances whereas soft occlusal splints produce a slight increase in masseter and temporalis muscle activity at maximal intercuspation.[29,30] The combination of those hard and soft materials, also known as dual laminated or bilaminar materials, present inner soft and outer hard material and are available in a range of different thickness. It has been proposed as an alternative occlusal splint for sleep bruxism cases.[31] In this situation, data about the effect on muscle activity by a dual laminate occlusal splint is inadequate. However, another case report also showed an increase of muscle activity after treatment.[32] Regarding a study with healthy participants via a hard material of occlusal splint, muscle activity reduction has been found and a larger number of feedback signaling outputs from periodontal ligament, muscle, and TMJ might be expected with maximum clenching.[30] Therefore, the protective mechanisms of perioral proprioceptive receptors are initiated to help people beware of tooth fracture when biting on a rigid substance.[30,33] Soft materials, on the other hand, distribute a masticatory effort and are presumably more comfortable to bite on.[30] Hence, the muscle activity might increase with soft materials.

Relocation of the mandible

Another type of appliance that combines a forward jaw positioning with an increase in the bite is a functional appliance. A study of an activator showed the combination effects of vertical and sagittal mandibular changes. It revealed no immediate change in muscle activity at rest, but significantly decreased during maximum biting, especially in the temporalis muscle more than the masseter muscle.[34] Long term studies presented decreasing temporalis and masseter muscle activity during maximum clenching[11], but they gradually returned to their previous status and found no significant difference for masticatory muscle activity with a good neuromuscular equilibrium after one or two years of treatment with functional appliances in children.[35,36] It was suggested that the balance during masticatory muscle contraction is more favorable for long stable results in both orthopedic-functional treatment and orthodontic treatment.[37,38]

The jaw position might be another interesting factor. A prior study showed greater temporalis and masseter muscle activity at the rest position in skeletal Class III patients than for those in Class I and Class II. During clenching, the skeletal Class II and Class III groups presented lower activity compared to Class I.[39] To support this, the musculoskeletal axis and its actual direction may influence and affect the performance of these elevator muscles. Significant change in muscle activity was found due to jaw reposition such as orthognathic surgery[40,41] and growth redirection with functional appliances.[14,34,36,42] Regarding the non-conclusive relationship between sagittal malocclusion and muscle activity, it is possible that the changes in muscle activity happened due to new circumoral environmental changes and required time for adaptation.

An additional effect of the soft material on top of the jaw relocation could be seen in a study of a functional appliance made from polyurethane for children. It presented decreasing anterior temporalis and masseter muscle activity during clenching after eight months.[43] Although it was not an exact immediate response, the results from this study claims that there were combined effects with the relocation of the mandible, normal developmental growth, vertical bite-raising components, and materials stiffness.

Wearing duration

Recently, the use of fixed bite-raising has become popular. Unlike intermittent wearing of removable bite planes, fixed bite-raising provides a continuous bite opening, which may pose different responses to the neuromuscular system. An electromyographic study showed no difference in muscle activity at rest, but significant immediate reduction in the activity of the masseter and anterior temporalis muscles while clenching and mastication after placing of the light-cured orthodontic band cement on the palatal cusp of both maxillary molars in 30 adults with normal occlusion.[44] It was mentioned a physiologic protective mechanism, which was the result of mandible instability due to the occlusal change. The elevator muscles contribute to maintain the occlusion by reducing its activity to avoid damage to circumoral structures.[24] Moreover, the masticatory function is also affected by the bite-raising appliance: for example, the immediate reduction of both objective and subjective masticatory functions after bite-raising with orthodontic band cement[7] have been investigated and reported. After a week of treatment with clear acrylic resin fixed on posterior teeth, no difference in muscle activity in healthy participants was found.[19] It may imply that there was an adaptation of the muscle's response. An ultrasonographic study was performed after treatment with a removable posterior bite plane where no difference in muscle thickness was found, and where there was the same function between treatment time and the control group.[45,46] However, the effects of bite-raising appliance over an extended period and the difference between wearing duration are inconclusive.

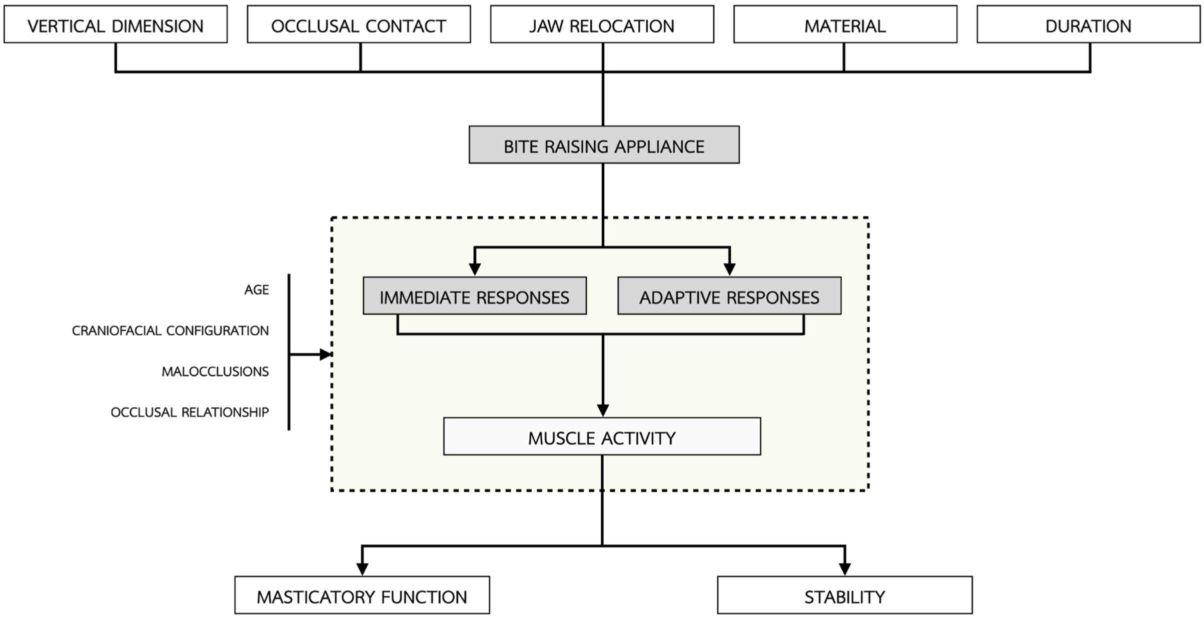

Figure 1 *Factors related to masticatory muscle responses on bite-raising appliances*

Conclusions

Due to various publications and inconclusive data about the effects of orthodontic bite-raising appliances on masticatory muscle response, it can be inferred that most of the bite-raising appliances do not change the muscle activity at rest but temporarily decrease it during clenching. In addition, adaptation occurred over long-term treatment.

The vertical dimension, number of occlusal contacts, relocation of the mandible, and material types are together confounding factors which affect the outcomes. In addition, age[47], craniofacial configuration[48,49], malocclusion, and occlusal relationships[50] might also influence the response as well. These factors may co-operate and should be controlled in further studies if the main effects of these appliances are to be investigated. However, further well designed randomized controlled trial studies should be considered with factors such as the difference between anterior and posterior disocclusion, the effects of material hardness in each appliance design, and wearing duration, including the differences between fixed and removable appliances.

Disclosure statement: The authors declare that they have no conflict of interests.

Ethics approval and consent to participate: Ethical approval was not required.

References

1. Akarsu-Guven B, Dds A, Dds S. Evaluation of the Effects of Fixed Anterior Biteplane Treatment on the Dental and Skeletal Structures and Masticatory Muscles in Patients with Deep Bite. ***Hacettepe Diş Hekimliği Fakültesi Dergisi*** 2010;34:10–22.

2. Cardelli P, Massaro P, Lattari M, Fiorito R, Ottria L, Barlattani A. The bite plane in temporomandibular joint disorders therapy. ***Gazz Med Ital*** 2004;163:227–31.

3. Al-Saad M, Akeel RF. EMG and pain severity evaluation in patients with TMD using two different occlusal devices. ***Int J Prosthodont*** 2001;14(1):15–21.

4. The Glossary of Prosthodontic Terms. ***J Prosthet Dent*** 2017; 117(5):C1-e105.

5. Dahlström L, Haraldson T. Immediate electromyographic response in masseter and temporal muscles to bite plates and stabilization splints. ***Eur J Oral Sci*** 1989;97(6):533–8.

6. Lai A, Korgaonkar M, Gomes L, Whittle T, Foster S, Williams L, *et al.* fMRI Study on Human Subjects with Sudden Occlusal Vertical Dimension Increase. ***Jacobs j dent res*** 2015;2:20.

7. Changsiripun C, Pativetpinyo D. Masticatory function after bite-raising with light-cured orthodontic band cement in healthy adults. ***Angle Orthod*** 2020;90(2):263–8.

8. Satokawa Y, Minami I, Wakabayashi N. Short-term changes in chewing efficiency and subjective evaluation in normal dentate subjects after insertion of oral appliances with an occlusal flat table. ***J Oral Rehabil*** 2018;45(2):116–25.

9. Grünheid T, Langenbach GEJ, Korfage JAM, Zentner A, van Eijden TMGJ. The adaptive response of jaw muscles to varying functional demands. ***Eur J Orthod*** 2009;31(6):596–612.

10. Yabushita T, Zeredo JL, Fujita K, Toda K, Soma K. Functional adaptability of jaw-muscle spindles after bite-raising. ***J Dent Res*** 2006;85(9):849–53.
11. Sood S, Kharbanda OP, Duggal R, Sood M, Gulati S. Neuromuscular adaptations with flexible fixed functional appliance--a 2-year follow-up study. ***J Orofac Orthop*** 2011;72(6):434–45.
12. Dahlström L, Haraldson T. Bite plates and stabilization splints in mandibular dysfunction: A clinical and electromyographic comparison. ***Acta Odontol Scand*** 1985;43(2):109–14.
13. Georgiakaki I, Tortopidis D, Garefis P, Kiliaridis S. Ultrasonographic thickness and electromyographic activity of masseter muscle of human females. ***J Oral Rehabil*** 2007;34(2):121–8.
14. Antonarakis GS, Kiliaridis S. Predictive value of masseter muscle thickness and bite force on Class II functional appliance treatment: a prospective controlled study. ***Eur J Orthod*** 2015;37(6):570–7.
15. Kiliaridis S, Mills C, Antonarakis G. Masseter muscle thickness as a predictive variable in treatment outcome of the twin-block appliance and masseteric thickness changes during treatment: Masseter muscle thickness and twin-block treatment. ***Orthod Craniofac Res*** 2010;13(4):203–13.
16. Strini PJSA, Strini PJSA, Barbosa T de S, Gavião MBD. Assessment of thickness and function of masticatory and cervical muscles in adults with and without temporomandibular disorders. ***Arch Oral Biol*** 2013;58(9):1100–8.
17. Akat B, Görür SA, Bayrak A, Eren H, Eres N, Erkcan Y, *et al.* Ultrasonographic and electromyographic evaluation of three types of occlusal splints on masticatory muscle activity, thickness, and length in patients with bruxism. ***CRANIO®*** 2020;1–10.
18. Grünheid T, Langenbach GEJ, Korfage JAM, Zentner A, van Eijden TMGJ. The adaptive response of jaw muscles to varying functional demands. ***Eur J Orthod*** 2009;31(6):596–612.
19. Carlsson GE, Ingervall B, Kocak G. Effect of increasing vertical dimension on the masticatory system in subjects with natural teeth. ***J Prosthet Dent*** 1979;41(3):284–9.
20. Koc D, Dogan A, Bek B, Yucel M. Effects of increasing the jaw opening on the maximum bite force and electromyographic activities of jaw muscles. ***J Oral Sci*** 2012;7(1):14–9.
21. Yabushita T, Zeredo JL, Toda K, Soma K. Role of Occlusal Vertical Dimension in Spindle Function. ***J Dent Res*** 2005;84(3):245–9.
22. Manns A, Miralles R, Palazzi C. EMG, bite force, and elongation of the masseter muscle under isometric voluntary contractions and variations of vertical dimension. ***J Prosthet Dent*** 1979;42(6):674–82.
23. Nordstrom SH, Bishop M, Yemm R. The effect of jaw opening on the sarcomere length of the masseter and temporal muscles of the rat. ***Arch Oral Biol*** 1974;19(2):151–5.
24. Jiménez ID. Dental stability and maximal masticatory muscle activity. ***J Oral Rehabil*** 1987;14(6):591–8.
25. Felício CM de, Couto GA do, Ferreira CLP, Mestriner Junior W. Reliability of masticatory efficiency with beads and correlation with the muscle activity. ***Pró-Fono R Atual Cient*** 2008;20(4):225–30.
26. Cuevas MJ, Cacho A, Alarcón JA, Martín C. Longitudinal evaluation of jaw muscle activity and mandibular kinematics in young patients with Class II malocclusion treated with the Teuscher activator. ***Med Oral Patol Oral Cir Bucal*** 2013;18(3):e497-504.
27. Pita MS, Ribeiro AB, Garcia AR, Pedrazzi V, Zuim PRJ. Effect of occlusal splint thickness on electrical masticatory muscle activity during rest and clenching. ***Braz oral res*** 2011;25(6):506–11.
28. Suvinen T, Reade P, Könönen M, Kemppainen P. Vertical jaw separation and masseter muscle electromyographic activity: a comparative study between asymptomatic controls & patients with temporomandibular pain & dysfunction. ***J Oral Rehabil*** 2003;30(8):765-72.
29. Okeson JP. The effects of hard and soft occlusal splints on nocturnal bruxism. ***J Am Dent Assoc*** 1987;114(6):788–91.
30. Al Quran FAM, Lyons MF. The immediate effect of hard and soft splints on the EMG activity of the masseter and temporalis muscles. ***J Oral Rehabil*** 1999;26(7):559–63.
31. Longridge NN, Milosevic A. The bilaminar (Dual-Laminate) protective night guard. ***Dental Update*** 2017;44(7):648–54.
32. Karakis D, Demirdag ED. Adjustment of Occlusal Splint with Synchronized T-Scan III Digital Occlusal Analysis System and Bio-EMG III in a Patient with Sleep Bruxism. ***J Adv Oral Res*** 2021;12(1):170–5.
33. Paphangkorakit J, Osborn JW. Effects on human maximum bite force of biting on a softer or harder object. ***Arch Oral Biol*** 1998; 43(11):833–9.
34. Tabe H, Ueda HM, Kato M, Nagaoka K, Nakashima Y, Matsumoto E, *et al.* Influence of functional appliances on masticatory muscle activity. ***Angle Orthod*** 2005;75(4):616–24.
35. Di Palma E, Tepedino M, Chimenti C, Tartaglia GM, Sforza C. Effects of the functional orthopaedic therapy on masticatory muscles activity. ***J Clin Exp Dent*** 2017;9(7):e886–91.
36. Castroflorio T, Talpone F, Deregibus A, Piancino MG, Bracco P. Effects of a functional appliance on masticatory muscles of young adults suffering from muscle-related temporomandibular disorders. ***J Oral Rehabil*** 2004;31(6):524–9.
37. Ferrario VF, Marciandi PV, Tartaglia GM, Dellavia C, Sforza C. Neuromuscular evaluation of post-orthodontic stability: an experimental protocol. ***Int J Adult Orthodon Orthognath Surg*** 2002;17(4):307–13.
38. Ferrario VF, Sforza C, Miani A, D'Addona A, Barbini E. Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. ***J Oral Rehabil*** 1993;20(3):271–80.
39. Miralles R, Hevia R, Contreras L, Carvajal R, Bull R, Manns A.

Patterns of electromyographic activity in subjects with different skeletal facial types. ***Angle Orthod*** 1991;61(4):277–84.
40. Celakil D, Ozdemir F, Eraydin F, Celakil T. Effect of orthognathic surgery on masticatory performance and muscle activity in skeletal Class III patients. ***CRANIO®*** 2018;36(3):174–80.
41. Kim KA, Park HS, Lee SY, Kim SJ, Baek SH, Ahn HW. Short-term changes in muscle activity and jaw movement patterns after orthognathic surgery in skeletal Class III patients with facial asymmetry. ***Korean J Orthod*** 2019;49(4):254–64.
42. Sessle BJ, Woodside DG, Bourque P, Gurza S, Powell G, Voudouris J, *et al.* Effect of functional appliances on jaw muscle activity. ***Am J Orthod Dentofacial Orthop*** 1990;98(3):222–30.
43. Uysal T, Yagci A, Kara S, Okkesim S. Influence of Pre-Orthodontic Trainer treatment on the perioral and masticatory muscles in patients with Class II division 1 malocclusion. ***Eur J Orthod*** 2012;34(1):96–101.
44. Pativetpinyo D, Supronsinchai W, Changsiripun C. Immediate effects of temporary bite-raising with light-cured orthodontic band cement on the electromyographic response of masticatory muscles. ***J Appl Oral Sci*** 2018;26:e20170214.
45. Lione R, Kiliaridis S, Noviello A, Franchi L, Antonarakis GS, Cozza P. Evaluation of masseter muscles in relation to treatment with removable bite-blocks in dolichofacial growing subjects: A prospective controlled study. ***Am J Orthod Dentofacial Orthop*** 2017;151(6):1058–64.
46. Castelo PM, Gavião MBD, Pereira LJ, Bonjardim LR. Evaluation of changes in muscle thickness, bite force and facial asymmetry during early treatment of functional posterior crossbite. ***J Clin Pediatr Dent*** 2010;34(4):369–74.
47. Cecílio FA, Regalo SCH, Palinkas M, Issa JPM, Siéssere S, Hallak JEC, *et al.* Ageing and surface EMG activity patterns of masticatory muscles. ***J Oral Rehabil*** 2010;37(4):248–55.
48. Gomes SGF, Custodio W, Faot F, Del Bel Cury AA, Garcia RCMR. Masticatory features, EMG activity and muscle effort of subjects with different facial patterns: EFFECT OF FACIAL TYPE ON MASTICATORY PARAMETERS. ***J Oral Rehabil*** 2010;37(11):813–9.
49. Ingervall B, Thilander B. Relation between facial morphology and activity of the masticatory muscles. ***J Oral Rehabil*** 1974;1(2):131–47.
50. Wieczorek A, Loster JE. Activity of the masticatory muscles and occlusal contacts in young adults with and without orthodontic treatment. ***BMC Oral Health*** 2015;15(1):116.