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Original article

The Change of Occlusal Bite Force during Clear Aligner Treatment and Squeezing Exercise

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Abstract

Background: No studies revealed the change of occlusal bite force during clear aligner treatment combined with the squeezing exercise. **Objective:** To study the change of occlusal bite force during anterior open bite treatment with clear aligners and squeezing exercise. **Materials and methods:** Twenty-two adults with anterior open bite were treated with customized clear aligners. Anterior open bite was corrected using clear aligners combined with squeezing exercise. Squeezing exercise was done by clenching on the clear aligner with submaximal bite force around 80 %. Occlusal bite force was collected at pretreatment (T0), 1 month (T1), 2 months (T2), 3 months (T3), 4 months (T4), 5 months (T5), and 6 months of treatment (T6). Parametric tests were used for statistical analysis. **Results:** After commencement the treatment, the maximum bite force was significantly higher than the squeezing bite force at all time intervals. Both maximum and squeezing bite force substantially increased from T0 to T2, gradually increased from T2 to T4, and remained stable from T4 to T6. **Conclusions:** Clear aligner treatment combined with squeezing exercises enhanced both maximum and squeezing bite force during a 6-month observation period.

Keywords: Anterior open bite, Clear aligner treatment, Occlusal bite force, Squeezing exercise

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Introduction

The occlusal bite force serves as a significant indicator of masticatory function[1] and it's linked to the activity of masticatory muscles during jaw movements. Several factors affect occlusal bite force, including age, gender, craniofacial morphology, periodontal condition, temporomandibular joint, and dental status.[2] The increased bite force exerted on the posterior dental arch is contingent upon the larger occlusal surface area, contact area, and the number of teeth engaged during the biting process.[3]

Moreover, the changes in vertical dimension can influence periodontal mechanoreceptors and proprioception.[4,5] Previous studies have sought to investigate the impact of occlusal coverage appliances on muscular response.[6,7] However, the findings remain contentious and vary depending on the type of appliances using and the characteristics of the subjects. Removable appliances have been reported to either increase the activity of the temporalis and masseter muscles[8] or decrease muscle activity,[9] depending on the design of the appliance.

Anterior open bite is characterized by the upper incisors failing to overlap the incisal third of the lower incisors. Its prevalence worldwide varies from 1.5 % to 16.9 % according to several studies.[10-12] Despite its relatively low occurrence, this malocclusion poses a significant challenge to orthodontists in terms of providing treatment that achieves both esthetic improvement and functional stability. Previous study has indicated that a notable portion, ranging from 18 % to 25 %, of patients with anterior open bite relapse after orthodontic treatment.[13]

Managing anterior open bite presents a significant challenge in orthodontics. Clear aligners have emerged as a treatment option for anterior open bite due to their advantages, including being comfortable, removable, non-invasive, and aesthetically pleasing. Previous studies have suggested that biting on the occlusal thermoplastic sheet of clear aligners can lead to intrusion of posterior teeth.[6,7,14] However, conflicting findings have been reported, with some studies indicating that after the appliance was delivered, occlusal bite force either increased or decreased,[15,16] which can influence dental movement.[8,17]

Squeezing or clenching exercise is a common component of myofunctional therapy often employed in anterior open bite patients with compromised masticatory function.[18] This exercise engages various masticatory muscles, including the temporalis, masseter, medial pterygoid, and lateral pterygoid. Previous study has proposed squeezing exercises as a means to manage vertical dimension and enhance the stability of anterior open bite treatment.[19] In literature, short-term effect of squeezing exercise was enhance muscle strength resulted in increasing maximum bite force.[20] However, the report about long-term training more than 6 weeks was not evidence. The investigation of cyclic change of occlusal force can enlighten the clear aligner treatment with squeezing exercise in term of the neuromuscular response for improve exercise regimen for anterior open bite patient in the future.

The objective of this study is to investigate the change of occlusal bite force in anterior open bite patients treated by clear aligners combined with squeezing exercise during a 6-month period.

Materials and methods

This study was performed at Dental Hospital, the Faculty of Dentistry, Prince of Songkla University. The study protocol was approved by the Institutional Review Board for human patients (protocol EC 6308-030) of Human Ethic Committee of the Faculty of Dentistry, Prince of Songkla University and the study was conducted in accordance with the Declaration of Helsinki. Informed consent was collected from all subjects in this study.

The sample size was calculated by G*Power (Version 3.1) using the effect size of 0.8, α = 0.05, and

80 % power of test. Twenty-one subjects were needed. The estimate dropout rate was about 10 %. Thus, this study was required twenty-three subjects.

Subjects were recruited based on criteria. Inclusion criteria comprised: 1) Individuals aged between 18 to 35 years; 2) Anterior open bite ranging from 0 to 4 mm; 3) Angle Class I or mild Angle Class II malocclusion; 4) Healthy periodontal condition. Exclusion criteria included: 1) Previous history of dental trauma; 2) Systemic diseases affecting bone metabolism; 3) Neuromuscular disorders.

Individual participant was briefed about the study and provided their signature on the consent form. Data were gathered at seven intervals: 1) before treatment (T0), 2) after 1 month (T1), 3) after 2 months (T2), 4) after 3 months (T3), 5) after 4 months (T4), 6) after 5 months (T5), and 7) after 6 months of treatment (T6). Changes in overbite and occlusal bite force were documented.

Clear aligner treatment

The custom-made clear aligners were performed by using the intraoral scanner (TRIOS 3, 3Shape, Copenhagen, Denmark) and then importing STL file to 3Shape OrthoAnalyzer™ program. The attachments design were adopt from the previous study.[14]

Squeezing exercise

Squeezing exercise was performed while wearing clear aligners, with the protocol adapted from the previous study.[21] Participants were instructed to bite down on the aligner for one minute during each session. Each session consisted of six cycles, alternating between five seconds of isometric clenching (80 % of maximum bite force) and five seconds of rest. This exercise routine was repeated at least five times daily, with the aligner wearing for a minimum of twenty-two hours per day, excluding times for brushing and eating.

Occlusal bite force measurement

Participants were instructed to assume an upright seated position and unwind for a duration of 5 minutes in a secluded room where environmental conditions were carefully regulated before the commencement of measurements. A bite force recording device, developed using the FlexiForce™ ELF system and sensors (Tekscan®, Boston, USA), was employed. Custom holders were crafted to accommodate the sensors size 1.5x1.3 mm^2 (Figure1), Force was transfered to the sensing area by the flat transducer designed changing the shear force as the direct force to the center of sensor. The handle were positioned on the mesiobuccal cusp of upper first molars on both the right and left sides, with the measurements displayed in Newton units. The device was calibrated with the universal testing machine before the measurement. (Figure 2)

Occlusal bite forces were measured from T0 to T6 in two types of occlusal bite force as followings. (Figure 3)

1. Maximum bite force

All participant received instructions to exert maximum biting force for 3 seconds, ensuring it caused no discomfort, followed by 20 seconds of resting period. This cycle was repeated with 1-minute intervals between sessions to avoid muscle fatigue.

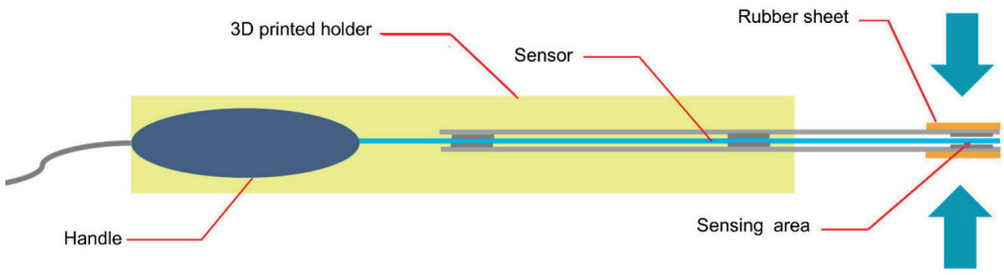

Figure 1 Bite force recording device

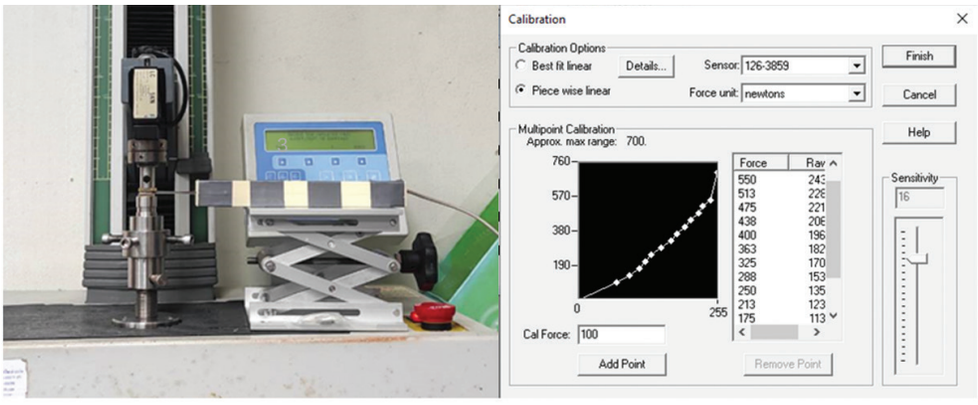

Figure 2 Bite force recording device calibration with universal testing machine

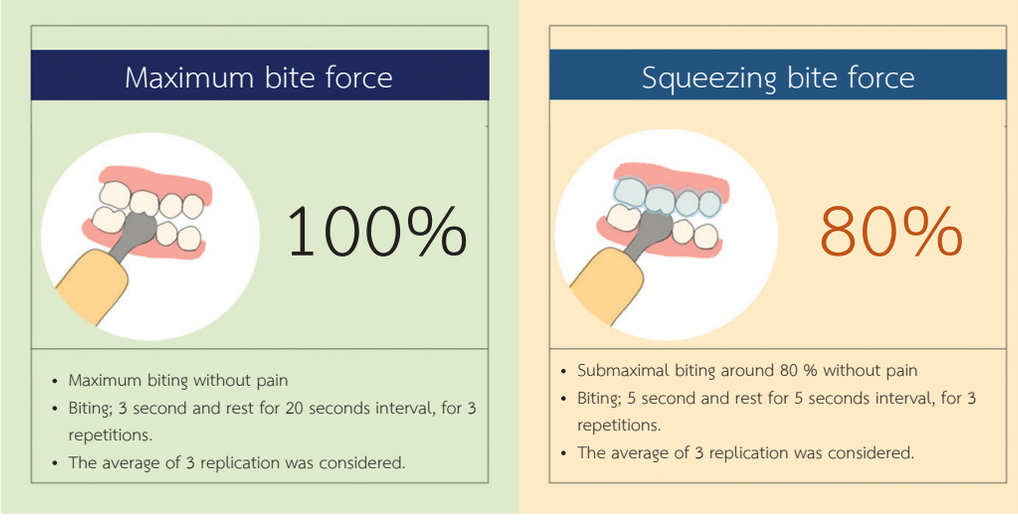

Figure 3 Maximum and squeezing bite force measurement

The average of three repetitions was taken into account.

2. Squeezing bite force

The applied pressure involved isometric clenching without discomfort and was kept below the maximum biting force. This pressure was sustained for 5 seconds, followed by 5 seconds of resting period, repeated three times within each session. The average of three repetitions was taken into consideration.

Statistical analysis

All parameters were evaluated by one examiner. Ten samples were randomly reassessed the error and reliability after a two-week interval. The intraclass correlation coefficient exceeding 0.91 indicated excellent reliability. Random errors were 3.6 % for occlusal bite force measurements, which were acceptable.

All data subjected to the Shapiro-Wilk test exhibited a normal distribution. Changes in occlusal bite force within and between groups were assessed using paired t-tests and independent t-tests, respectively. Changes in occlusal bite force of seven time points were assessed using ANOVA and post hoc comparison by Bonferroni correction. Statistical analyses were conducted using SPSS version 26, with a significance level set at 0.05 for all tests.

Results

Twenty-three participants meeting the inclusion criteria and consenting were recruited for this study. One participant discontinued the intervention, resulting

Table 1 The maximum and squeezing bite force at pretreatment (T0)

Measured side	Occlusal bite force (Mean ± SD, N)			*P* value
	Maximum bite force	Squeezing bite force	Differences	
Left	254.17 ± 6.98	194.77 ± 5.78	59.40 ± 1.51	< 0.001***
Right	253.72 ± 6.16	195.62 ± 6.44	58.10 ± 1.38	< 0.001***

The statistical analysis was tested by paired t-test.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 2 The change of maximum bite force from pretreatment (T0) to 6 months of treatment (T6).

Measured side	Maximun bite force (Mean ± SD, N)						
	T0	T1	T2	T3	T4	T5	T6
Left	254.17 ± 6.98	344.43 ± 6.19	402.83 ± 6.49	440.75 ± 5.45	450.56 ± 5.15	450.67 ± 5.90	448.18 ± 4.85
Right	253.72 ± 6.16	346.97 ± 6.74	401.11 ± 5.53	439.94 ± 5.04	449.69 ± 4.75	450.50 ± 4.97	447.82 ± 6.14

Table 2 Continued

Measured side	F	*P* value	Post hoc comparison by Bonferroni correction
Left	3111.62	< 0.001***	T0 < T1 < T2 < T3 < T4 = T5 = T6
Right	3284.34	< 0.001***	T0 < T1 < T2 < T3 < T4 = T5 = T6

The statistical analysis was tested by ANOVA.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

in a final cohort of twenty-two individuals (comprising 7 males and 15 females) with an average age of 20.55 ± 2.08 years. Initially, overbite measurements ranged from 0 to -3 mm, with an average initial overbite of -1.16 ± 0.97 mm. The maximum bite force was significantly higher than the squeezing bite force on both the left and right sides (Table 1). The differences of maximum and squeezing bite force were 59.40 and 58.10 Newtons for the left and right sides, respectively.

After six months of treatment (T6), the overbite increased significantly, with a mean of 1.30 ± 0.40 mm (ranging from 0 to 2 mm), and the mean overbite at six months of treatment was 0.14 ± 0.80 mm.

Table 2 displayed the change in maximum bite force from pretreatment to 6 months of treatment. There was no significant difference observed between the left and right sides. On both sides, at 4 months of treatment (T4), the force did not significantly differ from those at 5 and 6 months of treatment (T5 and T6), but it was greater than the force measured from pretreatment to 3 months (T0-T3) ($P < 0.001$).

Table 3 displayed the change in squeezing bite force from pretreatment to 6 months of treatment. On the left side, at 4 months of treatment (T4), the force did not significantly differ from those at 5 and 6 months of treatment (T5 and T6), but it was greater than the force measured from pretreatment to 3 months (T0-T3). On the right side, at 2 months of treatment (T2), the force did not significantly differ from that at 3 months of treatment (T3), but it was greater than the

Table 3 The change of squeezing bite force from pretreatment (T0) to 6 months of treatment (T6).

Measured side	Squeezing bite force (Mean ± SD, N)						
	T0	T1	T2	T3	T4	T5	T6
Left	194.77 ± 5.78	255.00 ± 6.89	319.85 ± 6.88	331.10 ± 7.61	339.96 ± 7.49	340.72 ± 7.10	340.47 ± 5.48
Right	195.62 ± 6.44	252.26 ± 6.68	323.39 ± 7.18	327.20 ± 7.19	337.63 ± 7.30	342.75 ± 6.99	345.44 ± 6.90

Table 3 Continued

Measured side	*F*	*P* value	Post hoc comparison by Bonferroni correction
Left	1393.66	< 0.001***	T0 < T1 < T2 < T3 < T4 = T5 = T6
Right	1354.03	< 0.001***	T0 < T1 < T2 = T3 < T4 = T5 = T6

The statistical analysis was tested by ANOVA.

*P < 0.05, **P < 0.01, ***P < 0.001

Table 4 The change of average maximum and squeezing bite forces between pretreatment (T0) and 6 months of treatment (T6).

Occlusal bite force (Mean ± SD, N)	T0	T6	Differences	*P* value
Maximum bite force	253.97 ± 6.66	448.02 ± 3.83	194.05 ± 2.37	< 0.001***
Squeezing bite force	195.23 ± 5.77	342.98 ± 4.80	147.75 ± 2.41	< 0.001***

The statistical analysis was tested by paired t-test.

*P < 0.05, **P < 0.01, ***P < 0.001

force measured from pretreatment to 1 month (T0-T1) and lesser than the force measured at 4 months (T4). Moreover, at 4 months of treatment (T4), the force did not significantly differ from those at 5 and 6 months of treatment (T5-T6) (P < 0.001).

Following 6 months of treatment (T6), there was a notable increase in both the average maximum and squeezing bite force, amounting to 194.05 and 147.75 Newtons, respectively. The maximum bite force exhibited a greater increase compared to the squeezing bite force, with a difference of 46.30 Newtons (Table 4).

The cyclic change in average maximum and squeezing bite force from pretreatment (T0) to 6 months of treatment (T6) was depicted in Figure 4. Both average maximum and squeezing bite force substantially increased from pretreatment (T0) to 2 months of treatment (T2), gradually increased from 2 months of treatment (T2) to 4 months of treatment (T4), and remained almost stable from 4 months of treatment (T4) to 6 months of treatment (T6). The average maximum bite force was significantly higher than the squeezing bite force in all time intervals.

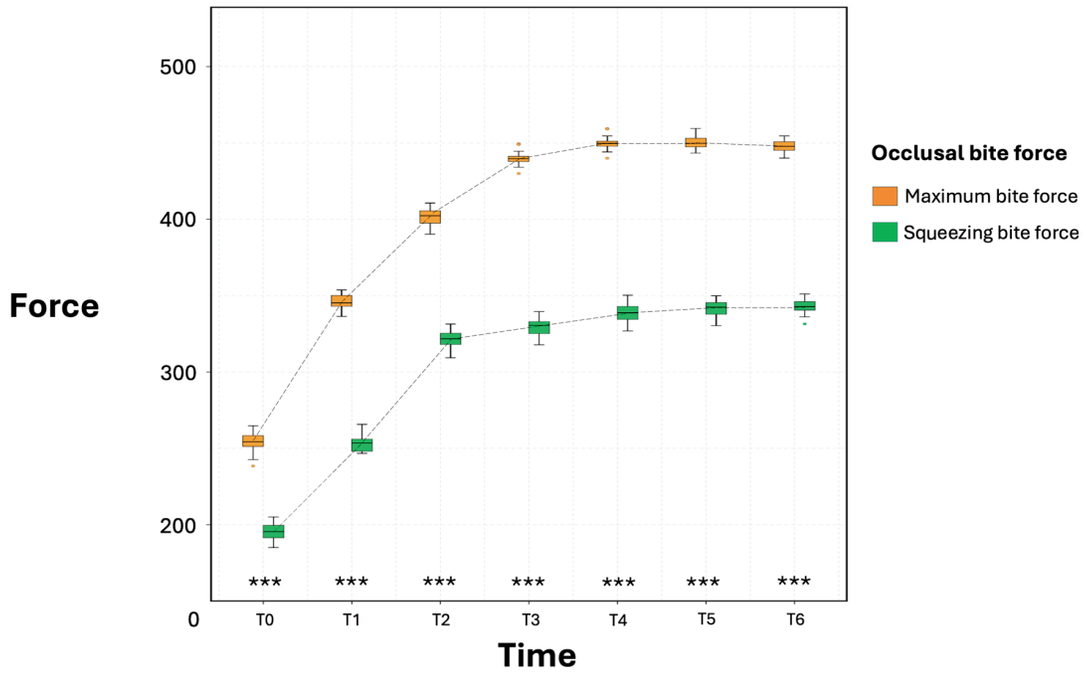

Figure 4 The cyclic change of average maximum and squeezing bite force from pretreatment (T0) to 6 months of treatment (T6).

The statistical analysis was tested by paired t-test.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Discussion

This study enrolled individuals with anterior open bite to investigate the impact of clear aligner treatment and squeezing exercises. The squeezing exercise generates the bite block effect and enhances the stability of anterior open bite treatment.[21] However, no previous studies have evaluated the cycle of changes in occlusal bite force during clear aligner treatment with squeezing exercise. Therefore, this study aimed to assess the change in occlusal bite forces among the participants.

The measurement of occlusal bite force provides valuable insights into the functional condition of the masticatory system and the stress placed on the teeth, and it can be easily conducted within clinical settings. The magnitude of bite force is influenced by the coordinated activity of the muscles responsible for jaw elevation, which is further shaped by jaw biomechanics and reflex mechanisms.[22] Moreover, masticatory force plays a crucial role in diagnosing and treating dysfunction.[23] However, it's also influenced by the gender, the mean of maximal bite force was shown approximately 30 % higher in the male than in the female.[24] The most subjects in this study were females. Therefore, the magnitude of force results should be carefully applied.

The increase in occlusal bite force from pretreatment to 4 months of treatment was supported by the previous study,[25] It's explained that squeezing exercise was the isometric masticatory muscle training which activated myophysiological response of muscle during clenching. It improved the muscular fibers, thickness and strength. An increased biting force will naturally result from strengthening the masticatory muscles.[26] Nevertheless, the occlusal bite force has remained relatively stable since the 4th month of treatment, attributed to the adaptability of the masticatory muscles. Previous studies suggested that this adaptability is time-dependent and linked to alterations in sensory input, which in turn modify motor output to regulate motor skills and fine-motor control.[27] The adaptability varies from 10 weeks to a year.[27-31]

This study differed from another prior investigation that examined changes in bite force over a 6-month period of fixed appliance treatment without involving any squeezing exercises. Their findings showed a notable decrease in bite force, approximately by 50 % compared to pretreatment levels, during the initial month of orthodontic treatment. However, the bite force returned to pretreatment levels by the conclusion of the sixth month.[32] Moreover, the type of orthodontic appliance, observation period, and myofunctional exercise affect the measured occlusal bite force. Therefore, observation with a comparison group is recommended for further investigation.

Evaluating bite force throughout orthodontic treatment provides valuable insights to orthodontists regarding the appropriate mechanics to utilize. It also aids in identifying any interferences within the stomatognathic system during orthodontic procedures.[33] However, only a limited number of studies have investigated the alterations in occlusal bite force during fixed orthodontic appliance.[32,34] Despite evidence indicating changes of bite forces during routine orthodontic procedures, variations in bite forces have been observed in relation to different facial patterns.

Moreover, the clear aligner treatment protocol for anterior open bite, patients were directed to apply pressure to the aligners for approximately 30 seconds twice daily to aid in closing the open bite. Additionally, the squeezing exercise protocol recommended for anterior open bite treatment studies involved one-minute sessions comprising 5 seconds of isometric clenching (at 80 % of maximum force), followed by 5 seconds of rest, repeated six times, totaling 1 minute. This exercise regimen[21,35] was approved to reduce the risk of anterior open bite relapse. And this study showed the better performance of masticatory muscle function after this protocol training.

This study provided the 6-month cycle change in occlusal bite force during clear aligner treatment. The explanation of clear aligner treatment and squeezing exercise enhances muscle strength and occlusal bite force in the first three months, and it stabilized by the fourth month of treatment. However, the results of this study may apply to adult patients with mild to moderate anterior open bite who undergo both clear aligner treatment and squeezing exercise. It is recommended to explore the effect of a single intervention, compare groups, or extend the observation period.

Conclusion

1. Clear aligner treatment combined with squeezing exercise enhanced the increase in occlusal bite force during six months of observation.

2. Both maximum and squeezing bite forces increased from T0 to T3 and remained almost stable at the 4th month of treatment.

Author contributions

WW: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing-Original draft preparation; CL: Visualization, Investigation, Resources, Supervision, Funding acquisition; ST: Software, Validation, Data curation, Writing- Reviewing and Editing, Project administration.

Ethical statement

The study protocol was approved by the Institutional Review Board for human patients (protocol EC 6308-030) of Human Ethic Committee of the Faculty of Dentistry, Prince of Songkla University.

Disclosure statement

Authors have no the conflict of interest.

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