MASTICATORY MUSCLE FUNCTIONS FOLLOWING ANTERIOR BITE PLANE THERAPY IN GROWING PATIENTS WITH SKELETAL CLASS II MALOCCLUSION

Jedtapon SALEECHAN[1], Jittima PUMKLIN[1], Peraya PUAPICHARTDUMRONG[1], Saengdao SIRIJAROENPUN[1], Aphiwat SEDTASUPPANA[1] and Thosapol PIYAPATTAMIN[1]

1 Faculty of Dentistry, Naresuan University, Thailand; jedtapons66@nu.ac.th (J. S.); jittimap@nu.ac.th (J. P.); perayap@nu.ac.th (P. P.); saengdaos@nu.ac.th (S. S); aphiwats@nu.ac.th (A. S.); thosapolp@nu.ac.th (T. P.)

ABSTRACT

This study evaluated changes in several masticatory muscle activities following anterior bite plane (ABP) therapy in growing patients with skeletal Class II malocclusion using surface electromyography. Surface electromyographic recordings were performed to assess temporalis anterior (TA) and masseter muscle (MM) activity during rest, maximum voluntary clenching (MVC), and chewing before and after ABP therapy. Parameters included muscle activity, bilateral symmetry, muscle synergy coordination, and relative muscle effort. Results showed overbite reduction after treatment. Non-significant changes ($p > 0.05$) in resting muscle activity and MVC were observed in both muscles ($p > 0.05$). Slight increases in TA and MM activity during chewing were detected, despite their non-significances ($p > 0.05$). Muscle symmetry during MVC and chewing remained stable following treatment, with non-significant changes in TA and MM synergy. Muscle synergy and occlusal units remained stable throughout the treatment period and among all patients following treatment, respectively. These findings indicated that ABP therapy effectively reduces deep bite while maintaining normal neuromuscular function and coordination in growing patients with skeletal Class II malocclusion.

Keywords: Anterior Bite Plane, Electromyography, Skeletal Class II, Masticatory Muscle

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INTRODUCTION

Skeletal Class II malocclusion represents a common dentofacial disharmony. It is characterized by a posterior relationship of the mandible relative to the maxilla, dental deep bite, and an increased overjet (McNamara, 1981). Early interceptive treatment during growth period is crucial for achieving optimal skeletal and dental corrections. Neuromuscular balances are maintainable and more complex treatment in adulthood avoidable (Franchi et al., 2013).

Removable orthodontic appliances (ROA) with anterior bite plane (ABP) have been used in the interceptive approach for managing patients with skeletal Class II and dental deep bite (Baccetti et al., 2012). The appliance incorporates an acrylic platform positioned palatal to the maxillary incisors, designed to create temporary posterior disclusion while facilitating vertical eruption and potential mandibular (Md) repositioning (Isaacson et al., 2002; Moore et al., 1989). Its therapeutic mechanism involves neuromuscular adaptation to altered occlusal relationships, which may influence recruitment patterns of masticatory muscles and long-term functional outcomes.

Surface electromyography (SEMG) has become a valuable non-invasive tool for objectively assessing masticatory muscle activity, together with providing quantitative data on muscle coordination, symmetry, and functional patterns (Castroflorio et al., 2008). Occlusal stability directly correlates with muscle performance, as subjects with higher occlusal stability exhibit better muscular responses during mastication (Bakke, 1993; Pumklin et al., 2023). This relationship suggests that occlusal alterations result in measurable changes in SEMG patterns (Pumklin et al., 2023), rendering SEMG a valuable tool for evaluating treatment outcomes beyond traditional morphological assessments (Sumonsiri & Thongudomporn, 2017).

Unlike the widespread clinical use of ABP therapy, some limited research has investigated its effects on masticatory muscle function using objective assessment methods. This study was, therefore, designed as a preliminary investigation to provide some initial SEMG observations among growing Class II patients receiving an ABP therapy, while acknowledging the constraints related to its limited participant number and absence of comparative controls. Understanding these neuromuscular adaptations is crucial for optimizing treatment protocols and predicting long-term functional outcomes. Hence, this study aimed to evaluate the feasibility of SEMG for assessing neuromuscular adaptations and to explore preliminary patterns in masticatory muscle activity, symmetry, and coordination following ABP therapy in growing patients with skeletal Class II malocclusion using comprehensive SEMG analyses.

LITERATURE REVIEWS

Early Treatment for Skeletal Class II Patients

Early treatment for patients with skeletal Class II during their growth periods offers significant advantages for achieving optimal treatment outcomes. Functional appliances have been widely used to correct Class II discrepancies by modifying growth patterns and dental relationships (Franchi et al., 2013). The timing of treatment is crucial, with pre-pubertal and pubertal growth periods being most favorable for skeletal modifications (Perinetti et al., 2015). Systematic reviews have demonstrated that removable functional appliances can produce both skeletal and dentoalveolar changes, though the extent of skeletal modification varies among individuals (Koretsi et al., 2015).

ROA in Class II Treatment

ROA offer several advantages in Class II treatment including patient compliance monitoring and ease of oral hygiene maintenance. Simple functional appliances, such as an anterior bite plane, work by transmitting forces to dental and skeletal structures through patient’s muscle activity (Graber & Neumann, 1977). These appliances create temporary posterior disclusion, facilitating differential eruption patterns that contribute to overbite reduction and potential Md repositioning (Isaacson et al., 2002). The therapeutic mechanism involves creating predetermined vertical separation between posterior teeth, allowing for neuromuscular adaptation and potential skeletal modifications (Moore et al., 1989).

Masticatory Muscles

The masticatory apparatus is primarily facilitated by four key muscles: temporalis, medial pterygoid, lateral pterygoid, and masseter muscles (MM), each contributing to complex jaw movements (Hiatt, 2020). Temporalis muscle originates from temporal fossa and inserts at coronoid process, functioning primarily in Md elevation and posterior movement. MM originates from inferior zygomatic arch and attaches to Md ramus, which is responsible for Md elevation, retraction, and protrusion. These muscles work in coordination to maintain proper occlusal function and respond to changes in dental relationships (MacKinnon & Morris, 2005).

Craniofacial Morphology and Masticatory Muscle Activity in Class II

Skeletal morphology has a significant impact on masticatory muscle function, with Class II malocclusions exhibiting distinct electromyographic patterns. Class II division 1 malocclusions are associated with reduced EMG activity of MM and temporalis anterior (TA) (Pancherz & Anehus-Pancherz, 1980; Vianna-Lara et al., 2009). Vertical facial dimensions also influence muscle activity patterns, with long-faced individuals exhibiting higher TA activity, while short-faced individuals demonstrate greater MM activity (Cha et al., 2007).

SEMG in Orthodontics

SEMG provides a non-invasive assessment of masticatory muscle functions by capturing electrical potentials during muscle activity (Castroflorio et al., 2008). Accuracy depends on proper electrode placement, interelectrode distance, and minimizing movement artifacts (Hogrel et al., 1998). Biological factors—age, gender, and facial morphology—affect SEMG readings (Ferrario & Sforza, 1996).

SEMG effectively evaluates treatment outcomes and neuromuscular adaptations in orthodontic research (Kulchutisin et al., 2023). While some studies indicate functional appliances improve neuromuscular equilibrium (Di Palma et al., 2017), limited research has examined neuromuscular adaptations following ABP therapy in Class II patients, highlighting the need for further investigation using objective assessment methods.

RESEARCH METHODOLOGY

Participant Selections

This prospective observational study was approved by Naresuan University Ethical Committee (IRB No. P1-0150/2566). Five participants were recruited from patients seeking an orthodontic treatment at Naresuan University Dental Hospital between February 2024 and January 2025. The study was designed as a preliminary investigation to assess the feasibility and estimate the variability of SEMG outcomes in growing Class II patients undergoing an ABP therapy. Five participants were recruited, which was consistent with the purpose of a pilot study focusing on feasibility and variance estimation, rather than confirmatory testing (Thabane et al., 2010). A *post hoc* power analysis based on MM and TA activity during MVC and chewing demonstrated small effect sizes (Cohen's $d = 0.026–0.271$) and achieved power $< 10\%$. These effect size estimates indicated that future adequately powered studies would require 100–180 participants per group to detect similar EMG changes with 80% power at $\alpha = 0.05$. Alternatively, targeting clinically meaningful medium effect sizes ($d = 0.5$) would require 34 participants per group with 80% power (G*Power 3.1).

Those with a craniofacial deformity, a previous orthodontic treatment, or a history of any temporomandibular disorder were excluded from this study. The participants were patients with 9–13 years of age, a body mass index within the normal range (18.50–24.99 kg/m^2), and no psychological disorder. All participants presented with skeletal Class II malocclusion (ANB angle > 4°) and were clinically indicated for an orthodontic treatment by ROA with anterior bite plane as the initial phase of interceptive therapy, followed by fixed orthodontic appliances.

Skeletal Sagittal Classifications

A lateral cephalogram was obtained using a digital X-ray machine (Veraview X800; J. Morita Corporation, Kyoto, Japan) with participant in maximum intercuspation (MIP). Post-tracing of the lateral cephalogram, ANB angle was measured to classify each participant's skeletal sagittal relationship. Those with an ANB angle over 4° were classified as skeletal Class II and included in this study.

Reliability of the ANB measurements was assessed by the same investigator with a one-week interval. The intraexaminer reliability was assessed by calculating the intraclass correlation coefficient, with values above 0.80 indicating excellent agreement.

Data Collections

Pre- and post-treatments using ROA with ABP, each participant underwent routine clinical orthodontic examinations and radiography. The former provided data on the number of teeth present, along with overjet and overbite degrees. Quantity of the posterior tooth contacts during occlusion (occlusal units) was recorded.

Design and Protocol of an ROA with ABP

An ROA with ABP comprised retentive component (stainless steel clasp and labial arch wire), together with acrylic baseplate and ABP. Maxillary and Md first permanent molars were 2–4 mm vertically separated when Md incisors contacted the ABP's acrylic surface. Until an acceptable overbite correction was achieved, participants had to wear the appliances at all times, except during tooth brushing. Participant's compliance was monitored through monthly clinical examinations.

SEMG Assessment

SEMG recordings were performed using an 8-channel BioEMG III system (BioResearch Associates Inc., WI, USA). Data acquisition and analysis were performed using BioPAK software version 8 (BioResearch Associates Inc.). Bipolar surface electrodes with a 25-mm interelectrode distance were used for recording muscle activity, with a ground electrode (Cardinal Health Inc., OH, USA) placed over the 7th cervical vertebra. A standardized 19×35 mm² piece of chewing gum (Mondelēz International Inc., Bangkok, Thailand) was used for masticatory function assessment. SEMG recordings were obtained at baseline, before treatment, and after treatment using ROA with ABP.

BioEMG III systems using BioPAK program have demonstrated an acceptable measurement reliability for masticatory muscle assessments among children, with intraclass correlation coefficients of 0.65–0.79 for EMG variables (Wasinwasukul et al., 2022).

EMG Recording Protocol and Data Analysis

Participants were seated upright with heads in a natural position. After a 10-min rest, skin over MM and TA muscles was cleansed with 70% ethanol. Electrodes were placed bilaterally, that is, MM anterior to Md angle and parallel to muscle fibers, as well as TA along anterior margin aligned with the frontoparietal suture.

EMG recordings included rest position (10 sec), maximum voluntary clenching (MVC) at MIP (3 sec; repeated three times with 3-min intervals), and habitual chewing with standardized gum (10 sec; analyzing the first five cycles). Mean amplitudes were calculated from three MVC trials for muscle activity, symmetry, and synergy assessment. Using the BioPAK software (Figure 1), EMG recordings were analyzed, and the following parameters were calculated:

(1) muscle activity—averaged EMG amplitude (μV) of MM and TA during rest, MVC at MIP, and during chewing;

(2) symmetry of muscle activity—bilateral balance (%) derived from comparing EMG amplitudes between the contralateral muscles;

(3) muscle synergy—coordination (%) between ipsilateral MM and TA to evaluate their functional relationship during Md movements.

In addition, muscle effort (%) was calculated as chewing activity multiplied by 100 and divided by MVC activity to determine the relative effort required for functional chewing, when compared to maximum muscle capacity.

Statistical Analysis

Using SPSS version 25.0 (IBM; NY, USA), all statistical analyses were performed, and descriptive statistics were presented as mean ± standard deviation. The Shapiro–Wilk test was used to assess the data normality. Comparisons between pre- and post-treatment measurements employed paired *t*-tests or Wilcoxon signed-rank tests depending on the data distribution.

Regardless of statistical significance, effect sizes (Cohen's d) were calculated to assess a clinical relevance. Statistical significance was set at $p < 0.05$.

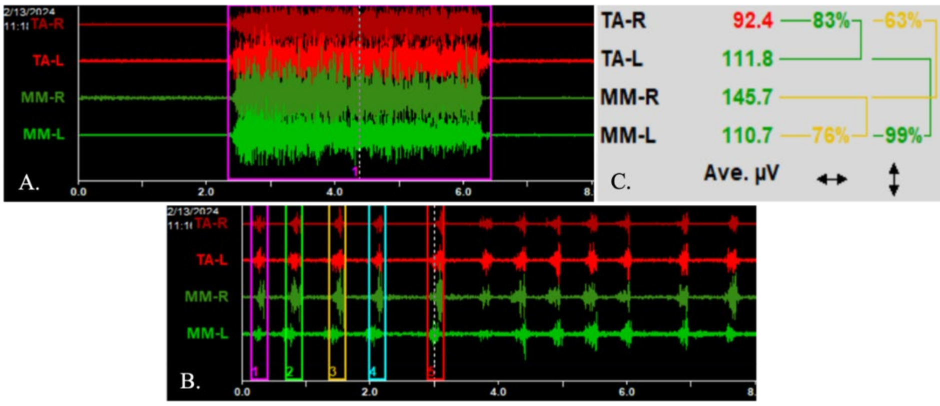

Figure 1 Temporalis anterior (TA, red lines) and masseter muscle (MM, green lines) activity during maximum voluntary clenching (A) and chewing (B) analyzed from the first five cycles by using BioPAK program. The time recordings are shown on each figure's x-axis. Symmetry (%) of a participant's muscle activity is calculated by the program (C). The column with horizontal double arrowheads shows each muscle's symmetry (left and right balances), while that with the vertical ones the synergy between TA and MM. Ave., averaged; L, Left; R, right.

RESEARCH RESULTS

Table 1 Participants' characteristics (n = 5). (All parameters are expressed in mean ± standard deviation, unless otherwise indicated.)

Characteristics	
Age (years)	12.41 ± 2.06
Weight (kg)	39.30 ± 10.66
Height (cm)	155.10 ± 10.01
BMI (kg/m²)	16.05 ± 2.71
Gender	
Male; n (%)	4 (80%)
Female; n (%)	1 (20%)
Pre-treatment measurements	
Overjet (mm)	8.20 ± 2.14
Overbite (mm)	6.40 ± 1.67
Post-treatment measurements	
Overjet (mm)	8.80 ± 3.03
Overbite (mm)	3.70 ± 2.22

Demography and Characteristics of the Five Participants (Table 1)

At the 95% confidence interval, the intraclass correlation coefficient of 0.97 was obtained for cephalometric analyses. Post-treatments with the appliances, all participants were seen with a non-significant reduction of the overbite ($p > 0.05$). No significant difference in the overjet was seen between pre- and post-treatments.

EMG Data Obtained from the Masticatory Muscles (Table 2)

Muscle activity

During resting periods, TA and MM activity remained relatively stable following treatment (TA +2.74 µV, d = 0.324; MM +0.51 µV, d = 0.102), but without a significant change ($p >$ 0.05) among participants. Participants were shown with non-significant changes ($p > 0.05$) in MVC activity in both muscles. At post-treatment period, TA activity during MVC remained unchanged (-0.40 µV, d = 0.026), while MM activity demonstrated a slight increase with a small effect size (+5.42 µV, d = 0.260). No significant change ($p > 0.05$) in TA and MM muscle activity during chewing was found among patients. Both TA and MM muscle activity exhibited positive mean changes during chewing, with small effect sizes and consistent directional changes across all participants (TA +3.21 µV, d = 0.209; MM +2.51 µV, d = 0.271), but without a significant difference ($p > 0.05$).

Table 2 Muscle activity, symmetry of muscle activity, muscle synergy, muscle effort, and occlusal units of the participants pre- and post-treatments with anterior bite plane appliance. (All values are expressed in mean ± standard deviation)

Parameters			**pre**	**post**	**diff**	***p*-value**
			Muscle activity (µV)			
Temporalis muscle (anterior fibers)	Rest	Averaged	9.24 ± 4.34	11.97 ± 7.07	2.74 ± 8.45	0.509
	MVC	Averaged	77.81 ± 27.35	77.40 ± 38.72	-0.40 ± 15.59	0.957
	Chewing	Averaged	41.96 ± 16.97	45.17 ± 24.03	3.21 ± 15.37	0.665
Masseter muscle (superficial head)	Rest	Averaged	11.19 ± 4.44	11.69 ± 3.62	0.51 ± 4.99	0.829
	MVC	Averaged	91.23 ± 42.52	96.65 ± 57.05	5.42 ± 20.82	0.592
	Chewing	Averaged	54.60 ± 20.26	57.10 ± 23.91	2.51 ± 9.25	0.577
			Symmetry of muscle activity (%)			
Temporalis muscle (anterior fibers)	MVC		80.34 ± 7.72	81.72 ± 16.90	1.38 ± 21.85	0.895
	Chewing		82.66 ± 10.54	75.12 ± 15.73	-7.54 ± 14.42	0.307
Masseter muscle (superficial head)	MVC		88.12 ± 11.28	83.06 ± 12.37	-5.06 ± 18.26	0.569
	Chewing		75.20 ± 18.12	77.14 ± 24.32	1.94 ± 12.18	0.740
			Muscle synergy (%)			
	MVC		76.54 ± 17.18	76.49 ± 7.49	-0.05 ± 21.93	0.996
	Chewing		74.11 ± 13.71	72.67 ± 16.54	-1.74 ± 14.94	0.807
			Muscle effort (%)			
Temporalis muscle (anterior fibers)			56.00 ± 16.66	62.36 ± 22.66	6.36 ± 13.32	0.346
Masseter muscle (superficial head)			65.87 ± 22.18	69.46 ± 28.37	3.59 ± 21.63	0.729
Occlusal units (number)			6.20 ± 1.10	6.20 ± 1.10	0.00 ± 0.00	-

Abbreviations: diff, different value; MVC, maximum voluntary clenching; post, post-treatment; pre, pre-treatment.

Note: All numerical data are analyzed using a paired t-test, significant difference at $p < 0.05$.

Symmetry of Muscle Activity

Muscle symmetry during MVC and chewing remained stable following treatment. TA symmetry during MVC showed minimal change (+1.38%, d = 0.063) with a non-significant decrease ($p > 0.05$) during chewing (-7.54%, d = 0.523). The chewing symmetry demonstrated the largest mean difference among all symmetry measures, corresponding to a medium effect size. MM symmetry was detected with slight improvements during chewing (+1.94%, d = 0.159), but a marginal decrease during MVC (-5.06%, d = 0.277). None of these changes was significant ($p > 0.05$).

Muscle Synergy and Coordination

Non-significant changes ($p > 0.05$) in the participants' TA and MM synergy were seen during chewing and in MVC after the treatment. Muscle synergy values remained stable throughout the treatment period, with minimal changes between pre- and post-treatment measurements (MVC synergy -0.05%, d = 0.002; chewing synergy -1.74%, d = 0.116).

Muscle Effort and Efficiency

Non-significant increases ($p > 0.05$) in both TA and MM effort of the participants were found following treatment. Increase in TA effort was more pronounced than that in MM one (TA +6.36%, d = 0.477; MM +3.59%, d = 0.166).

Occlusal Contact Units

The occlusal contact units remained stable across all patients following treatment, but without significant changes ($p > 0.05$).

Variability of SEMG Outcomes

Boxplots of all SEMG outcomes (Figure 2) showed wide data dispersion and overlapping pre- and post-treatment distributions. This pattern was apparent in muscle activity and percentage-based measures (symmetry, synergy, and effort), demonstrating a substantial variability across participants in this pilot sample.

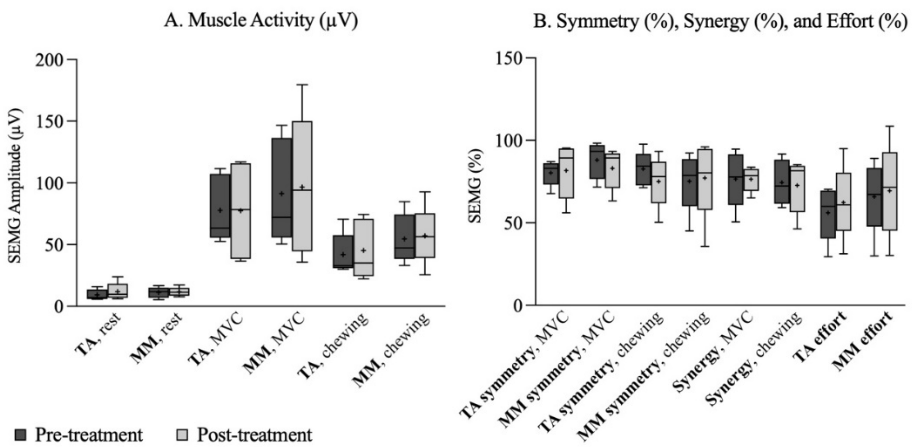

Figure 2 Boxplots of surface electromyography outcomes in participants pre- and post-treatments with anterior bite plane appliance. A. Muscle activity for temporalis anterior (TA) and masseter (MM) at rest, maximum voluntary clenching (MVC), and chewing. B. Bilateral muscles' symmetry, ipsilateral muscles' synergy, and muscle effort of TA and MM.

DISCUSSION & CONCLUSION

This study evaluated changes in SEMG among growing patients with skeletal Class II following orthodontic therapy by ROA with ABP. The treatment achieved a 2.70-mm-overbite reduction with an averaged 8.4-month-treatment time. This is comparable to those in previous studies showing the reductions ranged 1.9–3.1 mm (Baccetti et al., 2012; Franchi et al., 2011; Huang et al., 2012).

ABP therapy has been disclosed to induce only transient changes in muscle activity without compromising neuromuscular coordination. Resting muscle activity remained stable post-

treatment, indicating good patient adaptation without muscular strain or parafunctional activity during neuromuscular rest (Di Palma et al., 2017; Wasinwasukul et al., 2022).
During MVC, MM activity was non-significantly increased while TA remained stable. This phenomenon reflects initial changes in muscle activity upon an insertion of ROA with ABP, followed by normalization as muscles efficiently adapt to temporary posterior disclusion (Wasinwasukul et al., 2022). Some slight non-significant increases ($p > 0.05$) in both TA and MM activity were detectable during functional chewing post-treatment. The trend suggests a potential improvement in mastication after an overbite correction (Di Palma et al., 2017).
Muscle symmetry and synergy remained preserved throughout the treatment. The symmetry index and muscle synergy percentages showed no significant change, indicating balanced bilateral activations and coordinated TA-MM functions (Ferrario & Sforza, 1996; Wasinwasukul et al., 2022). These results illustrated ROA with ABP did not compromise neuromuscular coordination, which is crucial for maintaining functional stability during an orthodontic treatment. In addition, no significant change in the occlusal contact units was seen following the treatment, despite a successful correction of the overbite. It has confirmed that a functional bite correction guaranteed no occlusal stability (Bakke, 1993).
The neuromuscular system demonstrates remarkable plasticity. It reflects a successful accommodation of the vertical changes, during functional integrity maintenance (Castroflorio et al., 2008; Tecco et al., 2010). Such findings provide important clinical reassurance that, despite temporarily altered occlusal relationships, an ROA with ABP used in a growing patient negatively impact neither masticatory muscle function nor coordination.
Most SEMG outcomes in this pilot study were non-significant, possibly reflecting a type II error due to the small sample size and high interindividual variability, as evidence in the boxplot distributions (Cohen, 1988). Despite the non-significant results, small increases in TA and MM activity during chewing may reflect early neuromuscular adaptation to the ABP. In contrast, the stable muscle symmetry and synergy may suggest that neuromuscular coordination was preserved, potentially through compensatory mechanisms (Pumklin et al., 2023). These patterns are preliminary and highlight the complex muscle responses during deep bite correction with ABP.
Study limitations included a small sample size preventing an adequate statistical power, a short follow-up duration insufficient for capturing long-term muscle adaptation patterns, and the absence of a control group, making it challenging to isolate treatment effects from regular developmental changes. Consequently, further studies with larger sample sizes, extended follow-up periods, and controlled designs are required to investigate muscle activity, symmetry, and functional adaptation. The integration of complementary methods, such as T-scan occlusal analysis for bite force distribution (Prabahar et al., 2021), could enhance SEMG findings. Meanwhile, individual factors including craniofacial morphology and baseline muscle activity patterns should be examined to forecast a treatment response variability.
Within this pilot study's limitations, the treatment of deep bite using an ROA with ABP demonstrated feasibility in maintaining normal neuromuscular performance among the growing children with skeletal Class II and dental deep bite. Future investigations with larger sample sizes, control groups, and extended follow-up periods are recommended to validate these findings and assess the long-term functional effects of ABP on the masticatory muscles.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.