Int J Clin Exp Med 2017;10(11):15323-15328
www.ijcem.com /ISSN:1940-5901/IJCEM0033200

Original Article

Assessment of oral parafunctional behaviors and electromyographic activities of the masticatory muscles in young female patients with orthodontic Invisalign treatment

Panpan Liu[1,2,3], Guangxue Wu[1,2], Jing Liu[1,2], Delong Jiao[1,2], Jing Guo[1,2]

Departments of [1]Orthodontics, [3]Pediatric Dentistry, School & Hospital of Stomatology, Shandong University, Jinan, Shandong, China; [2]Key Laboratory of Oral Biomedicine of Shandong Province, Jinan, Shandong, China

Received June 2, 2016; Accepted October 30, 2016; Epub November 15, 2017; Published November 30, 2017

Abstract: Objectives: To evaluate the effect of Invisalign treatment on the oral parafunctional behaviors and the electromyographic activities of masticatory muscles. Methods: Twenty-three female patients (mean age 26.8±2.4) were included. All patients had received the Invisalign treatment for at least 6 months. The Oral Behavior Checklist (OBC) was completed at T0, i.e., before wearing the aligner; at T1, i.e., after 3 months of treatment; and at T2, i.e., after 6 months of treatment. The surface Electromyographic (sEMG) activities of the bilateral anterior temporal (TA), masseter (MM) and sternocleidomastoid (SCM) were recorded at the mandibular postural position (MPP) and during maximal voluntary contraction (MVC) at T0, T1 and T2, respectively. Results: (1) The OBC score significantly decreased betweenT0 and T1 ($P<0.05$). (2) When measured at the MPP, the activity of the TA increased significantly between T0 and T1 ($P<0.05$). During MVC, the activities of the TA and SCM at T1 were significantly higher than those of T0 ($P<0.05$). At the MPP and MVC, we found no difference in TA, MM or SCM activities between T1 and T2. Conclusions: The clear aligners of Invisalign treatment have a relevant effect on the orofacial system, which suggests that some functional mechanics may underlie this type of the appliance.

Keywords: Invisalign, oral behavior checklist, surface electromyography, masticatory muscle

Introduction

Invisalign made of polyurethane material was introduced into the orthodontic field in 1997. Such appliances offer the advantages of esthetics, comfort and excellent maintenance of oral hygiene compared with the conventional fixed appliance [1-3]. Currently, most investigations have paid attention to the mechanical characteristics and teeth movement efficacy about this appliance. However, the functional assessment has been neglected. According to the literature [4], each slice of clear aligner appliance is 0.030 inch (0.77 mm), and the thickness of the upper and lower aligners combined is approximately 1.5 mm. The two-layer aligners occupy most of and even exceed the interocclusal freeway space at the mandibular posture position (MPP). Therefore, it was not unusual to observe that the posterior teeth became a premature point and the overbite became much swallower when the two-layer aligners were inserted into the mouth simultaneously. Thus, wearing two-layer aligners disrupts the stable environment of a gnathic system, and the teeth disclusion may consequently affect the activity of the masticatory muscles.

Masticatory muscles, as one of the most important parts of the gnathic system, affect not only the growth of the jaw but also the orofacial harmony and stability [5]. Surface electromyography (sEMG), also known as the dynamic EMG, was used to collect and record the action potentials and measure the activities of the muscles. The anterior funicle of the temporal muscle (TA), the masseter muscle (MM) and the sternocleidomastoid muscle (SCM), with superficial and strong muscle bundles, are usually chosen as the target muscles in some investigations.

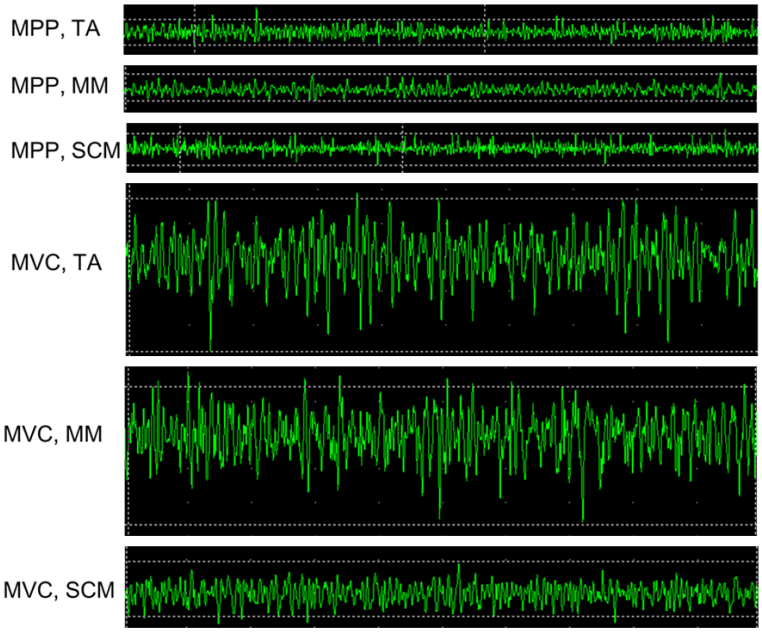

Figure 1. The surface electromyographic (sEMG) activities of TA, MM and SCM inT0 at MPP and during MVC respectively. The standard parameters are set as 50 uV/D, 20 ms/D at MPP and 0.1 mV/D, 20 ms/D during MVC on the screen of the electromyographic instrument.

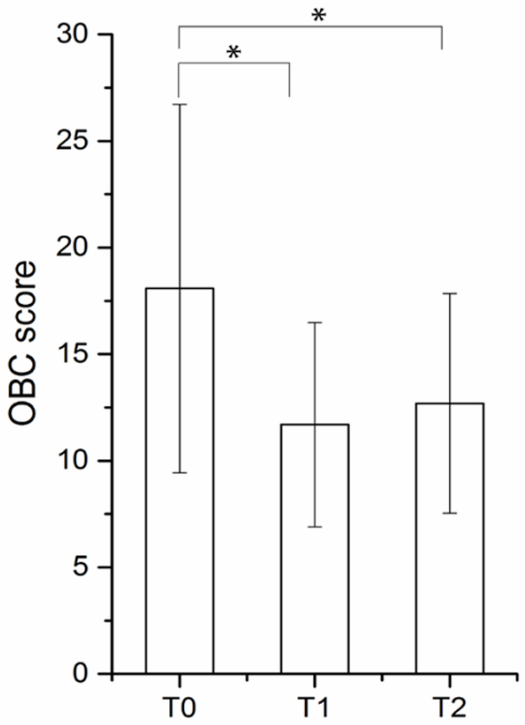

Figure 2. The OBC score at T0, T1 and T2. "*" indicates that *P*-value is less than 0.05 between the two phases that are connected by the line.

Oral parafunctional behaviors, which are the overuse of the orofacial system, have been reported to overload the masticatory system and may result in craniomandibular disorders [6, 7]. Several investigations have revealed that frequent oral parafunctional behaviors may be the risk factors for orofacial pain [8, 9]. Although Invisalignis widely accepted as orthodontic appliance, it has not been clarified whether the effect could be induced by the clear aligners on oral functional behaviors. Thus, the purpose of this study was to assess the effect of the orthodontic clear aligner appliance on the frequency of oral parafunctional behaviors and the electromyographic activity of masticatory muscles.

Subjects and methods

Subjects

Twenty-three female patients ranging from 20 to 28 years old (mean age 26.8±2.4) were recruited at the Stomatology Hospital of Shandong University from June 2013 to June 2015. All patients had received Invisalign treatment for at least 6 months. The inclusion criteria were (1) full permanent dentition; (2) no obvious condylar resorption; (3) no history of occlusal reconstruction, crown restoration or orthodontic treatment; (4) good adherence (wearing the appliance about 18-22 hours per day) and a scheduled visit; and (5) a body mass index (BMI) ranging from 18 to 24 kg/m^2. The exclusion criteria were (1) systemic diseases that may affect activities of the masticatory muscles; (2) medications, such as muscle relaxants, that may affect muscle function; (3) neurological diseases; and (4) anxiety and depression. The local ethics committee of Shandong University approved the study protocol, and the subjects provided their informed consent to participating in this study.

Clear aligner appliance

To ensure the consistency of the material thickness, these appliances were manufactured by the Invisalign Company (Invisalign, Align Technology, USA). Subjects were assigned to a 2-week schedule to receive new aligners to

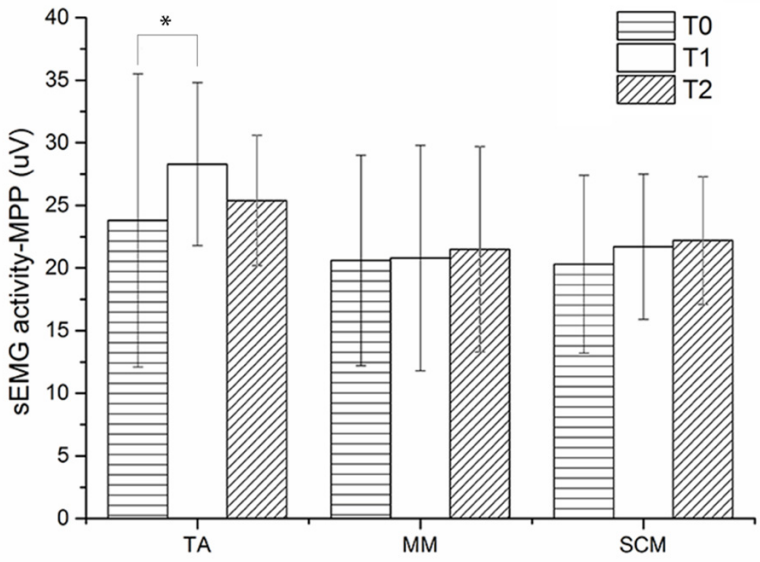

Figure 3. sEMG activities of the tested muscles at MPP. TA, anterior funicle of the temporal muscle; MM, masseter muscle; SCM, sternocleidomastoid muscle. "*" indicates that *P*-value is less than 0.05 between the two phases that are connected by the line.

reduce the effect of material aging. In our study, tooth movement was not tested, allowing us to focus on the effect of the clear aligner appliance on the experimental results.

OBC self-evaluation

The Oral Behavior Checklist (OBC), a DC/TMD (Diagnostic Criteria for Temporomandibular Disorders) axis II questionnaire [10], was completed before wearing the clear aligners (T0), after three months of treatment (T1) and after six months of treatment (T2). The OBC questionnaire assesses 21 oral parafunctional behaviors and the frequency of these behaviors includes "none of the time", "<1 night/month", "1-3 nights/month", "1-3 nights/week" and "4-7 nights/week". The corresponding scores are 0, 1, 2, 3 and 4 points, respectively. The total score is calculated by summing the scores of the 21 questions.

sEMG recording

Before the test was performed, the subjects were instructed to relax and sit upright with their eyes looking forward. A quiet environment was essential. Next, 75% alcohol was used to clean the skin to reduce impedance. The electrodes were placed according to previously described methods [11].

The activities of the anterior temporalis (TA), masseter (MM) and sternocleidomastoid muscles (SCM) were tested bilaterally at the mandibular posture position (MPP) and during maximum voluntary clenches (MVC) at T0, T1 and T2, respectively, without the aligners in the mouth. We used the 3 M disposable Ag_2-AgCl bipolar electrodes and the electromyogram instrument keypoint 4 (Alpine Biomed APS, Denmark) with the sampling frequency of 25 HZ. In order to record the data, the standard parameters of the electromyographic activities on the screen of the electromyogram instrument were set as 50 uV/D, 20 ms/D at the MPP and 0.1 mV/D, 20 ms/D during the MVC (**Figure 1**). Three trials were recorded during each session, and ten-minute intervals were required to obtain sufficient relaxation. The absolute amplitude values of the electromyograms of the targeted muscles were recorded and expressed in microvolts (uV).

Statistical analysis

Data were analyzed with SPSS software version 16.0 (SPSS, China, III) and the significance level was set at $P<0.05$. The OBC score and the sEMG values of TA, MM and SCM at T0, T1 and T2 were compared using the repeated measures analysis of variance (ANOVA).

Results

OBC self-evaluation

The OBC scores of T1 and T2 were significantly lower than that of T0 ($P<0.05$), and no significant difference was revealed between T1 and T2. The OBC score significantly decreased initially and then changed with a minor increase from T1 to T2 (**Figure 2**).

sEMG evaluation

sEMG evaluation at MPP: The electromyographic activity of TA at T1 was significantly larger

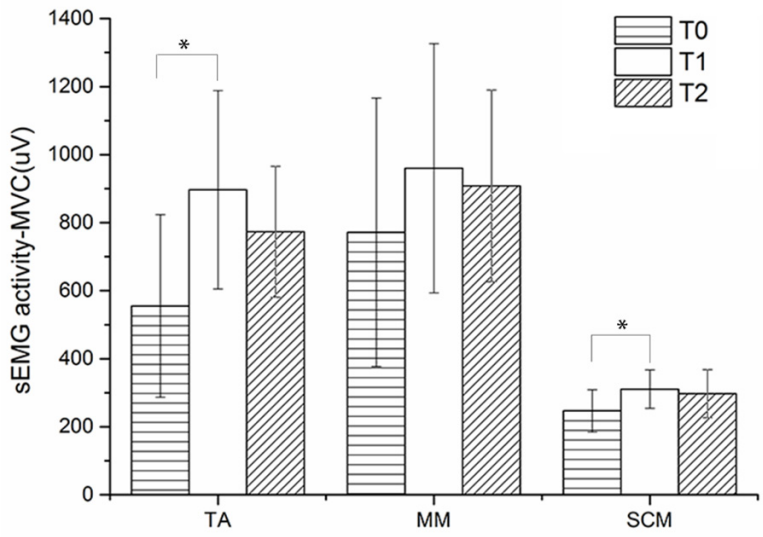

Figure 4. sEMG activities of the tested muscles during MVC. Other abbreviations are identical to those explained in **Figure 3**.

than that of T0 (28.3±6.5 vs. 23.8±11.7, P<0.05). Next, the electromyographic activity of TA slightly decreased from T1 to T2, and the value of T2 remained larger than that of T0 (P>0.05). The electromyographic activities of MM and SCM showed no significant changes between T0, T1 and T2 (**Figure 3**).

sEMG evaluation during MVC: The electromyographic activities of TA and SCM at T1 were significantly larger than those of T0 (P<0.05) and showed a reduced trend at T2,which remained larger than the activity of T0.The electromyographic activity of MM showed no difference between T0, T1 and T2 (**Figure 4**).

Discussion

This study assessed the oral parafunctional behaviors and activity of the orofacial muscle of young females after wearing two-layer clear aligners for 6 months. The recorded activities of the masticatory muscles varied across age groups. The activity of the masseter muscle increased with age, while the contrasting results were obtained in the anterior temporal region. In addition, the participants were susceptible to muscle discomfort and TMJ-related clinical signs. Because female samples were more accessible, the subjects in our sample were limited to young female patients.

The OBC in our study was one of the revised DC/TMD Axis II questionnaires, and its high validity and specificity have been confirmed [10, 12]. A previous study indicated that the subjects could understand the oral behavior-related terms in this questionnaire [13]. The OBC score is a valid and reliable tool for clinicians to identify the adverse stimulation of orofacial health, which is closely associated with the possibility of TMD and chronic facial pain [8, 9].

In the present study, we observed that the OBC score significantly decreased after three months and then showed a minor increase from T1 to T2. Therefore, it can be concluded that the clear aligners could play a role in reducing the frequency of oral parafunctional behaviors, producing a favorable change in the orofacial system. Levrini had successfully treated a mild open bite adolescent patient with thumb-sucking habits using the Invisalign teen series [14]. A bite ramp on the palate surface of the upper aligner was added to discourage thumb sucking and terminate the pleasant and peaceful feeling induced by this bad habit [15, 16]. Thus, the clear aligner appliance can be used to combine the orthodontic and cognitive behavioral treatment to successfully treat patients with oral parafunctional behaviors.

The activity of the anterior temporalis significantly increased after three months, and a minor reduction was observed after six months, although this reduction was not significant. The clear aligners had some effect on the orofacial muscles at the MPP. The mechanism underlying this finding could be that two-layer aligners increased the occlusal vertical dimension, stretching and tensing the orofacial muscle fibers. Thus, the contraction intensity of the masticatory muscles was strengthened or the number of muscle fibers was increased to restore the stability of the orofacial system. Previous studies have shown that the anterior temporalis is the main keeper muscle at MPP [17, 18]. And, therefore, it is sensitive to changes in the mandibular position.

During MVC, the activities of the masticatory muscles, particularly TA and SCM, significantly increased after three months, and a minor

reduction was observed after six months. However, this reduction was not significant. The sEMG in our study was conducted without the clear aligner appliance in the mouth. Thus, we inferred that the electromyographic activities of the masticatory muscles could be affected by the mandibular position and did not change in the short interval when the clear aligners were removed. This phenomenon has been ascribed to muscle plasticity. In addition, it was found that the muscle activity had a trend of minor reduction from T1 to T2, which further confirmed the adaptation and plasticity of the orofacial muscle system. This reflected the functional adaptation of neuronal cells to the surrounding environmental of the orofacial system [19].

In conclusion, the orthodontic clear aligners have the relevant functional effect on the orofacial system, including oral parafunctional behaviors and the electromyographic activities of masticatory muscles. However, the effect of longer use on functional behaviors remains to be investigated and warrants further study.

Acknowledgements

We acknowledge the help of the neurologists from Qilu hospital in the electromyographic evaluation. Supported by the Natural Science Foundation of Shandong Province (2014ZRE-27266).

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Jing Guo, Department of Orthodontics, School & Hospital of Stomatology, Shandong University, 44-1#, Wenhua West Road, Jinan 250012, Shandong, China. Tel: +86-0531-88382070; E-mail: guojing@sdu.edu.cn

References

[1] Chenin DA, Trosien AH, Fong PF, Miller RA and Lee RS. Orthodontic treatment with a series of removable appliances. J Am Dent Assoc 2003; 134: 1232-1239.

[2] Djeu G, Shelton C and Maganzini A. Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. Am J Orthod Dentofacial Orthop 2005; 128: 292-298; discussion 298.

[3] Li W, Wang S and Zhang Y. The effectiveness of the Invisalign appliance in extraction cases using the the ABO model grading system: a multicenter randomized controlled trial. Int J Clin Exp Med 2015; 8: 8276.

[4] Miller RJ and Derakhshan M. The Invisalign System: Case report of a patient with deep bite, upper incisor flaring, and severe curve of spee. In Seminars in Orthodontics. Elsevier 2002; 43-50.

[5] Petrovic D and Horvat-Banic S. Electromyographic activity of the temporal and masseter muscles at different occlusal positions. Med Pregl 2007; 60: 134-139.

[6] Winocur E, Littner D, Adams I and Gavish A. Oral habits and their association with signs and symptoms of temporomandibular disorders in adolescents: a gender comparison. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006; 102: 482-487.

[7] Manfredini D and Lobbezoo F. Relationship between bruxism and temporomandibular disorders: a systematic review of literature from 1998 to 2008. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109: e26-50.

[8] Ohrbach R, Fillingim RB, Mulkey F, Gonzalez Y, Gordon S, Gremillion H, Lim PF, Ribeiro-Dasilva M, Greenspan JD, Knott C, Maixner W and Slade G. Clinical findings and pain symptoms as potential risk factors for chronic TMD: descriptive data and empirically identified domains from the OPPERA case-control study. J Pain 2011; 12: T27-45.

[9] Ohrbach R, Bair E, Fillingim RB, Gonzalez Y, Gordon SM, Lim PF, Ribeiro-Dasilva M, Diatchenko L, Dubner R, Greenspan JD, Knott C, Maixner W, Smith SB and Slade GD. Clinical orofacial characteristics associated with risk of first-onset TMD: the OPPERA prospective cohort study. J Pain 2013; 14: T33-50.

[10] Ohrbach R. Assessment and further development of RDC/TMD Axis II biobehavioural instruments: a research programme progress report. J Oral Rehabil 2010; 37: 784-798.

[11] Yuen SW, Hwang JC and Poon PW. EMG power spectrum patterns of anterior temporal and masseter muscles in children and adults. J Dent Res 1989; 68: 800-804.

[12] Ohrbach R, Markiewicz MR and McCall WD Jr. Waking-state oral parafunctional behaviors: specificity and validity as assessed by electromyography. Eur J Oral Sci 2008; 116: 438-444.

[13] Markiewicz MR, Ohrbach R and McCall WD Jr. Oral behaviors checklist: reliability of performance in targeted waking-state behaviors. J Orofac Pain 2006; 20: 306-316.

[14] Levrini L, Tettamanti L, Macchi A, Tagliabue A and Caprioglio A. Invisalign teen for thumb-

sucking management. A case report. Eur J Paediatr Dent 2012; 13: 155-158.
[15] Tseng AG and Biagioli FE. Counseling on early childhood concerns: sleep issues, thumb sucking, picky eating, and school readiness. Am Fam Physician 2009; 80: 139-142.
[16] Nasir A and Nasir L. Counseling on early childhood concerns: sleep issues, thumb-sucking, picky eating, school readiness, and oral health. Am Fam Physician 2015; 92: 274-278.
[17] Li J, Jiang T, Feng H, Wang K, Zhang Z and Ishikawa T. The electromyographic activity of masseter and anterior temporalis during orofacial symptoms induced by experimental occlusal highspot. J Oral Rehabil 2008; 35: 79-87.
[18] Lauriti L, Motta LJ, de Godoy CH, Biasotto-Gonzalez DA, Politti F, Mesquita-Ferrari RA, Fernandes KP and Bussadori SK. Influence of temporomandibular disorder on temporal and masseter muscles and occlusal contacts in adolescents: an electromyographic study. BMC Musculoskelet Disord 2014; 15: 123.
[19] Schupp W, Haubrich J and Neumann I. Invisalign((R)) treatment of patients with craniomandibular disorders. Int Orthod 2010; 8: 253-267